KARST RESEARCH INSTITUTE ZRC SAZU

Speleological Association of Slovenia
Slovenian National Commission for UNESCO
International Union of Speleology UIS
IGU Karst Commission

21st INTERNATIONAL KARSTOLOGICAL SCHOOL
"Classical Karst"

HYPOGENE SPELEOGENESIS (BETWEEN THEORY AND REALITY…)

GUIDE BOOK & ABSTRACTS

Editors
Bojan Otoničar, Petra Gostinčar, Franci Gabrovšek

Published by
Karst Research Institute, Scientific Research Centre of the Slovenian Academy of Sciences and Arts, Titov trg 2, 6230 Postojna, Slovenia

Organizing & Scientific committee
Bojan Otoničar, Franci Gabrovšek, Petra Gostinčar, Martin Knez, Janja Kogovšek, Andrej Mihevc, Janez Mulec, Metka Petrič, Tanja Pipan, Mitja Prelovšek, Nataša Viršek Ravbar, Tadej Slabe, Stanka Šebela, Nadja Zupan Hajna, Sonja Stamenković.

Organizer
Karst Research Institute, Scientific Research Centre of the Slovenian Academy of Sciences and Arts, Titov trg 2, 6230 Postojna, Slovenia

Supported by
Slovenian National Commission for UNESCO
Scientific Research Centre of the Slovenian Academy of Sciences and Arts
Municipality of Postojna
Turizem Kras, d.d.

Photo on front page
Bojan Otoničar (big calcite crystals from Cok Cave, Jelovica)

Postojna, 2013

ZNANSTVENORAZISKOVALNI CENTER
SLOVENSKE AKADEMIJE ZNANOSTI IN UMETNOSTI

CONTENT

GENERAL INFORMATION

Lunch

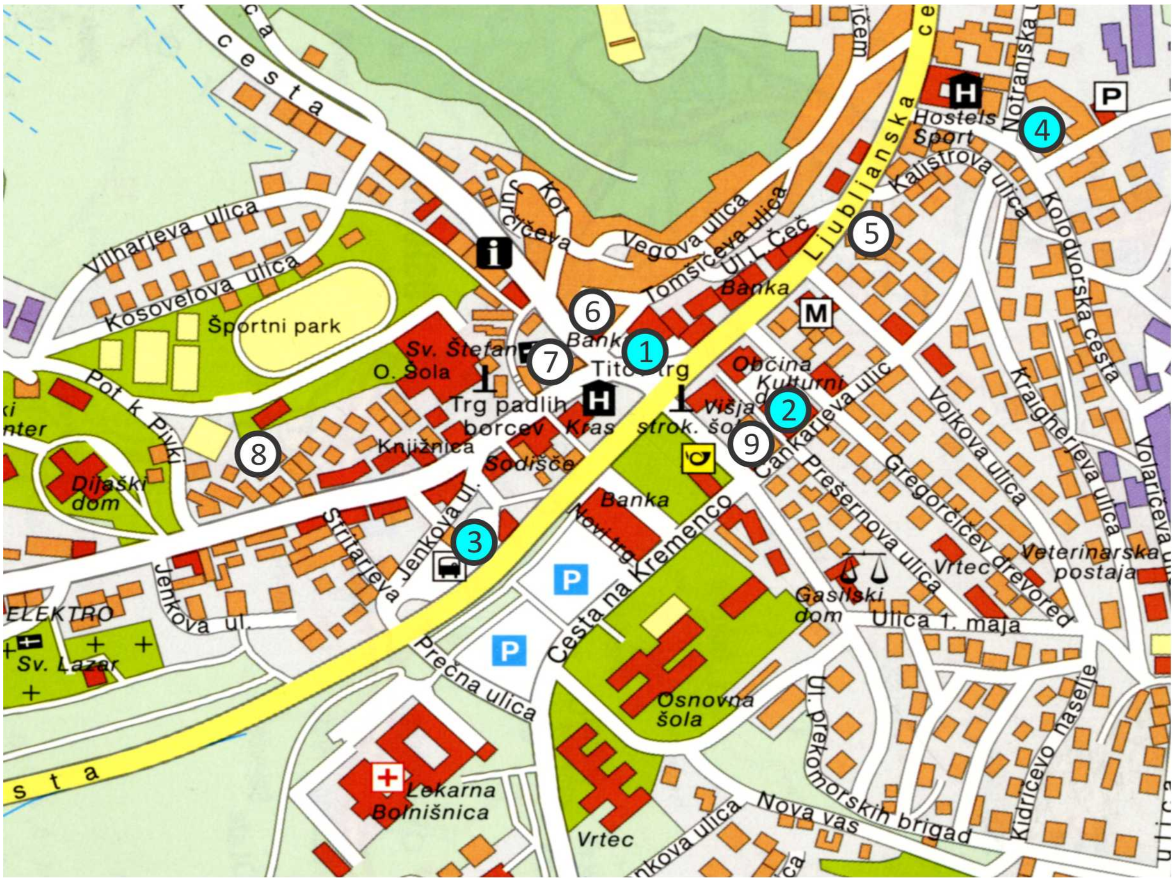
- Lunches are not organized on excursions and during the session days.
- 90-minute lunch breaks are in the schedule (see the places to eat given below) during the session days.

Excursions

- register **for each excursion** at the registration desk,
- bus departure for the field trips is from the parking place at the Bus station (No. 3 on the map below).
- head lights are recommended, walking shoes and field clothes are necessary,
- take care for additional information and changes regarding the bus departures,
- water will be available on all busses,
- **insect repellents** are recommended (we will be walking in the areas populated with **ticks** (*Ixodes ricinus*) that transfer mainly lyme desease and tick-borne meningitis,
- **participation on the excursions is at your own risk.**

Posters

- **Leave posters at registration desk on Monday before the lunch break**,
- posters will be divided according to their contents in different groups,
- stand by your poster during the poster sessions.



Map of the town centre with important places:

1 – Karst Research Institute ZRC SAZU, Titov trg 2

2 – Kulturni dom (Cultural Centre of Postojna), Prešernova ulica 1

3 – Start of field trips. Bus station, Titova cesta 2

4 – Notranjski muzej Postojna, Kolodvorska cesta 3

Places to eat:

5 – Minutka: restaurant with pizza, pasta, Balkan food and daily menu

6 – Proteus: restaurant with local and "global" food and daily menu

7 – Bar Bor: restaurant, simple but good local food, also serves daily meals

8 – Čuk: restaurant at the sport park, pizzeria, good pasta, local and global food

9 – Špajza: local and "global" food and daily menu

PROGRAMME

Monday, June 10th, 2013

8.00-13.00	**REGISTRATION**	**Cultural Centre Postojna**
9.00-11:00	**OPENING SESSION**	**Cultural Centre Postojna**
9.00-9:15	**Opening Ceremony**	
9.15-10.00	**Keynote lecture by** Bojan Otoničar: *Evidences of hypogene speleogenesis in Slovenian caves (introduction to the field trips)*	
10.00-11.00	**Keynote lecture by** Yuri Dublyansky: *Hypogene karst: speleogenetic mechanisms and geochemical methods of diagnostics*	
11.00-11.30	*Coffee break*	
11.30-13.00	**SESSION 1**	**Cultural Centre Postojna**
11.30-12.00	**Invited lecture by** Anita Erőss: *Hydrogeology of the Buda Thermal Karst (Hungary) – new models for the discharge zone*	
12.00-12.30	**Invited lecture by** Bogdan Onac: *Hypogene vs epigene caves: the S and O isotope fingerprint*	
12:30-12:50	Jo De Waele: *Folia, calcite rafts, cones and cave clouds: a typical association of hypogenic caves from an evident epigenic setting from Cuba*	
12:50-13:10	Marjan Temovski: *Phantom cave development in a thermal environment*	
13:10-13:30	Mihael Brenčič: *Regional groundwater flow in the context of karst development*	
13.30-15.00	*Lunch break*	
15.00-17.00	**Poster Session**	**Karst Research Institute**
18.00-22.00	Ice breaker and Unresolved Mysteries of karst	

Tuesday, June 11th, 2013

8.30-11.30	**SESSION 2**	**Cultural Centre Postojna**
8.30-9.00	**Home lecture by** Franci Gabrovšek: *Hypogenic Speleogenesis: Insights from the numerical models*	
9.00-9.30	**Invited lecture by** Philippe Audra*: Hypogene cave morphology and speleogenesis, in relation to geological setting*	
9.30-10.00	**Invited lecture by** Pavel Bosak, *Ascending speleogenesis in the Czech republic and Slovakia*	
10.00-10.30	*Coffee Break*	
10:30-10:50	Andrej Mihevc: *Morphogenetic types of caves on Klassical Karst*	
10:50-11:10	Lukas Plan: *Hypogene caves in Austria*	
11:10-11:30	Angeliki Reizopoulou & Markos Vaxevanopoulos: *Determining a strong relation between hypogenism and hydrothermal water circulation in Greek caves*	
11.30-13.00	*Lunch Break*	
13.00-20.00	Geology and speleogenesis of Vrh Sv. Treh Kraljev – "*The Three Holy Kings Hill*" (Dolomite vs. dedolomite caves)	**Afternoon Field Trip (A)**

Wednesday, June 12th, 2013

9.00-12.00	**SESSION 3**	**Cultural Centre Postojna**
9.00-9.30	**Invited lecture by** Andrzej Tyc: *Convergence of hypogene and epigene small-scale solution features in caves (examples from central Europe and eastern Australia)*	
9.30-10.00	**Invited lecture by** Marco Menichetti: *Hypogene speleogenesis - cases from Italy*	
10.00-10.30	*Coffee Break*	
10:30-10:50	Nadja Zupan Hajna: *Caves of "Classical Karst", to be or not to be hypogenic?*	
10:50-11:10	Ashraf Aboul-Fetooh Mostafa: *El-Balayza Caves: The first Hypogene Caves in the Nile Valley of Egypt*	
11:10-11:30	Didier Cailhol: *Cueva Bellamar, a hypogenic cave in Cuba*	
11:30-11:50	Dalibor Paar: *Scientific research in the Cave system Lukina jama – Trojama (-1421) on the Velebit karst massif (Croatia)*	
11:50-12.10	Tatjana Bakran-Petricioli: *Determining environmental conditions that shape shallow, partly submerged coastal cave today – case of Y-cave, Dugi otok, Croatia*	
12:10-12:30	Closing remarks	
12.30-14.00	*Lunch Break*	
14.00-19.00	Predjama cave (convergence of epigenic and hypogenic cave wall rock features)	**Afternoon Field Trip (B)**

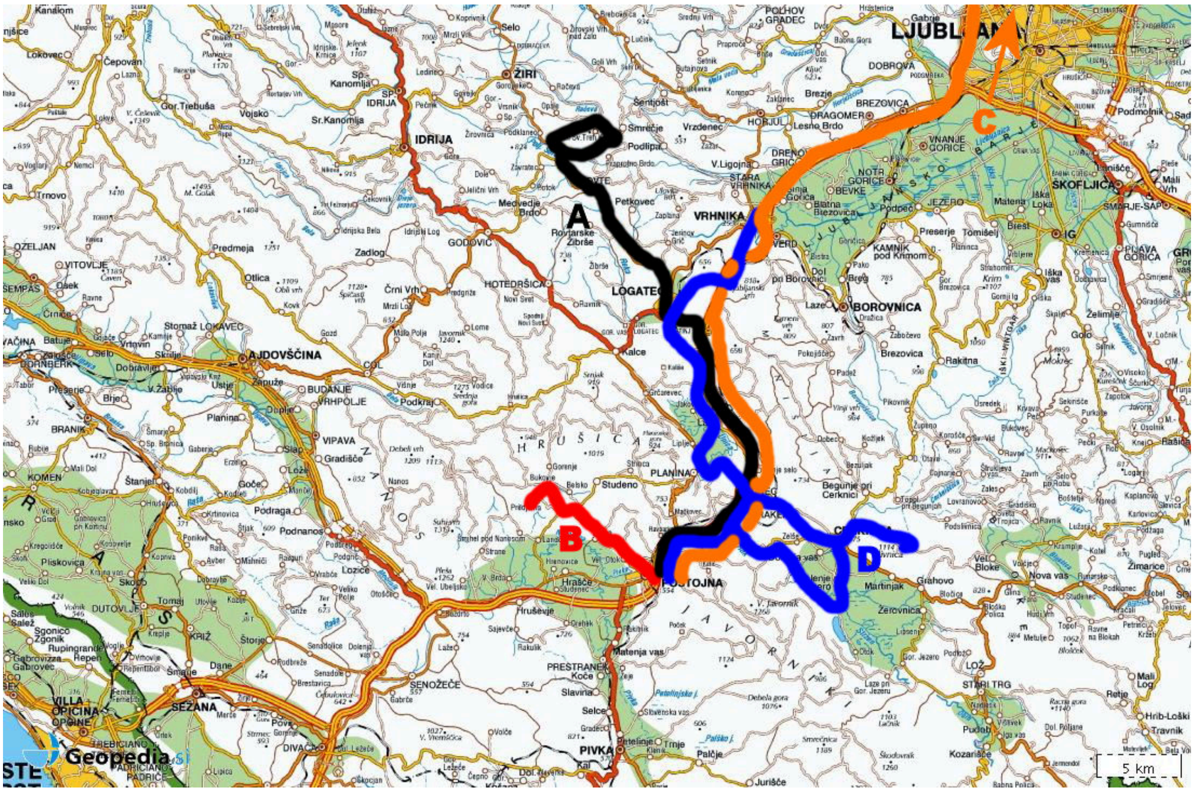
Thursday, June 13th, 2013

7.30-19.30	Jama pod Babjim Zobom and Cok caves (Jelovica Plateau): Big low temperature hydrothermal calcite crystals	**Whole-day Excursion (C)**
20.00 -	**Reception at the Karst Research Institute**	

Friday, June 14th, 2013

9.00-17.00	Geomorphology and hydrogeology of Notranjski kras	**Whole-day Excursion (D)**

FIELD TRIPS



Map of field trips:
Field trips and visits: Tuesday (A) and Wednesday (B) afternoon and whole day excursion on Friday (D).

Wear good walking shoes, field clothes and bring with your headlamp to see more.

Afternoon field trip (**A**)

GEOLOGY AND SPELEOGENESIS OF VRH SV. TREH KRALJEV

(*"The Three Holy Kings Hill"* – dolomite vs. dedolomite caves)

Tuesday, 11.6.2013, 13.00–20.00

Stops:
1 – Vrh Svetih Treh Kraljev (view point; geology and geomorphology of the area);
2 –Jama pri Sv. Treh Kraljih (artificial tunnel; pyrite weathering; precipitation of gypsum; maze cave; micro-displacements; extensiometer);
3 – Rodolfov mlin (»sulphuric« well, hydrogeochemistry, dissolution of Ca-evaporites, dedolomitization);
4 – Mravljetovo brezno v Gošarjevih rupah (maze cave developed in dedolomite);
5 – Matjaževe kamre-optional for those who will not go to Mravljetovo brezno (entrance part of maze cave, river and frost remodelling of the cave passages, Paleolitic).

Introduction

(Bojan Otoničar, Andrej Mihevc)

The hilly landscapes on the transition from Dinaric karst of inner Slovenia towards Prealps between the Hotenjsko Podolje karst plain on the west, the Logaško Polje on the south and the tectonic basin of Ljubljansko Barje (Ljubljana Moor) on the East are named Rovte (Figure 1). The name is derived from the type of the settlement – lonely isolated farms on suitable places in the woods or tiny settlements on the ridges. In this area the dolomites are the most abundant type of the carbonate rock.

The dolomite relief of Rovte covers an area of approximately 100 km^2 and continues to the north to higher Pre-alpine hills and mountains.

Surface waters in the northern and eastern part of Rovte flow into the valleys of the Idrijca, Sora and Ljubljanica rivers, while the central and southern part has only karstic discharge. There are 9 larger and 16 small sinking streams in this area. From these, water flows to the springs of the Idrijca and Ljubljanica.

A mixture of fluvial, karst and fluviokarst features can be seen in the area. Fluvial valleys are formed in noncarbonate rocks and in dolomite where surface gradient is steep. Karst areas with rocky surfaces and dolines as prevailing forms are developed on plateaus build of limestone. Characteristic features of dolomite areas are dells, dolines and large surfaces with underground drainage but no distinct karst surface relief features.

The excursion will be focused to three caves, between 300 m and 1000 m long. They are situated at different levels between the valley of river Sora at about 550 m a.s.l., and the peak Vrh Svetih Treh Kraljev (884 m a.s.l.) (Figure 2). The longest of the three caves (Jama pri Svetih Treh Kraljih) is close to the top of the mountain. It had been discovered during the constructions of military artificial tunnel before the Second World War and has no known natural entrance. The second cave (Mravljetovo brezno v Gošarjevih rupah) is located about two kilometres SW to the Jama pri Svetih Treh Kraljih cave and 200 m lower, on the eastern flank of the Sora River. The entrance to the third cave (Matjaževe kamre) is at the river bank approx. 400 m SW of the Mravljetovo brezno v Gošarjevih rupah cave.

All three exhibit clear ramiform and/or maze-like morphology and other evidences indicating their possible hypogenic origin.

The mountain with the three caves is topographically well expressed and surrounded by four valleys developed mainly along fault lines and at the contact of different lithologies. Between the faults, the mountain represents a relatively stable block where constant deep of the strata is disrupted only locally by few limited metre-scale strike-slips along unimportant local faults or fissures. The whole region is a part of Trnovo Nape structure, i.e. its highest internal thrust block which front is located only few kilometres from the area of interest.

Lithostratigraphically, a variety of non-carbonate and carbonate rocks of Middle Permian to Upper Triassic age intercalating through few hundred meters thick sequence. The caves developed exclusively in the Lower and Middle Triassic dolostone placed between siliciclastic rocks. No caves or dissolutionally enlarged fractures have been observed in highly calcareous Lower Triassic marly limestone and in the lenses/horizons of Lower Triassic oolitic limestone. The orientation of the channels in all three caves suggests that the origin of the main passages were guided by the same set of faults and joints.

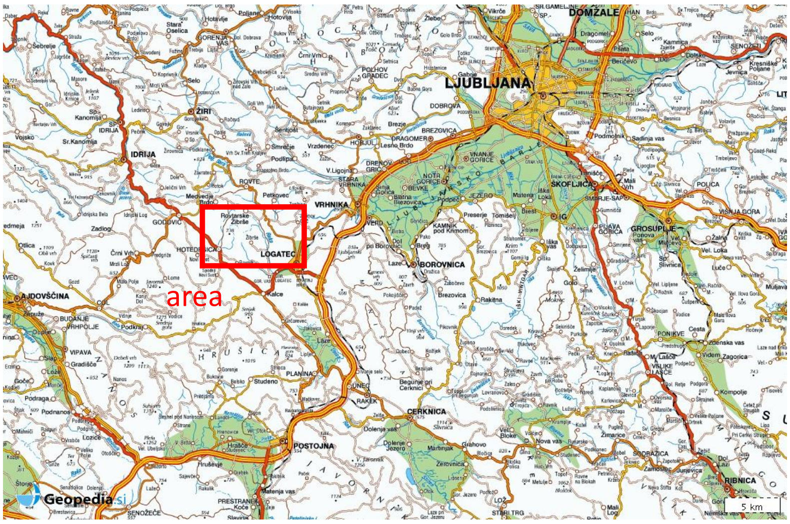


Fig.1: Location map of the wider surrounding of the Vrh Svetih Treh kraljev Hill.

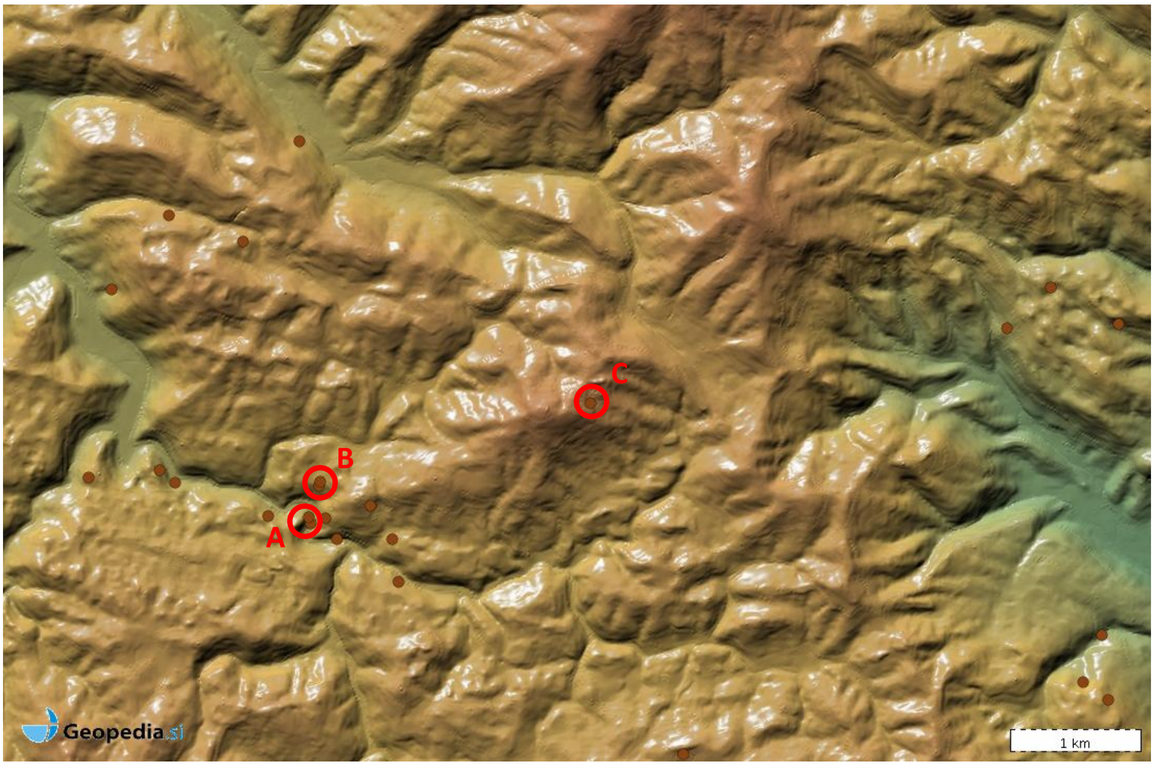


Fig. 2 : A digital terrain model showing location of the three discussed caves: A –-Matjaževe kamre, B – Mravljetovo brezno v Gošarjevih rupah, C – Jama pri Svetih Treh Kraljih.

Cave Jama pri Sv. Treh kraljih
(modified after Mihevc, 2005)

The cave had no known natural entrance; it was discovered during an excavation of artificial tunnel. The cave is 962 m long; the vertical difference between the extreme passages is 77 m. The tunnel and the cave are situated just below the top of the Vrh (884 m) at elevation 812 m.

In the first part the tunnel is built in Lower Triassic dolomite, while the second part is built in Lower Triassic marly limestone. Both parts include thin intercalations of shale. Cave itself is a maze of passages developed in phreatic conditions along steep faults and fractures. Although there is no one general direction of cave passages and no passage levels passages obviously follows the main trends of joints of the area. The passages are slightly modified by vadose seepage waters. The speleothems are rare, interesting are aragonite needles and stalactites. The cave is in several respects similar to Matjaževe kamre and especially to Mravljetovo brezno v Gošarjevih rupah caves (see ground plan of the caves: Figures 3, 9, 14).

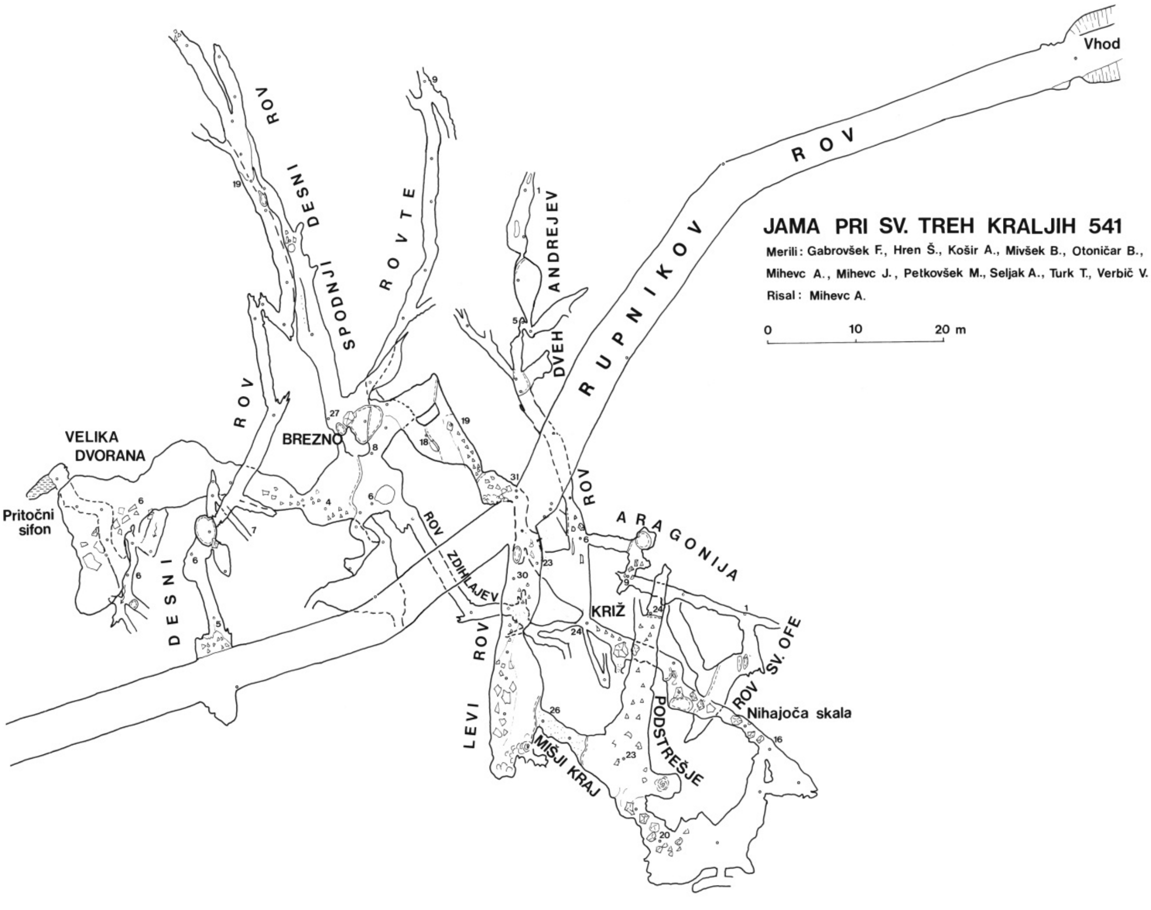


Fig. 3: A ground plan of the cave Jama pri Sv. Treh Kraljih. The passages of the cave are below and above the artificial tunnel.

Fig. 4: Typical morphology of the caves passages, irregular narrow and high channels guided by joints (photo: B. Otoničar).

Fig. 5: Rusty rock: "semi-natural model" for hypogenic spelogenesis. Weathering of primary pyrite rich shale by oxygenated percolating water produces sulfuric acid which dissolves underlying marly dolostone or dolomitized limestone of the artificial tunnel. In the process goethite-ferrihydrite (rust) and gypsum (white "dust" among gravel on the bottom of the wall) is precipitated (width of the photograph is approx. 1,5 m) (photo: B. Otoničar).

Micro-displacements detected by TM 71 exstensometers in Jama pri Sv. Treh kraljih (Rupnik tunnel)

(Stanka Šebela)

In geotectonic sense the position of Slovenia is at the contact between the Adria microplate in the south and Eurasia plate in the north. It is characterized by complex and neotectonically active geological conditions. Since the late Miocene to Pliocene paleomagnetic data indicates about 30° counter-clockwise rotation of the Adria microplate (Márton *et al.*, 2003).

The Paleogene to recent thrust belts along the Adria margin include Dinaric thrust systems, the South-Alpine thrust system and Dinaric faults. The Dinaric thrust systems are post-Eocene, representing a NW–SE striking fold-and-thrust belt that can be followed from the Istra peninsula towards north to the central Slovenia (Vrabec & Fodor 2006) and that belongs to the External Dinarides.

The S- to SE-verging fold-and-thrust-belt of the Southern Alps formed in the Pontian. Dinaric faults cut and displace both Dinaric and South-Alpine fold-and-thrust structures. Many Dinaric faults, including the Idrija Fault, formed as dip-slip normal faults and were only later dextrally reactivated (Vrabec & Fodor 2006).

Seismic activity along Ravne Fault (Fig. 1) was responsible for the strongest earthquakes in recent years in Slovenia, for *M*=5.6 earthquake in 1998 and for *M*=5.2 earthquake in 2004, both located north from Tolmin.

The GPS-based best-fitting angular velocity vector predicts actual convergence in the Dinarides at ≤ 5 mm/year (Weber *et al.*, 2010).

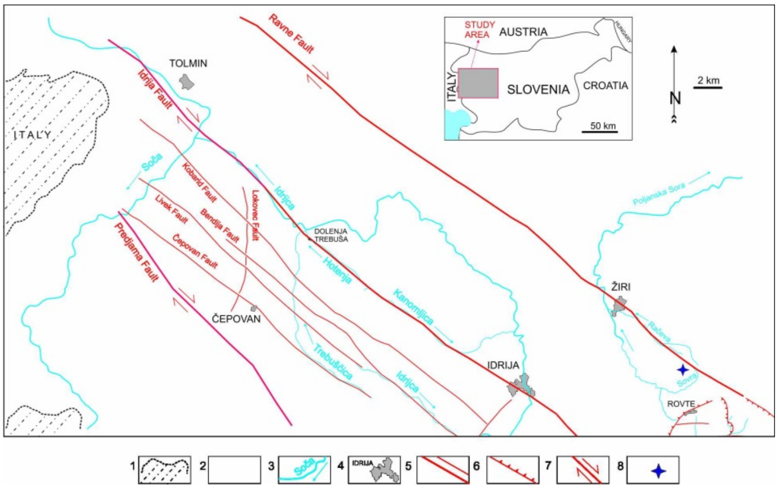


Fig. 6: Position of Jama pri Sv. Treh kraljih cave and Rupnik tunnel regarding the wider structural-geological situation of W Slovenia. 1-Italy, 2-Slovenia, 3-river or stream with flow direction, 4-town or village, 5-morphologicaly well expressed regional fault and less expressed fault, 6-thrust fault, 7-fault with dextral horizontal movement, 8-TM 71 extensometer monitoring site.

To better understand micro-displacements connected by tectonic activity along Ravne Fault TM 71 exstensometer (Stemberk *et al*. 2010, Šebela *et al*. 2009, Šebela & Mulec 2011) was installed at the crossing of almost N–S oriented fault with E–W oriented fault. Preliminary results during the year 2012 (Fig. 7) showed vertical movements for almost 0.3 mm (z), predominating sinistral horizontal movement for 0.1 mm (y) and compression for 0.17 mm (x).

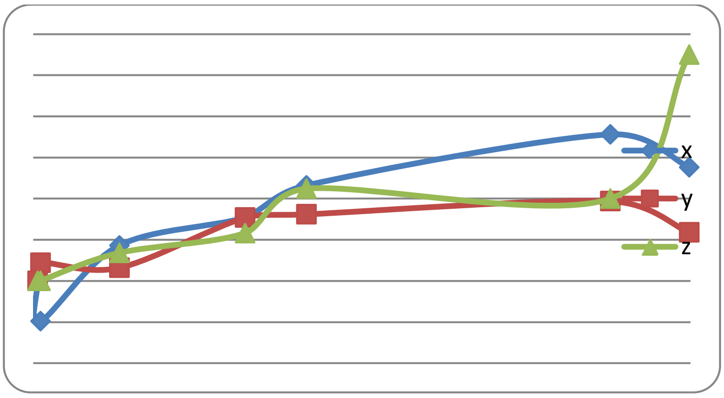


Fig. 7: Micro-displacements detected by TM 71 exstensometer in Rupnik tunnel (Jama pri Sv. Treh kraljih).

In-situ monitoring of micro-displacements showed the wider fault zone of Ravne Fault in the area of the hill Vrh Svetih Treh Kraljev (884 m) is tectonically active. The explication can be that the hill below which is Rupnik tunnel and the cave is within the active restraining bend of Ravne Fault zone. More studies are needed to better understand the active tectonic situation.

Hydrochemistry of Rodolfov Mlin well

(Sven Philipp[1])

The well Rodolfov Mlin (R; 435351.31 m E, 5094276.77 m N) (Figure 8) is situated in the vicinity of Rovte in Upper Carniola in West Slovenia. The well is reachable via the main road from Hlevni Vrh to Rovte, if you turn right after 1 km from Rovte.

Upon others, this well was drilled for prospections of mercury deposits from the mine in Idrija. It was measured three times from 17.03.2013 to 09.05.2013.

Fig.8: Picture of the Well Rodolfov Mlin in the vicinity of Rovte (Photo: S. Philipp)

The data from Rodolfov Mlin (Table 1) shows temperatures around 10 +/- 0,56°C. The Electronic Conductivity (EC) is 780,67 +/- 2,08 µS/cm. The mean $Mg^{2+} + Ca^{2+}$-concentration is 140,28 +/- 0,73 mg/l, for Mg^{2+} 39,07 +/- 1,56 mg/l and Ca^{2+} 101,22 +/- 1,72 mg/l. The Total Dissolved Solids (TDS, mean: 499,63 +/- 1,33 mg/l) are calculated from the electronic conductivity. Also Mg^{2+} is calculated from the substraction from $Mg^{2+} + Ca^{2+}$ minus Ca2+. The Mg^{2+}/ Ca^{2+}-ratio is 0,39 +/-0,02. The Carbonate Hardness is 168,55 +/- 0,70 mg/l. Because Cl^-, NO_3 and PO_4^{3-}-concentrations are significant lower compared to other values, that is why it is not explained further here. SO_4^{2-} shows highest values in these analyses with a mean of 499,63 +/- 1,33 mg/l.

It is worth to mention that this well smells extremely like rotten eggs, so it seems that it contains much H_2S, which probably comes from the sulfate ions in a reduction environment.

Sample	T [°C]	EC [µS/cm]	pH [-]	$Mg^{2+} + Ca^{2+}$ [mg/l]	Mg^{2+} [mg/l]	Ca^{2+} [mg/l]	Mg^{2+}/Ca^{2+} [-]	Carbonate Hardness [mg/l]	Cl^- [mg/l]	NO_3^- [mg/l]	PO_4^{3-} [mg/l]	SO_4^{2-} [mg/l]	TDS [mg/l]
R1	9,40	780,00	7,57	140,14	37,29	102,85	0,36	167,74	1,71	0,0621	0,0000	299,58	499,20
R2	10,10	779,00	7,51	141,07	39,70	101,37	0,39	168,95	1,43	0,0697	0,0000	247,87	498,56
R3	10,50	783,00	7,78	139,64	40,21	99,43	0,40	168,95	1,43	0,0204	0,0043	264,08	501,12
R Mean	10,00	780,67	7,62	140,28	39,07	101,22	0,39	168,55	1,52	0,0507	0,0014	270,51	499,63
R Median	10,10	780,00	7,57	140,14	39,70	101,37	0,39	168,95	1,43	0,0621	0,0000	264,08	499,20
R Stadev.	0,56	2,08	0,14	0,73	1,56	1,72	0,02	0,70	0,16	0,0265	0,0025	26,45	1,33

Tab. 1: Hydrochemistry analysis and statistic data of three measurements taken from the well R11/60, Rodolfov Mlin.

[1] Sven Philipp, Institute for Applied Geoscience, TU Darmstadt, Schnittspahnstraße 9, 64287 Darmstadt, Hessen, Germany, sven.philipp@stud.tu-darmstadt.de

Mravljetovo Brezno v Gošarjevih Rupah Cave: Dissolution of Dedolomite
(Bojan Otoničar, Andrzej Tyc[2], Norbert Sznober[3])

The Cave Mravljetovo Brezno v Gošarjevih Rupah (length = 726 m; depth = 73 m (between highest and lowest measured points); altitude of the main entrance = 613 m) (Fig. 9) is located at the eastern flank of the Sora Valley some 100 m above the river on the lower part of elongated mountain ridge Vrh Svetih Treh Kraljev in Rovtarsko Hribovje, the Pre-alpine region in the western part of central Slovenia (Fig. 2).

The mountain comprises a few hundred meters thick sequence of Middle Permian to Middle Triassic carbonate and siliciclastic rocks with intercalations of evaporates. In sixties, during the drilling course in the area of nearby Rovte Village up to 270 m thick evaporate horizon that forms up to 59% thickness of the Upper Permian and over 29% of Lower Scythian dolostone succession has been found in the subsurface (Čadež, 1977). There, up to metre thick lenses of gypsum and anhydrite alternate with dolostone that comprises veins and geodes of gypsum. The outflow from the nearby 500 m deep well is still rather constant, a few litres per second with the water comprises around 300 mg/l of SO_4^{2-}.

In general, the cave is developed in bedded fine to middle grained Middle Triassic (Anisian) dolostone formation. The cave channels exhibit ramiform and maze like orientation guided by faults and joints. The wall rock morphology show some features characteristic for dissolution with slowly flowing rising water (i.e. feeders, rising channels, cupolas, lack of fast flow scallops…) while some are characteristic also for descending percolating waters (i.e. shafts, down cutting vadose meanders, fluvial sediments of sandy and gravel size particles…). Locally wall rock surface is highly irregular and jagged.

One of the most distinguished characteristics of the cave is particular yellowish to reddish brown rock that looks at first sight as an eroded infilling deposit (Figure 11). However, gradual transition from this type of the rock to the host rock (Figure 10), its highly calcareous mineralogy, and preserved echinoderm bioclasts parallel to those in the host rock suggest different origin. Commonly, the cave floor is covered almost exclusively with cobles and blocks of this material.

As it was expected from outcrops and rock slabs also thin sections stained with alizarin red S reveal gradual transition between the host dolostone and dedolomite. At transition the dolomite crystals with dissolved crystal faces and patches of more or less unaltered dolostone within calcite occur (Figure 12). Petrographically, we can distinguish several major textural groups of dedolomite crystals, relatively coarse grained xsenotopic to locally hipidiotopic mosaic calcite, pseudospherulitic fibrous calcite, cone-like fibrous calcite, fibrous palisade calcite and brownish micritic calcite with or without meshy distributed needle fibre crystals or etched patches or individual crystals of coarser grained calcite mosaic. In places, needle fibre crystals may coalescent in xsenotopic mosaic of fine grained almost equant crystals. Coarser-grained dedolomite crystals commonly include abundant inclusions or remnants of the host dolomite.

[2] Department of Geomorphology, University of Silesia, ul. Będzińska 60, 41-200 Sosnowiec, Poland, andrzej.tyc@us.edu.pl
[3] Department of Geochemistry, Mineralogy and Petrography, University of Silesia, ul. Będzińska 60, 41-200 Sosnowiec, Poland, grazyna.bzowska@us.edu.pl

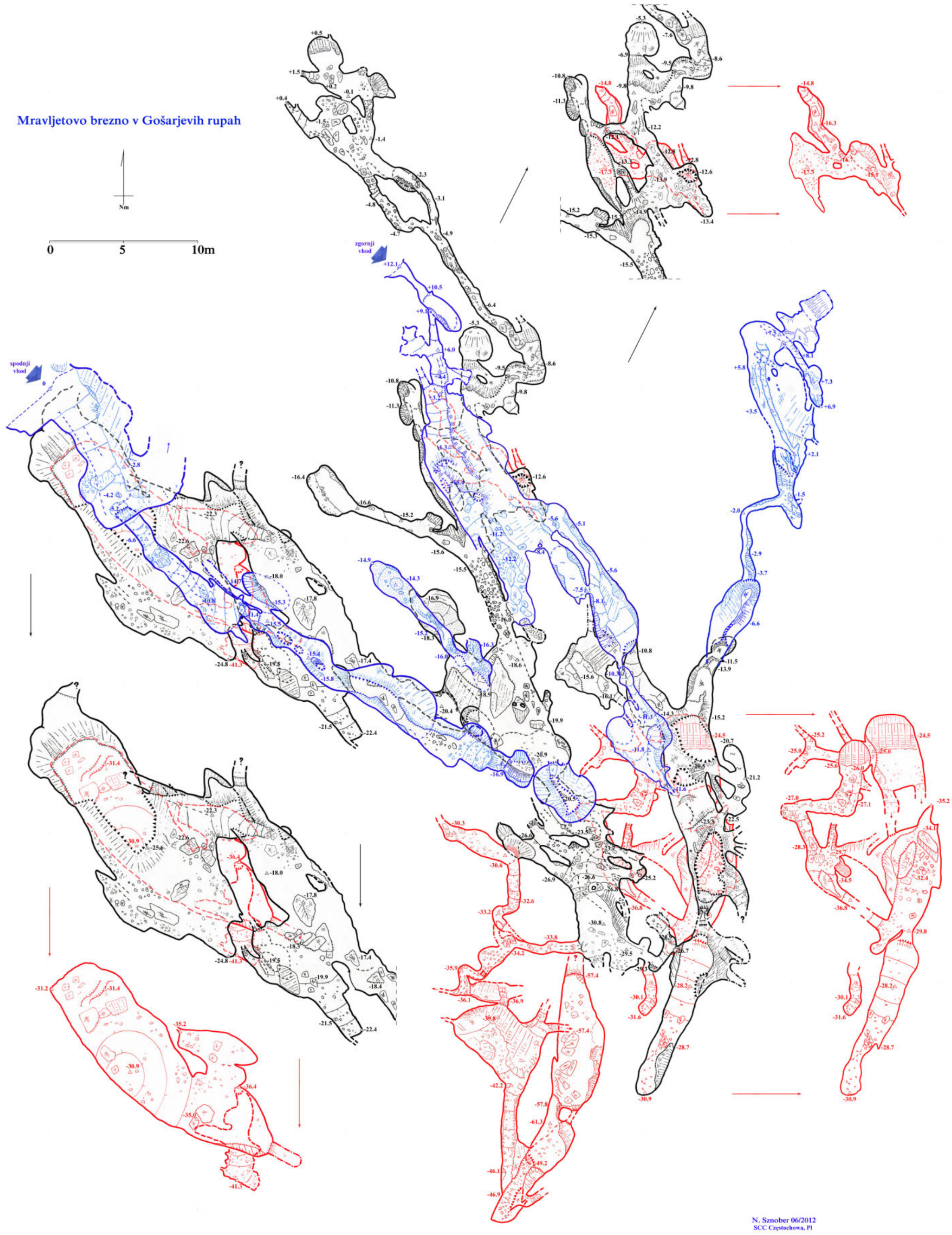
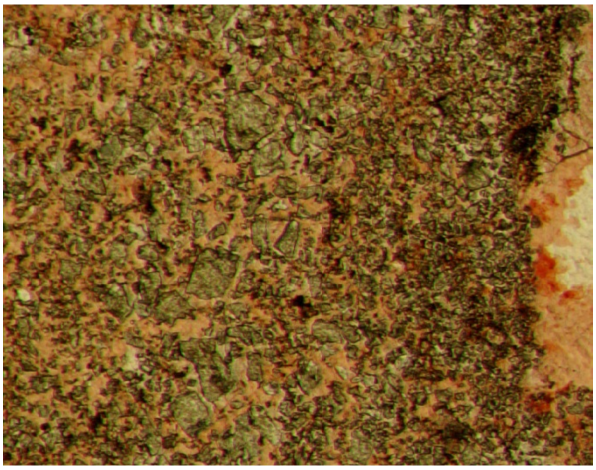


Fig. 9: Ground plan of the Mravljetovo Brezno v Gošarjevih Rupah cave. Blue colour: upper level; black colour: middle level; red colour: lower level.

Fig. 10: Transition from dolostone (dark gray) over partly dedolomititzed dolostone (pale gray) to dedolomite (yellowish brown).

Fig. 11: Cave passage entirely developed in yellowish brown dedolomite. Note remnants of secondary brownish infilling clayey deposits.



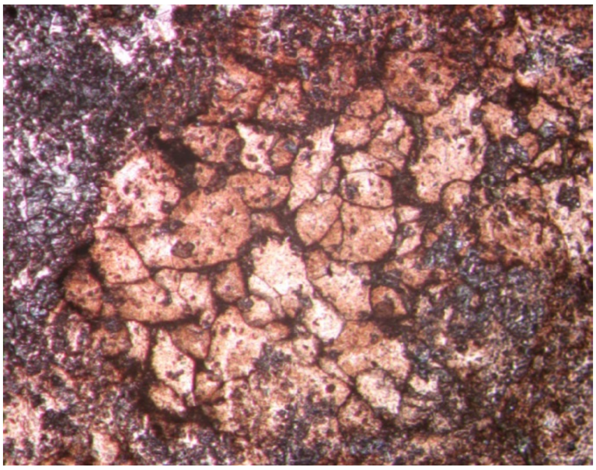


Fig. 12: Transition zone between dolomite (gray) and dedolomite (redish stained). Note etched crystals of dolomite. (width of the fotomicrograph is 2 mm).

Fig. 13: Patch of xenotopic mosaic of calcite crystals localy showing pseudospherulitic texture (stained with alizarin red). Note dolomite inclusions (grey). (width of the fotomicrograph is 2,2 mm).

XRD analyses (Otoničar *et al*. 2012) reveal that unaltered greyish host rock is built mainly of dolomite while yellowish brown altered rock of calcite with traces of dolomite in some samples. Between these two end members pale dolostone with gradually higher content of calcite occur. Yellowish to reddish brown colour of the samples is associated with small amount of Fe hydroxides (i.e. goethite and ferrihydrite). Among other minerals in yellowish brown deposit small amounts of kaolinite, illite, sericite and quartz have been detected. Locally, cave walls are coated with white up to a few mm thick crust predominantly comprises hydromagnesite. Some ledges are covered by earthy light rusty-coloured silty material built of gypsum with traces of goethite and ferrihydrite and sandy particles of calcite.

Thirteen samples of dolomite, yellowish brown calcite and transitional pale dolostone with gradually higher content of calcite have been analyzed for oxygen and carbon isotope composition:

1) Dolostone (n = 4): $\delta^{13}C$ = 2.80‰ to -0.55‰, average: 1.60‰, st. dev.: 1.50‰; $\delta^{18}O$ = -0.51‰ to -2.84‰, average: -1.45‰, st. dev.: 0.99‰,

2) yellowish brown calcite (n = 5): $\delta^{13}C$ = -6.50‰ to -8.42‰, average: -7.64‰, st. dev.: 0.90‰; $\delta^{18}O$ = -5.12‰ to -6.27‰, average: -5.76‰, st. dev.: 0.45‰,

3**)** transition zone between dolomite and yellowish brown calcite (n = 4): $\delta^{13}C$ = -2.70‰ to 5.45 ‰, average: -3.72‰, st. dev.: 1.26‰; $\delta^{18}O$ = -3.92‰ to -5.23‰, average: -4.41‰, st. dev.: 0.63‰.

Above listed $\delta^{13}C$ and $\delta^{18}O$ values display significant differences between dolostone host rock and yellowish brown calcite. While isotope values of dolostone are roughly comparable with values of carbonates precipitated from Middle Triassic marine water (see Veizer *et al.* 1999), yellowish brow calcite show isotopic values characteristic of meteoric diagenesis. Similarly to mineralogical composition, also $\delta^{13}C$ and $\delta^{18}O$ values of transition zone fall between values of dolostone and yellowish brown calcite.

On a basis of known general geological data, basic morphology of the cave channels, cave rocky relief, field and mineralogical evidences of the host rock alternation, and the geochemical data form the wells (Philipp *et al*., this volume) we suggest that the major part of the cave has been primarily partly or mainly developed in deep seated phreatic condition initially by the dissolution of previously dedolomitized portion of the host dolostone. Later, the cave has been modified above phreatic zone. For now it is hard to confirm that the channels have been at least partly formed by sulphuric acid but cave wall rock features, traces of secondary gypsum and evidence of later invasion of allogenic waters which possibly has dissolved majority of gypsum don't exclude this option.

We hypothesize that dedolomitization results from dissolution of gypsum and anhydrite in underlying Upper Permian and Lower Triassic successions (see Mlakar 1969 and Čadež 1977). In groundwater dolomite and calcite are close to equilibrium at ratio Mg/Ca = 1 at T=25°C but if this ratio is less than 1 dolomite would dissolve (Back *et al*. 1983). Thus, from one side a dissolution of Ca-sulphates that provides enough Ca-ions to maintain low Mg/Ca ratio is crucial in the process of dedolomitization, while from other side a precipitation of calcite and consequently removing of carbonate ions from solution is an obligatory condition to keep the solution undersaturated with respect to dolomite. Ca-ions released from dissolving Ca-sulphates keep water solution saturated or slightly oversaturated with respect to calcite what consequently leads to precipitation of calcite, because of the common-ion effect. With precipitation of calcite pH of groundwater will drop and more importantly also carbonate-ions will be consumed and consequently more dolostone will be dissolved. With this processes the amount of SO_4^{2-} and Mg^{2+} in groundwater would increase what is actually the case in the water that arising from the wells that penetrate the evaporate horizon. This suggests still ongoing dissolution of evaporates and dedolomitization (see Philipp *et al*., this volume).

According to stratigraphical position of afore mentioned evaporate horizon we suggest that "dedolomizing" groundwater had ascending character. That fractures represent an important prerequisite for dedolomitization results from orientation of the cave's passages which follow dedolomite and are in the same time also directions of the most important fissures of the area.

The research leading to these results has received funding from the [European Community's] Seventh Framework Programme [FP7/2007-2013] under grant agreement n°247616.

Matjaževe Kamre
(modified from Mihevc 2005)

Matjaževe kamre are over 300 m long cave (Figure 14) with entrances in walls of the entrenched meander of the Sora River. The Cave is formed in Middle Triassic limestone.

The entrances to the cave are about 10 m above the river; the lowest part of the cave reaches the level of the river. The cave developed in deep phreatic conditions along faults and fractures showing no signs of levels or common widths of passages. The down cutting of the meander of the river cut the cave, making several entrances to it. Similar but smaller caves are on other parts of the valley too.

There are two distinguished parts of the cave: the upper part with wider passages still shows the pattern of phreatic origin along the faults, but is much transformed by gelifraction that reshaped the walls and sediment on the floor of the cave (Figure 14). *Ursus spelaeus* bones and some Palaeolithic remains were found here (Osole, 1975).

The inner, lower part, where no cold air can penetrate, passages are much narrower and phreatic features on the walls are still preserved. In this part of the cave and on the lower side of meander below the cave there are some karst springs. Measurements of the temperature of the water show two types of water: the deep karst waters, with stable temperature around 8º C and the water with high variation of the temperature trough year – surface water of the river Sora that is using the cave as a shortcut trough the meander.

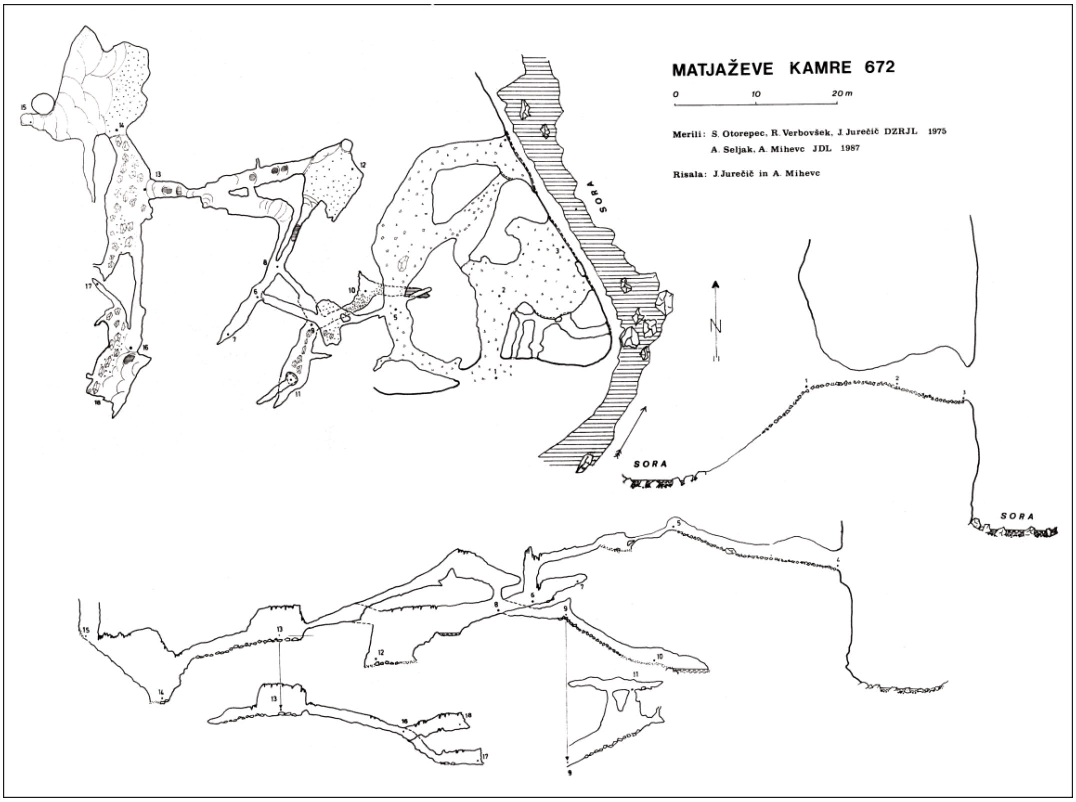


Fig. 14: Plan and section of the cave Matjaževe kamre.

.

Afternoon field trip (**B**)
PREDJAMA
(convergence of epigenic and hypogenic cave wall rock features)
Wednesday, 12.6.2013, 13.00–19.00

Stop:
1 – Predjama (cave geology, cave climate, convergence of epigenic and hypogenic features).

Predjama Cave characteristics
(Stanka Šebela)

Predjama Cave is Slovenia's fourth-longest karst cave at 13,092 m. The regular climatic and partial biological monitoring at selected locations in Predjama Cave has been undertaken since 2009 by Karst Research Institute ZRC SAZU, who acts as karstology consultants and cave advisers in matters relating to the implementation of the concession contract.

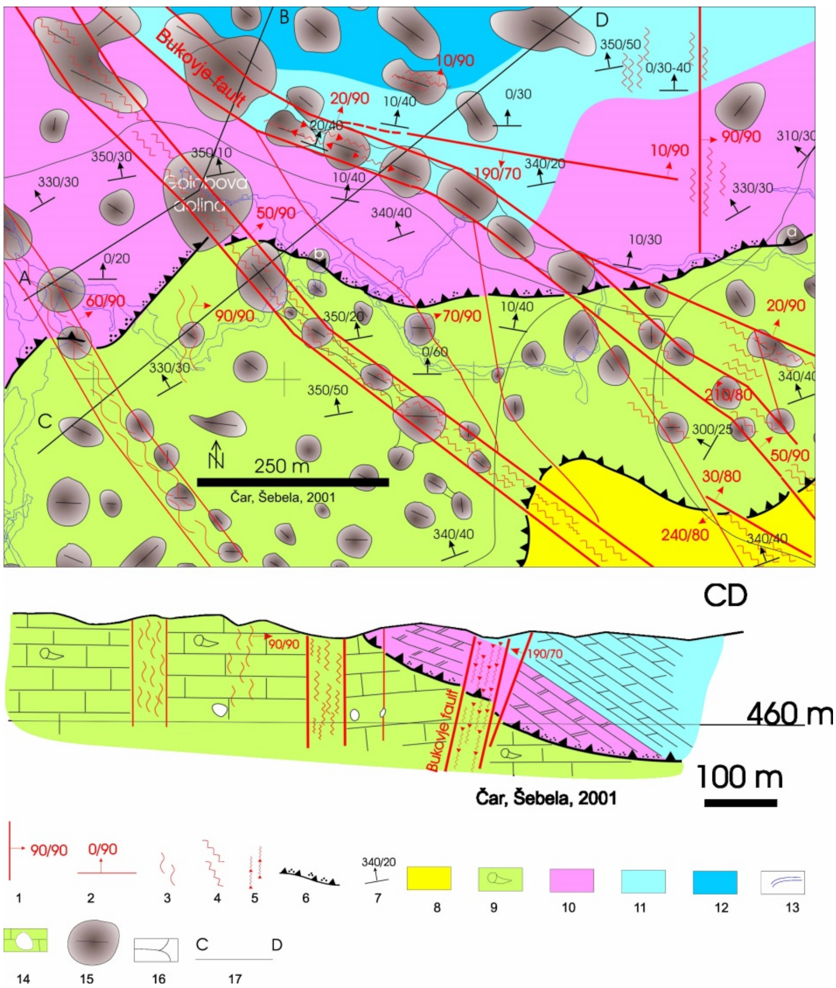


Fig. 15: Geology in the area of Predjama Cave. 1 stronger fault (dip direction/dip angle), 2 less expressed fault (dip direction/dip angle), 3 fissured zone, 4 broken zone, 5 crushed zone, 6 thrust and crushed zone along the thrust, 7 dip direction and dip angle of bedding planes, 8 Eocenski fliš ($E_{1,2}$), 9 Upper Cretaceous limestone ($K_2^{2,3}$), 10 Upper Triassic dolomite (T_3^{2+3}), 11 Upper Jurassic dolomite (J_1^1), 12 Upper Jurassic limestone (J_1^2), 13 Ground-plan of cave passages, 14 Cross section of cave passage, 15 Doline and it's orientation, 16 Road, 17 Cross section.

Predjama is a major tourist attraction partly because of the spectacular position and appearance of its medieval castle. Additionally, extensive cave passages are developed in Upper Cretaceous limestone, in Upper Triassic dolomite that is thrust over the Upper Cretaceous limestone and in Jurassic limestone and dolomite overlying the Upper Triassic dolomite stratigraphically (Čar & Šebela, 2001; Fig 16). Predjama Cave is situated 100–300 metres north from the regionaly important NW–SE oriented Predjama fault. Overthrusting deformations took place after the deposition of Eocene Flysch. A hydrological connection between the River Lokva sinking into Predjama Cave and the Vipava karst springs some 14 km to the west was first inferred by Valvasor in 1689. In recent years the microclimatic characteristics of the Predjama Cave entrance zones have been studied with the aim of recognizing the potential influences of tourist use on the cave (Šebela & Turk 2011, Culver *et al.* 2012).

Results of early meteorological recording in Predjama Cave were published by Schmidl (1854), and between 1941 and 1944 Anelli presented meteorological observations based on studies of air circulation and air temperature measurements in the cave. Cave meteorology data were presented also by Habe (1970), who described not only summer and winter climatic regimes, but also the transitional periods when winter and summer wind directions change in the Predjama Cave. Airflow during the summer is from Zahodni towards Vzhodni Rov, through the Vetrovna Luknja, to Velika Dvorana, where it meets colder air from Fiženca. Under these conditions colder air escapes through all openings of the Lokva and Zmajeva Luknja passages, which are the cave's lowest passages. In winter, however, air enters the system through Vetrovna Luknja into Črna Dvorana. Measurements of air temperature and humidity at Golobja Luknja and Vetrovna Luknja were obtained by Kranjc (1983).

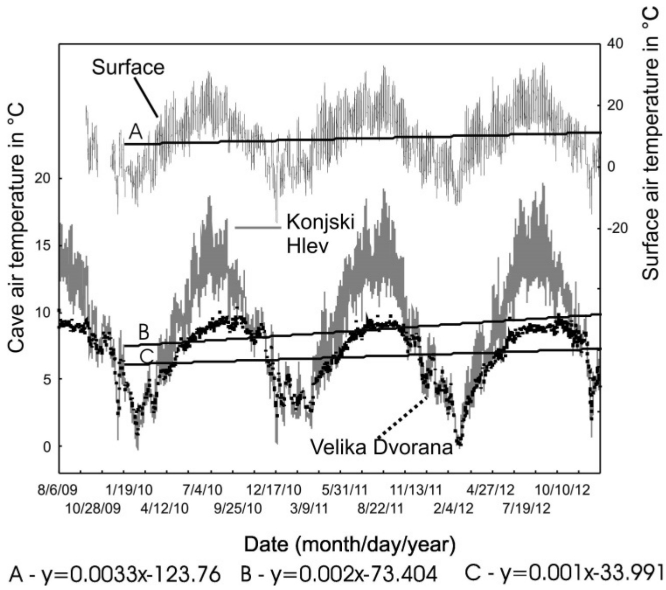


Fig. 16: Continuous measurements of cave-air temperature at Konjski Hlev and Velika Dvorana, and air temperatures on the surface in °C, for the period 06 August 2009 –31 December 2012. Trend-lines for the full years 2010, 2011 and 2012 are A – surface, B – Konjski Hlev, C – Velika Dvorana.

Comparison of measured cave values with outside air temperatures is shown for the period from 06 August 2009 to 31 December 2012 (Figure 16). Air temperature dynamics at Konjski Hlev are very similar to conditions on the surface. At the second monitoring site in Velika Dvorana chamber the situation is unlike that in Konjski Hlev because the effects of winter influences penetrating from outside the cave are stronger than external effects experienced during the summer months. During three complete years (2010–2012) a slight increase trend was recorded regarding mean annual temperature – at both monitoring locations in the cave and also on the surface. However, the smallest increase trend, measured at Velika Dvorana, indicates that cave-air temperatures at this site are more stable.

Mean annual outside air temperature increased during 2010–2012, being 8.39 °C in 2010, 9.43 °C in 2011 and 9.68 °C in 2012. Air temperature at Konjski Hlev shows direct dependence on the outside air temperature. In contrast the mean annual air temperature at Velika Dvorana does not reflect such trends. There the average annual air temperature in the period 2010–2012 was decreasing; in 2010 it was 6.83 °C, in 2011 it was 6.67 °C and in 2012 it was 6.56 °C.

Recently recorded visitor numbers of 6000 individuals per year create no notable impact on the natural cave microclimate, which remains dominantly influenced by climatic variations outside the cave.

Rocky relief of Predjama

(Tadej Slabe)

A lot of papers were written about the ponor cave Predjama and the castle above it. The most detailed description of its development was made by Habe (1970). Gams (1974, 219) studied it also. Šebela (1991) analyses the superficial geological structures and their influence on the cave development. Habe (1970,73) implies that at the end of Pliocene and at the beginning of Pleistocene the water drained into Fizenca and Erazmov Rov from the present-day valleys of Belščica and Osojščica, from Šmihelske and Stranske Ponikve and from a part of Nanoščica. The strong Belški Potok stream flowed through Vzhodni Rov when Stara Jama and Zahodni Rov were dry. This tributary joined the cave due to rapid deepening of the passages. When the water flow was displaced into lower-lying passages the two independent streams of Ribnik and Mrzlek started to appear and joined Belščica (Habe 1970, 76).

According to the rocky relief (Figure 17) in the passages we may infer several development phases of the cave. Slow water flow shaped Fiženca and Erazmov Rov in the phreatic zone. The upper part of Fiženca is composed of several smaller, meandering passages. The same indicates the cross-section of the final part of the passage. A slightly faster water flow drained from Konjski Hlev to Stara Jama in the entrance part of the cave. Larger scallops and ceiling pockets indicate the flow of medium velocity through water-filled passage towards the cave interior. The water gradually formed the passages at lower altitudes. The oldest traces of the water drainage in Vzhodni Rov are medium-sized scallops on the upper sides of the walls and solution cups on the ceiling. The breakdown in Polževa and Črna Dvorana and seasonal high waters caused to be the entrance part of the cave frequently flooded. The water flow upwards in Blatni Rov left larger scallops on the ceiling of the passage up to Črna Dvorana. More frequent high floods, after the present-day bottom of the cave had been already formed, are suggested by above-sediment features. The cave was filled by the sediments up to Imenski Rov, i.e. the whole Blatni Rov, the passage connecting Severjeva Dvorana and Vzhodni Rov, and the old passages of the central part of the cave. The present-day waters drain through the lower passage and, during floods, partly submerge Blatni Rov where finegrained sediments are deposited. Below-sediment solution bevels occur.

The rocky relief of Vzhodni Rov indicates that during the recent cave development the most efficient water flow is of high and medium velocity which floods one part of the passage. It incises scallops and smaller potholes and deepens the riverbed. In the swallow-hole of Lokva the rocky relief (scallops, ceiling cups) is formed by faster water that seasonally floods the whole passage. In the entrance part of the passage only the bottom of the river bed (small scallops) is formed by high velocity flow.

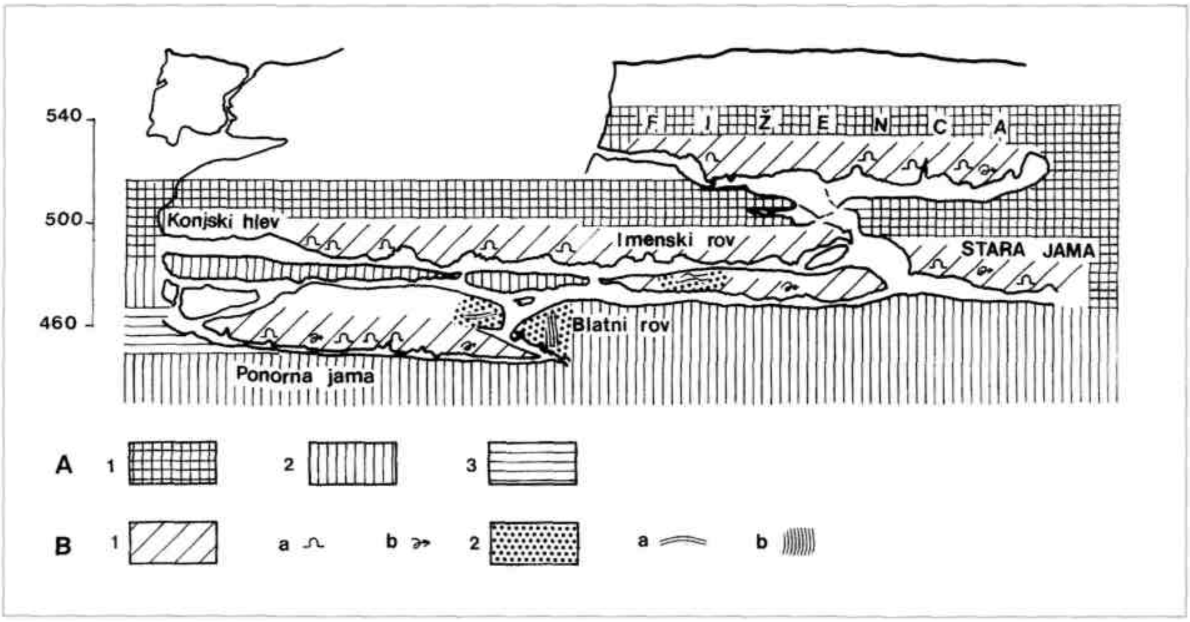


Fig. 17: Rocky relief and hydrological zones shaping. ***A****: 1. phreatic zone, 2. epiphreatic zone, 3. vadose zone.* ***B****: 1. rocky relief shaped by water flow (a. ceiling pockets, b. scallops). 2. along-sediment rocky relief (a. above-sediment channel, b. below-sediment channel).*

Detailed morphologicial studies in Netopirjev rov[4]

(R. Armstrong .L. Osborne[5])

Netopirjev Rov, a part of the upper level of Predjama Cave, is not a former fluvial cave passage but a complex void made up of coalesced, structurally guided elongate cavities with cupolas and a range of speleogens normally associated with hypogene caves. These cavities were initially separated and later became integrated by the breakdown of their common walls. The main chamber consists of at least two coalesced voids while an apparent bend, a pseudobend, towards the northern end of Netopirjev Rov results from the breakdown of the common wall near the ends of two adjacent elongate cavities. It is proposed that this section of cave was excavated by the action of water rising from below (per-ascensum speleogenesis), but the nature and source of this water remains unclear.

Predjama Cave is developed on three levels, the lowest level is an active streamway fed by Lokva Stream, which sinks just below the castle. The geological structure of the area is quite complex with significant thrust faults and strike-slip fault zones intersecting and displacing the limestone near the cave (Čar & Šebela 2001). Šebela & Čar (1991) investigated the relationship between faults and breakdown in Vzhodni rov, part of the second level of the cave (Figure 18).

Study area

Netopirjev Rov, a dead end passage in the Fiženca (upper) section of the cave, extends for some 100 m north north-west from the tourist path at the top of the main ladder leading down to Velika dvorana (Figure 19).

[4] For detailed description of the cave passages and rock features see Osborne 2008: http://carsologica.zrc-sazu.si/downloads/372/7Armstrong.pdf

[5] Faculty of Education and Social Work, A35, University of Sydney NSW 2006, Australia, a.osborne@edfac.usyd.edu.au

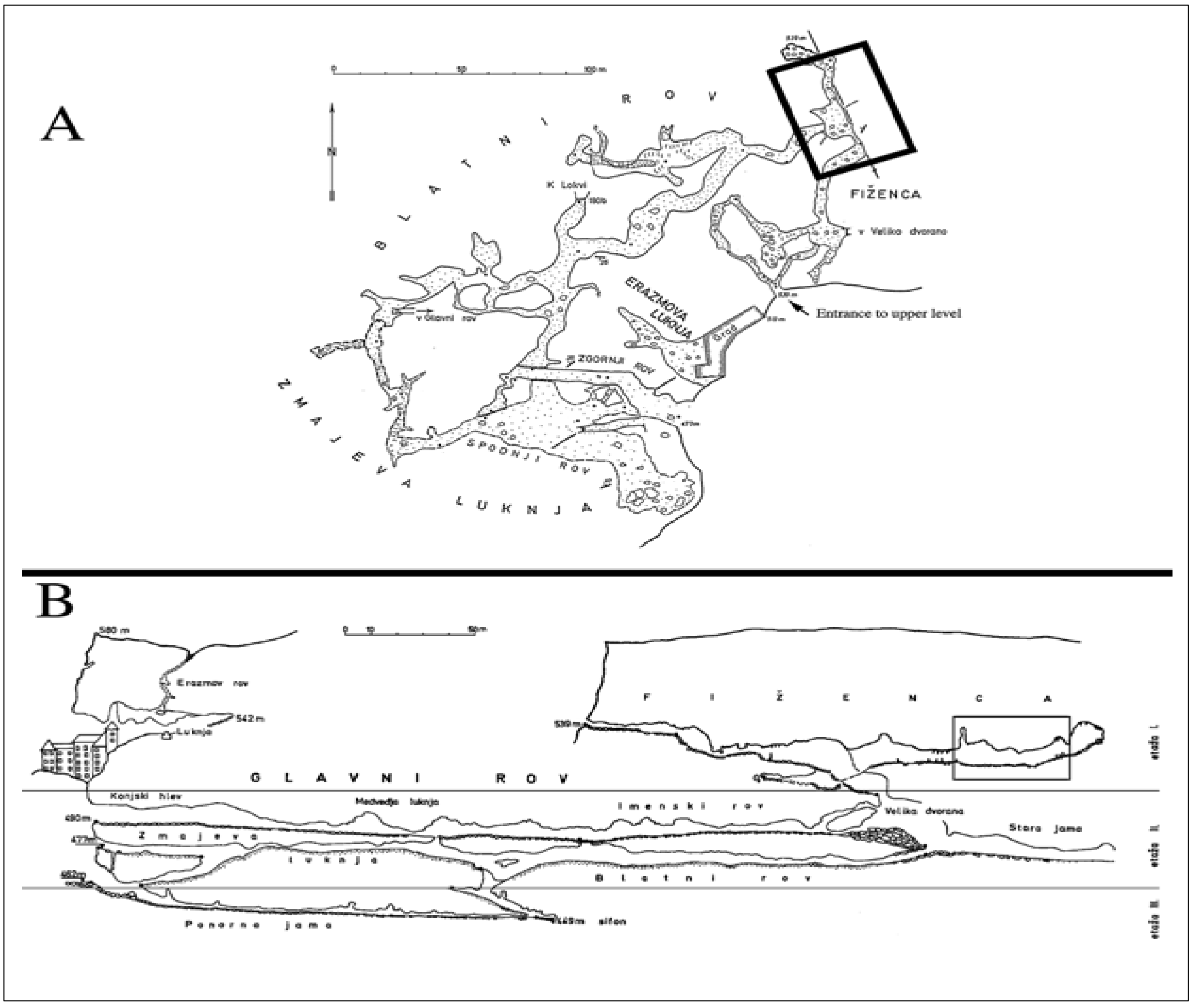


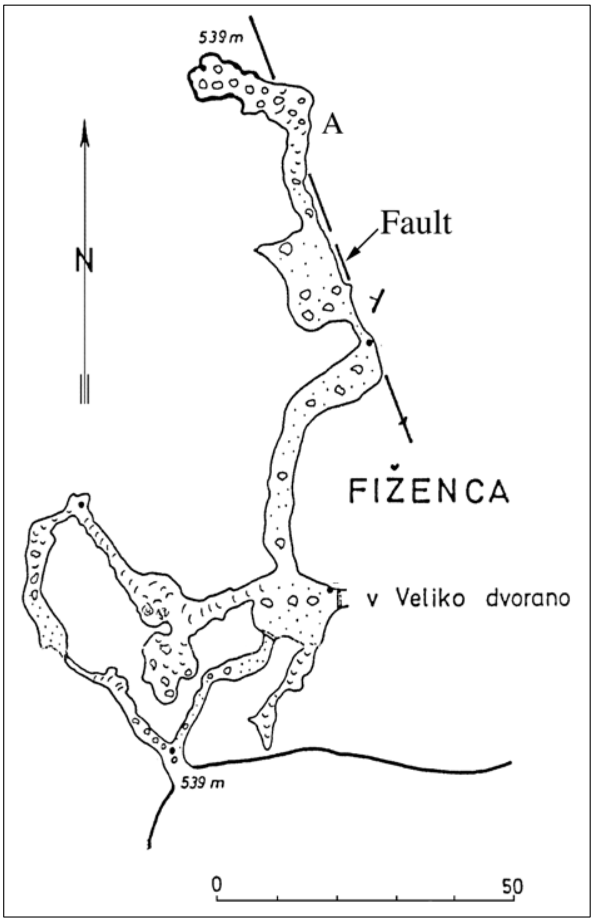
Fig. 18: Predjama Cave after Habe (1970). ***A:*** *plan showing the castle (Grad), middle and upper cave levels, rectangle indicates study area.* ***B:*** *developed long section show- ing upper, middle and lower levels, rectangle indicates study area.*

Gross morphology

Netopirjev Rov begins as a high, broad passage about 5 m wide. After about 20 m it turns to the NE and then sharply to the NNW and narrows to about 1 m. After five metres it broadens into a rectangular chamber 15 m long x 10 m wide and then narrows to about 3 m for another 15 m where it makes a distinct turn to the NW. The passage continues for another 20 m before terminating (Figure 19).

The study area in Netopirjev Rov consists of four distinct larger sections, a broad Southern Section, a Narrow Section, a Chamber and a Northern Section and three smaller sections; the Northwest Passage, the high-level Fossil Tube and the Eastern Tube.

The most distinct features of Netopirjev rov are ceiling vaults (Cathedrals) and cupolas (conical, elliptical and hemispherical). Vaults are narrow, elongated hollows in the cave ceiling with a roughly triangular cross-section guided by the NNW–SSE structures.



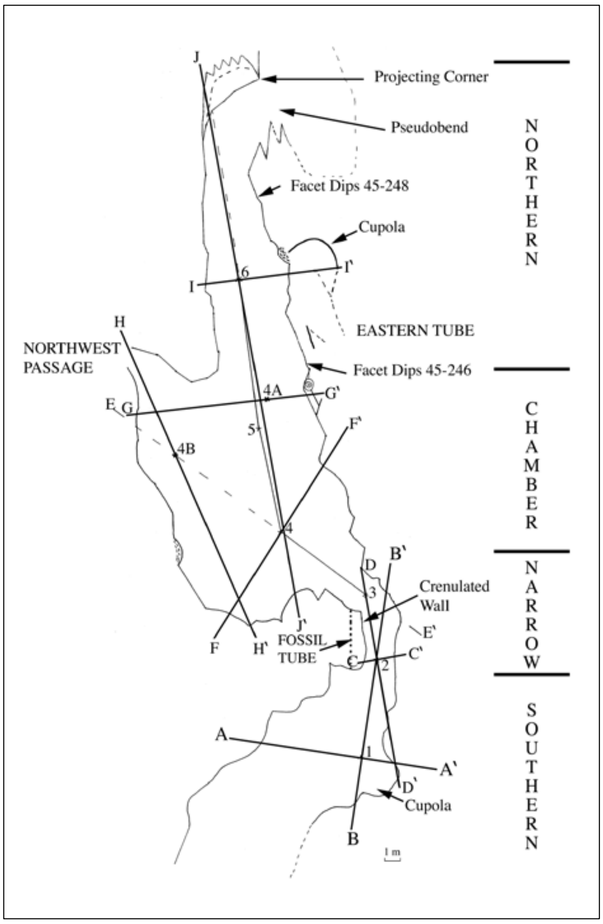


Fig. 19: Detail of Netopirjev Rov from Hajna (1996) at original mapping scale.

Fig. 20: Composite map of the study area based on wall contours plotted on a plane table at six stations at an original scale of 1:100.

Speleogens

Among speleogens notches, facets, pseudonotches, half tubes, tubes, blind pipes, blades, scallops(?), cusps, large shallow pockets and vertical and inclined structurally guided pockets occur.

Wall morphology

Wall morphology in the study area results from a complex interplay between geological structure and cave forming processes. Where cave walls are oblique or perpendicular to the principal structural planes complex morphologies develop, while walls parallel to the principal north-northwest to south-southeast trending structure tend to be planar. Crenulated walls are produced by the interaction of solution with two structural planes in the wall.

Breakdown

While much of the cave floor is composed of relatively small breakdown blocks, there is little evidence for recent breakdown in the study area.

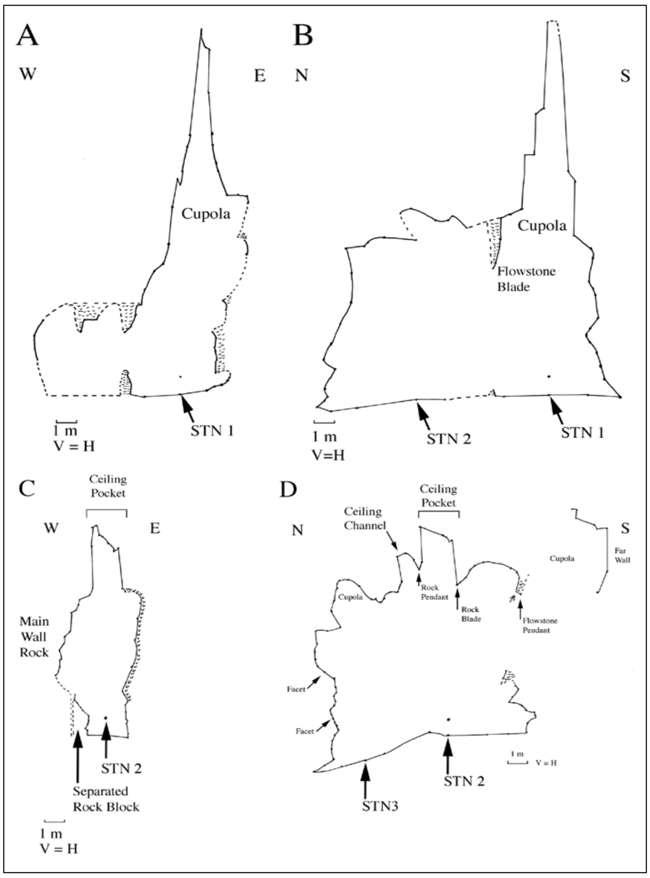


Fig. 21:
A – W–E Section at Station 1, A–A' in Fig. 20;
B – N–S Section at Station 1, B–B' in Fig. 20;
C – W–E Section at Station 2, C–C' in Fig. 20;
D – N–S Section at Station 2, D–D' in Fig. 20.

Morphostratigraphy

A morphostratigraphy for the study area can be constructed by examining the cross cutting relationships between different types of large cave voids and speleogens. This suggests the following stages of cavity development:

1. Development of the Fossil Tube and other phreatic tubes, now represented by pseudonotches (1 in Figure 22);
2. Development of rising tubes and cupolas (2 in Figure 22);
3. Development of cathedrals, now forming ceiling voids (3 in Figure 22);
4. Integration by breakdown of walls between cathedrals (4 in Figure 22).

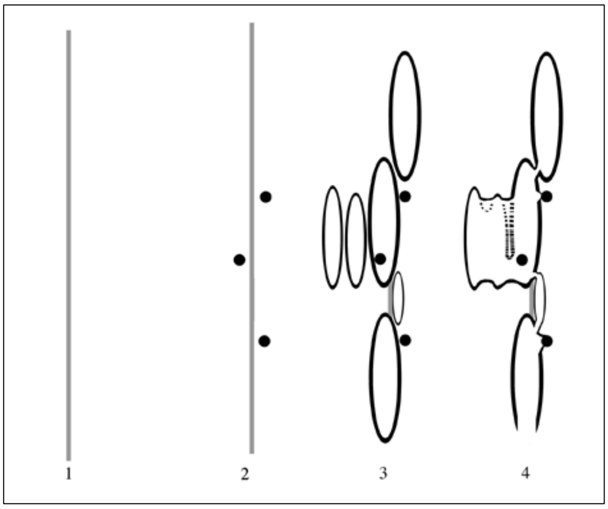


Fig. 22: Evolution of Netopirjev Rov
1 – Fossil phreatic tube forms;
2 – Cupolas and rising tubes form in first phase of hypogenic speleogenesis;
3 – Cathedrals form, intersecting the cupolas and rising tubes in second phase of hypogenic speleogenesis. The cathedrals are laterally disconnected;
4 – Cathedrals become integrated largely by breakdown (failure) of their adjoining walls.

Integration

After the third stage of development Netopirjev Rov would have not been a “passage”, but rather a series of isolated adjoining cavities (3 in Figure 22). The present condition of the cave results from the integration of these cavities. This was probably a result of solution thinning the walls between adjacent cavities, followed by the more obvious breakdown failure of the walls.

Discussion

Neither the general form of Netopirjev Rov, nor the suite of speleogens found there, are typical of those of conventional fluvial caves. There is nothing to indicate that water flowed horizontally from south to north (or from north to south) during the last two phases of cave development. The only scallops present are large and indicate slow upwards flow. Most of the major cavities and speleogens are guided to a significant degree, if not controlled by, geological structures, principally joints and shear planes. Bedding and lithology appear to play no role in cave development in the study area. There are no levels or planed ceilings suggesting epiphreatic or paragenetic development and no relict fluvial or paragenetic sediments.

Rising water could have entered this section of the cave as a result of flooding or due to sedimentation and paragenesis at a lower level. They simplest mechanism for this would be for water to rise up through the existing connection to Velika dvorana (prior to the breakdown), flow laterally northwards to the study area and then rise through open joints in the cave ceiling excavating the cupolas and ceiling vaults etc. (see Figure 18B). The problem with this mechanism is that prior to breakdown of the party wall the western vault of the chamber was blind along strike and could not have received lateral flow form the south. The same applies to the section of cave north of the study area. Prior to breakdown producing the projecting corner, the northern segment of the cave was also blind (see “4” in Figure 22).

Another possibility is that flood or paragenetic water rose from below directly into the blind cavities. This would require feeder connections from the lower section of the cave directly below the main chambers and the cupolas. As the cave floor is composed largely of gravel to cobble sized breakdown fragments it is impossible to determine the shape of the cavities below floor level, but it does not seem likely that there is filled are vertical con- nections below the floor to the lower cave levels.

Cavities and speleogens similar to those in Netopirjev Rov occur in hypogene caves of both thermal and artesian origin as described by Klimchouk (2007). While tube feeders do occur in these caves, the dissolving fluids were often directed through rifts developed directly up the structural planes (propagation planes) along which both large and small-scale cavities are excavated. These “fissure and rift-like feeders” (see Plate 5, p. 45 of Klimchouk, 2007) take the form of slots opening down the guiding structural plane in the cave floor. Such structures could easily be blocked and covered beneath breakdown below the cave floor.

Conclusions

The gross cave morphology and the speleogens in the study area are inconsistent with a single-phase fluvial origin for this section of cave. The gross cave morphology and the speleogens suggest that following an initial phreatic phase; two later phases of major cave excavation in Netopirjev Rov resulted from solution by rising groundwater. It seems likely that the dissolving groundwater directed upwards through structural planes in the limestone, rather than laterally along cave passages or up a “feeder” tube from a lower level. Netopirjev Rov is thus a multiphase non-fluvial, per-ascensum (i.e. Hypogene sensu Klimchouk, 2007) segment of cave with later modification by breakdown.

There is as yet no indication of the source, chemistry or temperature of the waters involved in the hypogene excavation of this section of cave. Its close association with a fault and fault-related shear planes suggests that waters travelling at depth along the fault plane may have been involved.

Whole-day excursion (**C**)
JAMA POD BABJIM ZOBOM AND COK CAVES (JELOVICA PLATEAU)
(big low-temeperature hydrothermal calcite crystals)
Thursday, 13.6.2013, 7.30–19.30

Stops:
1 – Jama pod Babjim Zobom (convergence of epigenic and hypogenic features, big calcite crystals, cave sediments);
2 – Cok (excavated cave, iron mine, large calcite crystals).

Oxygen and carbon isotopic composition of low-temperature hydrothermal calcite crystals and related host rock from hypogene karst of Slovenia
(Bojan Otoničar)

Introduction

In Slovenia, caves of partly and predominantly hydrothermal or hypogene origin had not been described in the literature until recently (Osborne 2008, Zupan Hajna *et al.* 2008, Knez & Slabe 2009, Otoničar & Perne 2010). They were defined mainly on the basis of morphological evidence although in the area where they occur, modern geothermal and hydrochemical features as well as distinctive vugs and veins of coarse calcite crystals also occur. The aim of this work is to evaluate oxygen and carbon isotopic values of such calcite crystals and related host rock from three caves in the NE part of the Jelovica plateau (Julian Pre-alps, NW Slovenia).

Geomorphology and geological setting

The NE Jelovica plateau (Jelovica) is approx. 12 km long and 6 km wide high alpine karstic plateau with altitudes mainly between 1000 and 1300 m surrounded mainly by steep slopes more than 500 m high.

Caves are developed in the Middle and Upper Triassic limestone sequence up to a few hundred meters thick which is as a part of post-Oligocene Southern Alpine nape structure overthrusted on carbonate and siliciclastic rocks of different age (Middle Triassic to Oligocene). In Jelovica, Oligocene shallow marine carbonate and deeper marine siliciclastic deposits were entirely eroded away. Along the NE foothills of Jelovica and northern Ljubljana depression, contact between Oligocene clastic deposits and Triassic carbonate rocks is over 1000 m deep below the surface.

The area is dissected by numerous faults and fissures some of which comprise coarse grained calcite crystals. In the foothills of Jelovica, the distinctive NW–SE striking Bled fault zone still controls the position and discharge of one mineral and a few subthermal and thermal springs. Post-Oligocene tectonic activities along Sava fault displaced the investigated areas from 25 to 65 km (see Placer 2008).

On the investigated NE part of the Jelovica more than 110 caves are registered. The biggest is 1264 m long and 536 m deep. A few caves comprise a big collapse chamber, with the biggest estimated to be over 500,000 m^3. Caves exhibit complex polygenetic development in different karstic phases under variable hydrogeological and climatic conditions. Numerous caves were filled with allochthonous non-carbonate sediments and flowstone. Paleomagnetic data of a flowstone profile from the cave "Jama pod Babjim zobom", which post-date allohtonous deposits, support ages greater than 780 ka (Zupan Hajna *et al.* 2008). All three investigated caves (Figure 23) contain numerous features characteristic of hypogene speleogenesis (i.e. feeders, variable passage cross-section, dead-end passages, rising wall and ceiling channels, rising shafts, cupolas, bell-holes…).

From medieval times till the end of 19th century the Jelovica was a site of numerous small iron mines where they were excavating karstic sediments that comprised ferrigenous nodules. With the excavations, miners commonly reopened filled caves and made them accessible. Below mentioned "Cok" is one of such caves (Figure 24).

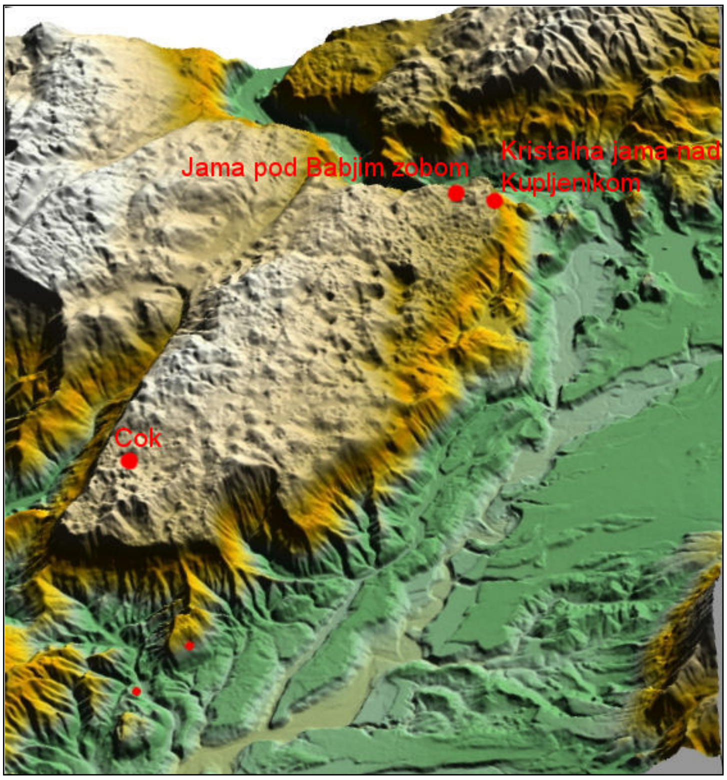


Fig. 23: A digital terrain model of Jelovica Plateau showing location of the three discussed caves. Note two other dots representing Turkovo in Jeralovo brezno Caves where morphology of passages and wall rock features diagnostic also for hypogene speleogenesis occur (Jelovica is approx. 12 km long).

Results

From distribution of carbon and oxygen isotopic composition, 3 distinctive groups of altered host rock, calcite crystals with related fine grained carbonate sediments, and flowstone have been separated in Jelovica caves (Figure 24).

In Jelovica, crystals and sediments are most extended in cave "Cok" (entrance: 1160 m a.s.l.; length: 279 m; depth: 36 m) where they may form up to 30 cm thick palisade linings on walls of dissolutionally enlarged joints (Figure 25) or fill vugs up to a few metres in diameter. In the latter case, they may form a depositional sequence of less than 20 cm thick geopetally deposited platy and laminated calcareous micrite with two intercalations of grayish translucent up to a few cm thick palisade rhombohedral calcite crystals (Figure 26). The remaining cavities were completely centripetally filled with very coarse-grained translucent and white non-transparent calcite crystals. Sharp crystal faces of approx. 30 cm long columnar scalenohedral calcite crystals that may form arch-like structures could be observed locally.

In the adjacent caves "Jama pod Babjim zobom" (entrance: 860 m a.s.l.; length: 359 m; depth: 50 m) and "Kristalna jama nad Kupljenikom" (entrance: 988 m a.s.l.; length: 220 m; depth: 10 m) up to 15 cm long crystals (usually less than 5 cm) may form linings on the cave walls, niches and widened joints (Figure 27). In some places, crystals linings occur only in the lower parts of the passages suggesting precipitation from cave pool. In this case, crystals post-date vadose flowstone deposits. Where crystal linings have been deposited directly on the host rock in isolated niches and opened joints, their relationship with stagnant pool water is less obvious and crystals remind one of the large calcite crystals that fill vugs and joints elsewhere in Jelovica.

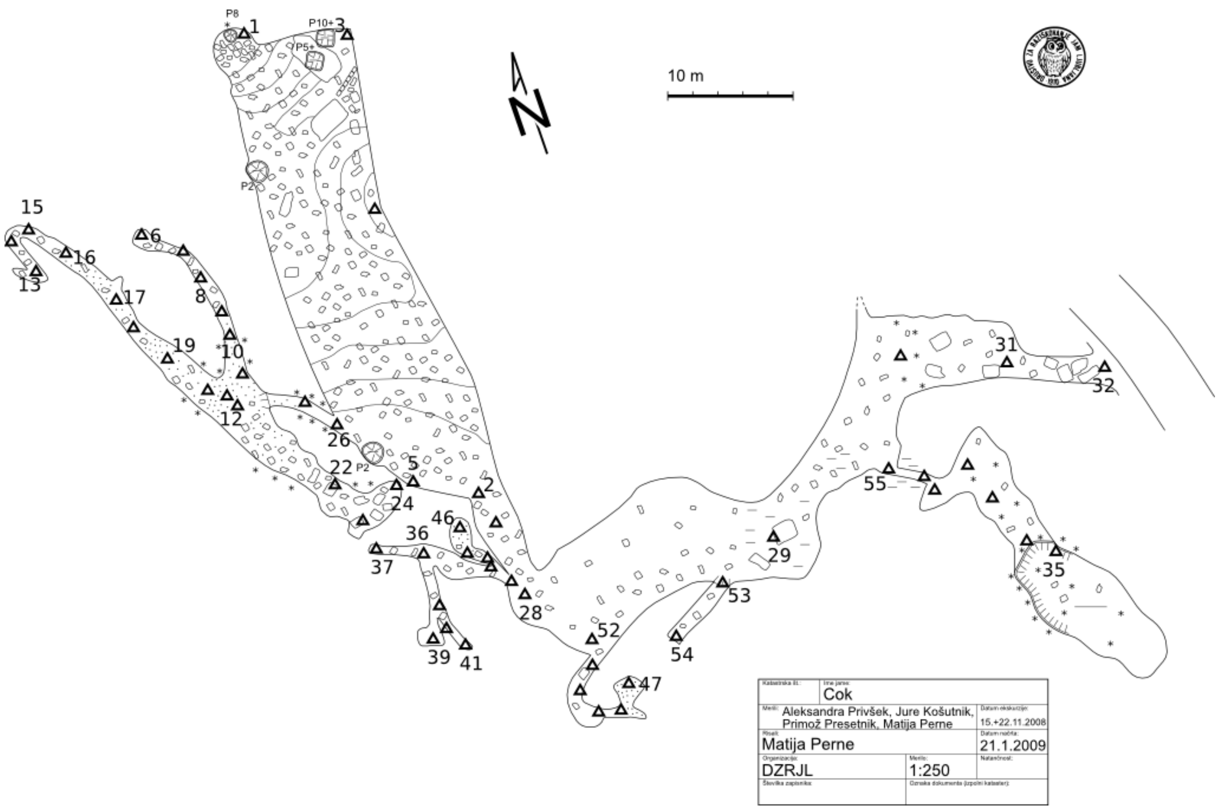


Fig. 24: Ground plane of the Cok Cave. Note the occurrence of big calcite crystals (small asterisk). Triangles are measuring points.

Fig. 25: Widened joint coated by approx. 20 cm thick palisade of calcite crystals (Cok Cave).

Fig. 26: Calcite crystals intercalated within geopetal calcareous sediment (lower part of big geode; Cok Cave); width of the photograph is 3cm.

Fig. 27: Big calcite crystals surround big niche in Jama pod Babjim Zobom Cave; width of the photograph is approx. 50 cm.

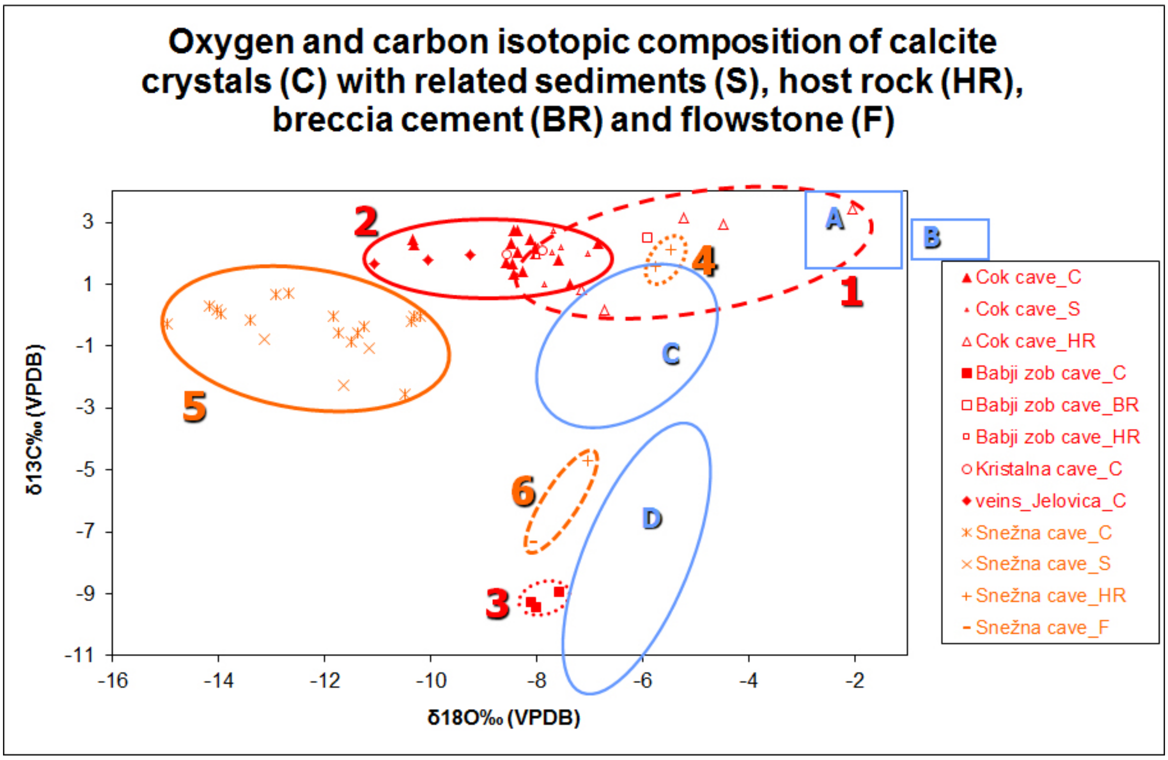


Fig. 28: Stable oxygen and carbon isotope composition of calcite crystals (C) with related sediments (S), host-rock (HR), breccia cement (BR) and flowstone (F) from three caves and veins in Jelovica Plateau (in red; 1 to 3). For comparison isotope composition of crystals, calcareous sediments, host rock and flowstone from Snežna Jama na Raduhi is added (in orange; 4 to 6). Blue circles represent isotope composition of flowstone from Slovenian caves (C – mountain regions; D – mainly Classical Karst), while blue rectangles average isotope composition of carbonates precipitated from Upper Triassic (A) and Oligocene (B) marine water.

Sixteen samples of coarse calcite crystals, 6 of the host rock and 5 of the fine grained calcite sediments related to crystal vugs were taken from the "Cok" cave, 4 samples of coarse calcite crystals and 1 sample of the host rock from the cave "Jama pod Babjim zobom" and 2 samples of the crystals form the cave "Kristalna jama nad Kupljenikom". Three samples of calcite crystals were taken from calcite veins in surface outcrops.

Here we classify oxygen and carbon composition of rocky samples in three rather distinctive groups (1 to 3 in Figure 28):

1) Host rock with synsedimentary cements (n = 7): variable but relatively high $\delta^{13}C$ values (from 0.19‰ to 3.44‰; average: 2.88‰; st. dev.: 1.22‰) and highly variable $\delta^{18}O$ values (from -8.01‰ to -2.04‰; average: -5.94‰; st. dev.: 2.17‰).

2) Coarse calcite crystals and calcite fine grained sediments, both related to geodes in the caves and coarse grained white non-translucent calcite crystals in veins (n = 26): relatively constant $\delta^{13}C$ values (from 0.99‰ to 2.74‰; average: 1.91‰; st. dev.: 0.56‰) and variable $\delta^{18}O$ values (from -11.05‰ to -6.84‰; average: -8.41 ‰; st. dev.: 1.03‰).

3) Coarse grained scalenohedral calcite crystals from cave "Jama pod Babjim zobom" probably all related to epiphreatic or vadose ponds (n = 3): low $\delta^{13}C$ values (from -9.42‰ to -8.91‰; average: -9.19‰; st. dev.: 0.26‰) as well as $\delta^{18}O$ values (from -8.12‰ to -7.58‰; average: -7.91‰; st. dev.: 0.29‰).

Interpretation and discussion

The highest value of the Upper Triassic marine limestone host rock sample from Jelovica falls within the range of Triassic marine calcitic values reported by Lohmann (1988) and Veizer *at al.* (1999). Other mainly micritic host rock samples from Jelovica comprise successively lower $\delta^{13}C$ and especially $\delta^{18}O$ values (Group 1 in Figure 28). Their lowest values are consistent with the upper limit of the range of coarse grained calcite crystals and sediments related to vugs and dissolutionally enlarged joints in Jelovica (Group 2 in Figure 28). We suggest that the observed shift towards lower $\delta^{13}C$ and especially $\delta^{18}O$ values of altered host rock is a result of wall-rock alternation in hydrothermal condition. This is also consistent with predominantly lower $\delta^{18}O$ values and more constant but generally lower $\delta^{13}C$ values of coarse calcite crystals in the area, a trend that continues from the host rock into calcite deposits (Group 1 and 2 in Figure 28). Similar distribution of host rock and crystal values is observed also in some low-temperature hydrothermal alpine caves in Austria (Spötl *et al.* 2009) and Black Hills in USA (Bakalowicz *et al.* 1987) where $\delta^{18}O$ values suggest that calcite deposits formed at temperatures similar to those of alternation rind of the host rock. More pronounced change in $\delta^{18}O$ values compared to that of $\delta^{13}C$ (Figure 28) in altered host rock suggest effective water/rock interaction or relatively low water/rock ratio during wall-rock alternation (Banner & Hanson 1990, Bottrell *et al.* 2001, Spötl *et al.* 2009). These alternations are supported also by progressively brighter cathodoluminescence, from non-luminescent host rock with the highest isotope values to patchy bright orange host rock with the lowest one. Suggested more or less restricted hydrogeological conditions are consistent also with progressively lower $\delta^{18}O$ values and more constant but generally lower $\delta^{13}C$ values of bright orange luminescent calcite crystals. Such long-lasting relative stabile conditions could be established in deep seated phreatic environment when considerable isotopic exchange between water and rock reservoir occurred (dissolution of hydrothermal karst releases CO_2 rich in $\delta^{13}C$). Relatively high and less variable, although lower $\delta^{13}C$ values than that of the host rock and Triassic marine calcite values (see Veizer 1999) indicate that besides $\delta^{13}C$ derived from soil-CO_2 and the host rock maybe some other deep-seated source of $\delta^{13}C$ (e.g. thermal degradation of organic matter, high temperature decarbonation of limestone, magmatic proccesses…) shouldn't be ignored (see Bakalowicz *et al.* 1987, Bottrell *et al.* 2001, Spötl *et al.* 2009). Coarse-grained scalenohedral calcite crystals from "Jama pod Babjim zobom" (Jelovica) that comprise uniform oxygen and carbon isotopic values typical of meteoric water (Group 3 in Fig. 2) are locally related to large cave pools. Oxygen isotopic composition is similar to that of flowstone from Raduha and falls just bellow the lower range of present-day flowstone from different parts of Slovenia (Urbanc et al., 1985; 1990). Low $\delta^{18}O$ values either represent higher depositional temperatures (for same water composition as today) or lower $\delta^{18}O$ water value than today. Rather low $\delta^{13}C$ values (- 9.19 ‰ in average) confirm significant portion of soil-CO_2 derived from C-3 plants in precipitated calcite deposits. However, relatively low values of both $\delta^{18}O$ and $\delta^{13}C$ may also reflect the cooling of thermal water and mixing with soil-derived meteoric water during the latest stages of hydrothermal system evolution as it was already suggested by Zupan Hajna et al. (2008).

Calcite linings with related host rock alternation from Slovenian caves could be compared with hydrothermal karst development in Transdanubian Range and the North Hungarian Range (Hungary) (Dublyansky 1995). There, calcite linings of the second generation caves comprise $\delta^{18}O$ values comparable to that of Raduha. In the Hungarian case study, fluid inclusions of crystals yield homogenization temperatures of 55 °C and less (Dublyansky 1995). Although similar relatively high $\delta^{13}C$ values may suggest precipitation during burial in a system closed with respect to soil-derived carbon (Ford & Takászné 1991), we can apply also for our case interpretation of Dublyansky (1995) who suggests formation within hydrologic system involving deep circulation of meteoric water when carbonates were uplifted and overlying impermeable strata began to be eroded.

Measured isotope values, single-phase fluid inclusions and occurrence of sub-thermal springs in the foothills of Jelovica suggest water temperatures from which the host rock was altered and crystals were deposited below 30 ^{0}C.

The research was also a part of UNESCO IGCP project No. 598 and the [European Community's] Seventh Framework Programme [FP7/2007-2013] under grant agreement n°247616.

Keywords: stable isotopes, calcite crystals, hypogene karst, Slovenia

Jama pod Babjim zobom

(Nadja Zupan Hajna, Andrej Mihevc, Petr Pruner[6], Pavel Bosák[7])

Site location and characteristics

Jama pod Babjim zobom (Reg. No. 129; 46°19´33.12˝N; 14°04´20.84˝E; 860 m a.s.l.; Figure) is situated in the valley of the Sava River on the western slope of the Jelovica plateau (Figure 30). The valley is a karst canyon between two high karst plateaus with numerous dolines and altitudes above 1000 m a.s.l., Pokljuka on the north-west and Jelovica on the south-east (Figure 29). The valley was glaciated and modified by a glacier from Bohinj valley.

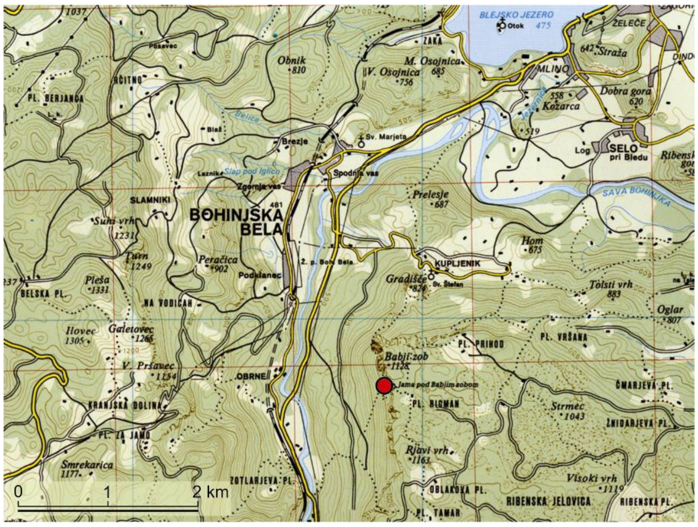


Fig. 29: Site location; Jama pod Babjim zobom (NW Slovenia; Zupan Hajna et al. 2008).

[6] Institute of Geology ASCR, v. v. i., Rozvojová 269, 165 00 Praha 6, Czech Republic, pruner@gli.cas.cz
[7] Institute of Geology ASCR, v. v. i., Rozvojová 269, 165 00 Praha 6, Czech Republic & Karst Research Institute ZRC SAZU, Titov trg 2, 6230 Postojna, Slovenia, bosak@gli.cas.cz

The cave entrance lies under the vertical walls of the upper part of the Jelovica plateau. Below the entrance of the cave scree slopes descend to the valley bottom, where the Sava River flows at 460 m a.s.l.

The cave was formed in the Upper Triassic limestones with dolomites and with a strata dip at 20° towards the south (Grad & Ferjančič 1974).

Jama pod Babjim zobom is 360 m long and 50 m deep. It consists of a horizontal passage and younger vadose shafts which pass through it. The mainly horizontal gallery extends eastwards along the strike with an average width of about 15 m. There are abundant speleothems (Gams 1962). Several types of calcite crystals cover walls and fill wall niches and ceiling pockets. There are no traces of Pleistocene glacial sediments or inflow to the cave, although the entire Sava valley was filled with the Bohinj glacier.

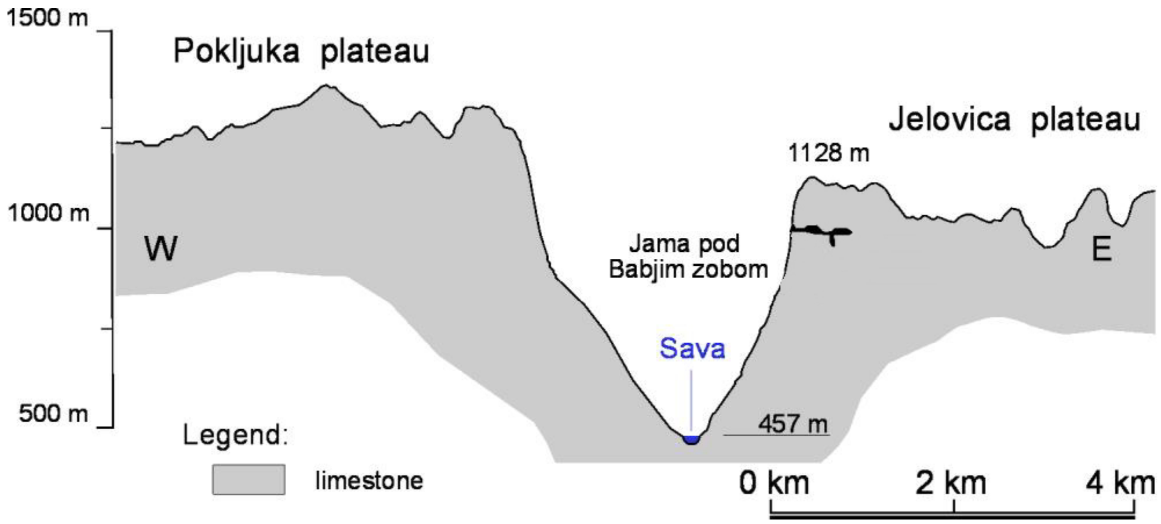


Fig. 30: Position of Jama pod Babjim zobom on the Jelovica plateau (Zupan Hajna et al. 2008).

Profile

The analysed flowstone profile is situated on the wall at the end of the cave (Figure 31).

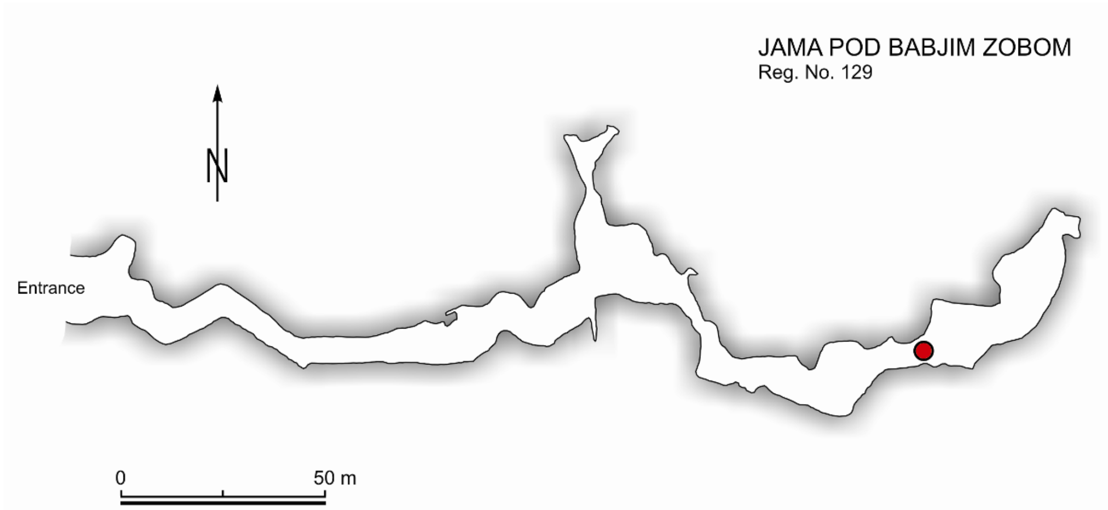


Fig. 31: Position of the profile on the cave map, Jama pod Babjim zobom (after Cave Register of JZS and IZRK ZRC SAZU, (Zupan Hajna et al. 2008).

Lithology

The section of flowstones and speleothems, about 2.2 m high, was composed of: (1) flowstone and stalagmite, white, yellowish in lower part, coarse-crystalline, laminated, (2) flowstone, white, yellowish in lower part, coarse-crystalline, laminated; (3) flowstone, brown, medium-crystalline, laminated, and (4) flowstone, massive, crystalline, columnar. Samples were mostly drilled out as solid cores.

Palaeomagnetic results

All samples from the Jama pod Babjim zobom profile were subjected to detailed AF demagnetization in 14 steps. Multi-component analysis was applied to separate the respective RM component for each sample. The *A-component* is undoubtedly of viscous origin and can be demagnetized in the AF (0–2 to 5 mT). The characteristic *C-HFC* is stable and can be demagnetized or isolated in the AF (ca 15–80 to100 mT). The mean values of J_n and k_n moduli are documented in Table 2.

Jama pod Babjim zobom	**Jn** [mA.m^{-1}]	**kn x 10-6** [SI]	**Interval** [m]*
Mean value	2.200	32.7	0.01–0.22
Standard deviation	1.060	36.8	
Number of samples	5	5	
Mean value	1.675	64.5	0.96–1.26
Standard deviation	1.180	61.2	
Number of samples	12	12	

* from top to base

Tab. 2: Mean palaeomagnetic values and standard deviations, Jama pod Babjim zobom (Zupan Hajna et al. 2008).

The mean value of the NRM is 0.0017 ± 0.0011 A.m^{-1} and the respective MS value is 52 ± 55 x 10^{-6} SI units. Stereographic projections of the C-component with N and R polarity are shown in Figures 32 and 33. Table 3 summarizes results of mean direction of samples from this profile. Mean palaeomagnetic directions of N polarized C-components for this profile are D = 343°, I = 51° and of R polarized C-components are D = 204°, I = -54°. The basic magnetic parameters are documented for 19 samples in Figure 34.

Tab. 3: Mean palaeomagnetic directions, Jama pod Babjim zobom (Zupan Hajna et al. 2008).

Jama pod Babjim zobom	**Polarity**	**Mean palaeomagnetic directions**		**α95** [o]	**k**	**n**
		D [o]	I [o]			
	N	343.39	50.86	5.76	147.45	4
	R	203.54	-53.67	8.73	21.45	12

The flowstone profile consists of two parts. The upper one contains an N polarized magnetozone and the lower one has R polarization.

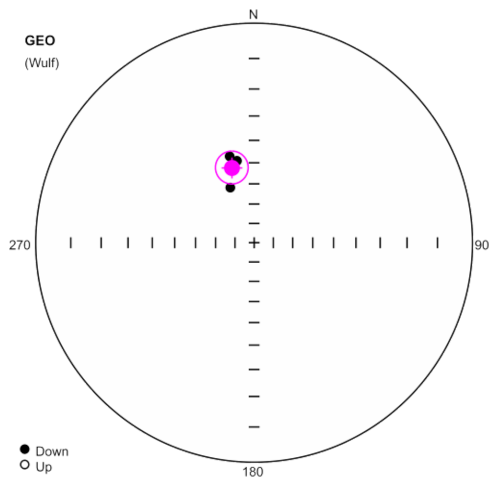


Fig. 32: Directions of C-components of remanence of samples with N polarity, Jama pod Babjim zobom (Zupan Hajna et al. 2008).

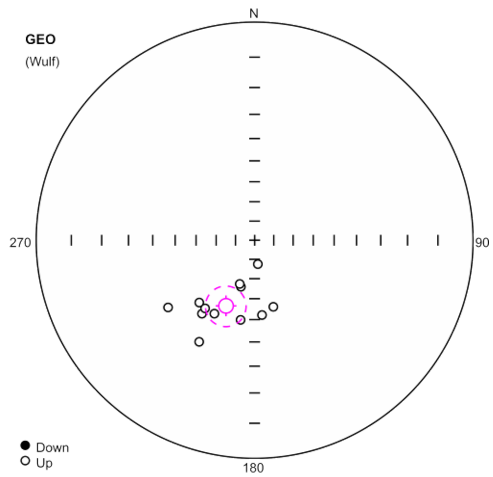


Fig. 33: Directions of C-components of remanence of samples with R polarity, Jama pod Babjim zobom (Zupan Hajna et al. 2008).

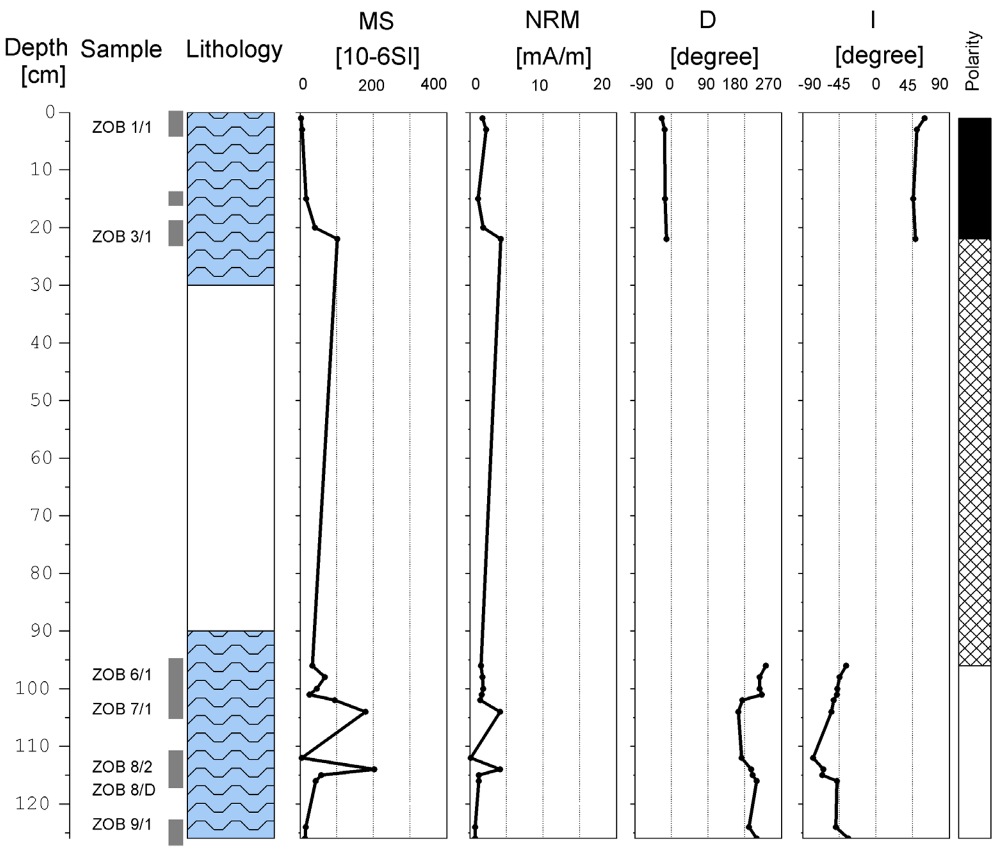


Fig. 34: Basic magnetic and palaeomagnetic properties, Jama pod Babjim zobom (Zupan Hajna et al. 2008).

Discussion of results

The origin of the cave is complex. It was probably formed before the Sava River entrenched some 650 m and separated the Jelovica plateau from the Pokljuka plateau, i.e. probably around the Miocene/Pliocene boundary. The cave could have been genetically connected with some stage in the evolution of surface on the Jelovica plateau, probably along a zone of mixing of meteoric and hypogene (hydrothermal) waters. The hypogene waters came from below, like some of the recent thermal springs existing in this general region. It is possible that the earliest stage was entirely hypogenic. The large calcite crystals (scalenohedrons) on walls of some copula-like niches in walls and cave roof and special features of some other speleogens support this idea. Crystallization of large scalenohedrons and deposition of some other speleothem types probably originated from degassing of up-welling thermal waters. Nevertheless, not all scalenohedral calcite crystals are thermal in origin. Smaller scalenohedrons were developed in cave pools and gours during later cave evolution, which resulted from cold water speleogenesis in epiphreatic conditions. This phase contributed to some remodelling of the cave, especially of vertical shafts, although hypogenic speleothems have been preserved. Fine-grained cave sediments were also deposited. The massive speleothems and some vadose shafts were formed in vadose conditions. Evolution of the vadose elements was connected with the entrenchment of the Sava river-bed. Deposition of the massive vadose speleothems cannot be correlated with the recent climatic conditions at their present elevations (Gams 1962).

The interpretation of palaeomagnetic data can easily support ages greater than 780 ka in spite of quite high degree of speleothem recrystallization.

Whole-day excursion (**D**)
GEOMORPHOLOGY AND HYDROGEOLOGY OF NOTRANJSKI KRAS
Friday, 14.6.2013, 9.00–17.00

Stops:
1 – Mount Slivnica (view on the Cerkniško polje);
2 – Rakov Škocjan;
3 – Planinska jama and Planinsko polje (discussion on Postojna-Planina cave system, morphology and hydrology of Planinsko polje);
4 – Gradišnica (hydrological observation in caves between Planinsko polje and Vrhnika);
5 – Velika Drnuljca (collapse dolines along the main ground water flow paths);
6 – Springs of Ljubljanica river and collapse dolines at Vrhnika.

Ljubljanica River system

Ljubljanica River collects the water from SW part of Dinaric karst in Slovenia and belongs as right Sava affluent to Danube and of Black Sea. The Ljubljanica water basin is about 1100–1200 km^2. Nearly all watershed of the river is in karst and therefore is not well defined. According to studies during the complex water tracing experiments of the nineteen-seventies, the catchment area of the Ljubljanica springs at Vrhnika, where the main river definitively leaves karst terrain, covers about 1100 km^2. The mean annual precipitation in the basin is 1300–3000 mm, during 100 to 150 rainy days. The one-day maximal amount to 100 mm, in extreme cases even 300 mm. The mean discharge is 38.60 m^3 sec^{-1}, with a specific run-off of 34.8 l sec^{-1} km^{-2}. Average mean denudation rate is 65 m^3 km^{-2} a^{-1}.

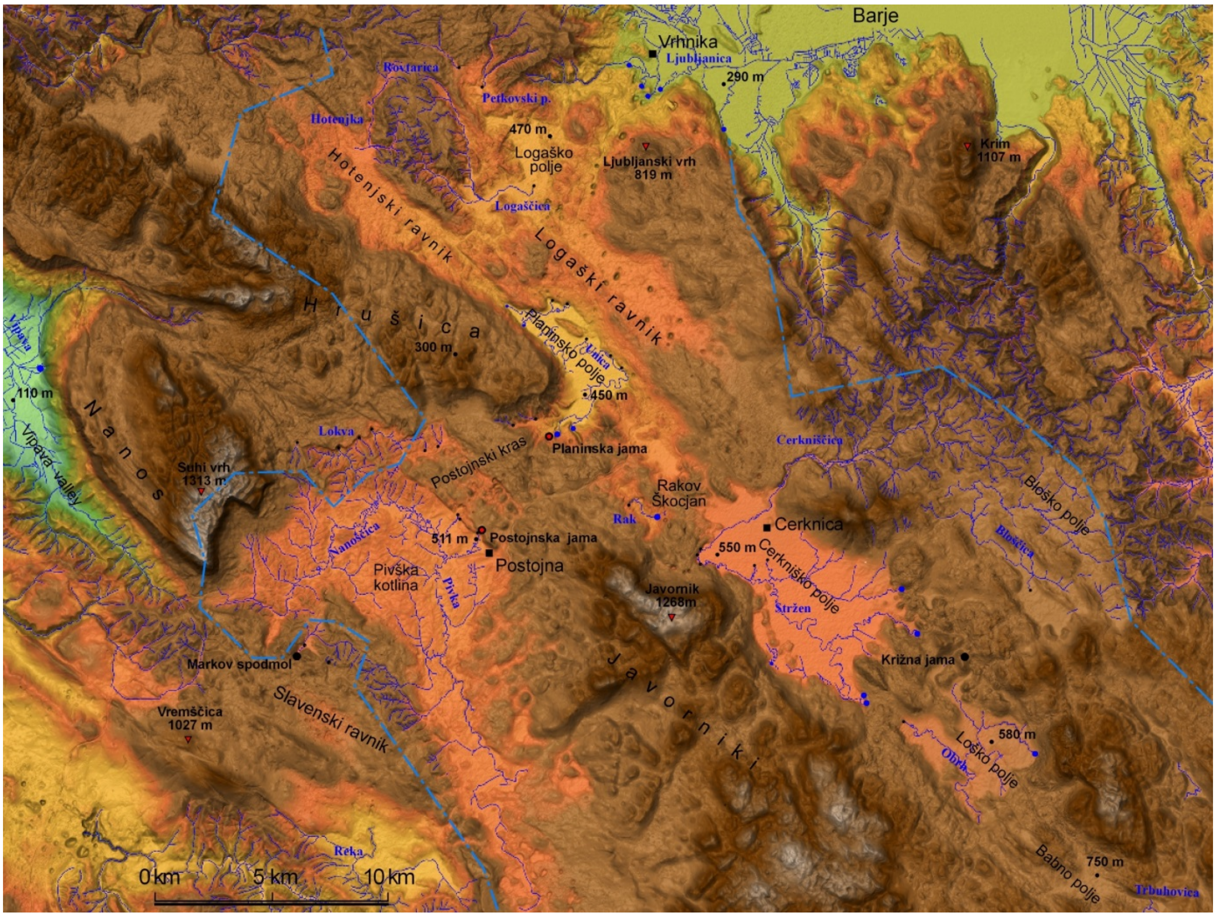


Fig. 35: Water basin of Ljubljanica river. High karst plateaus, lower poljes and levelled surfaces are main characteristics of the relief.

Most of the river basin is formed on the Mesozoic rocks, mostly limestone. On these rocks the precipitations infiltrate directly into the karst and there are no surface rivers. Triassic dolomite is important, allowing some surface flow, forming bottoms of some karst poljes or forming hydrologic barriers.

Structurally, the whole of the Ljubljanica basin belongs to the Adriatic sub-plate. The area is composed of several napes that were over thrust during the peak of Alpine orogeny in Oligocene, in a NE to SW direction. Later change of the plate movement direction brought about the formation of the Idria (dextral strike-slip) Fault, which runs through the area in a NW–SE direction.

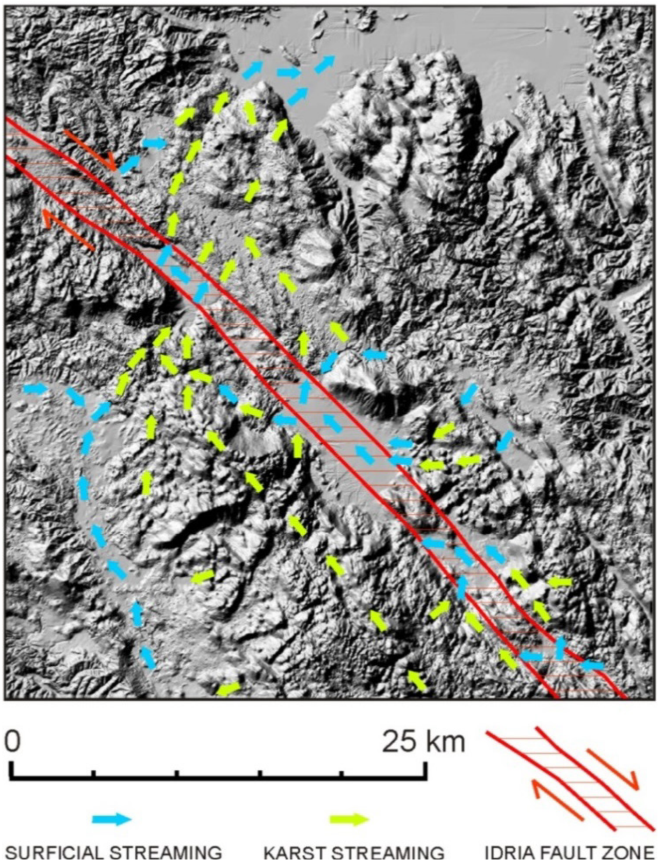


Fig. 36: Influence of the Idria Fault zone upon the karst poljes hydrology.

The highest parts of the basin are high karst plateaus Hrušica, Javorniki and Snežnik and Racna gora. On the poljes among them surface rivers appear only, but they have different names: Trbuhovica, Obrh, Stržen, Rak, Pivka, Unica and finally after the springs at Vrhnika the name Ljubljanica. The highest lying is the karst polje near Prezid (770 m), followed by Babno polje (750 m), Loško polje (580 m), Cerkniško polje (550 m), Rakov Škocjan and Unško polje (520 m), Planinsko polje (450m), Logaško polje (470 m) and finally by Ljubljansko Barje (300 m) where the Ljubljanica springs are at 300 m a.s.l. There are several large springs are dispersed along the edge of the Ljubljana Moor, which is connected with gradual tectonic subsidence of the area. Mean annual discharge of the Ljubljanica at springs is 38.6 m^3.

There are 1540 caves, accessible fragments of underground drainage system known in the catchment area of the Ljubljanica. The average length of the cave is 48 m and the depth 18 m. However, the largest caves are the ponor or spring caves; in them we can follow the 71 km of passages of the main rivers, tributaries of Ljubljanica.

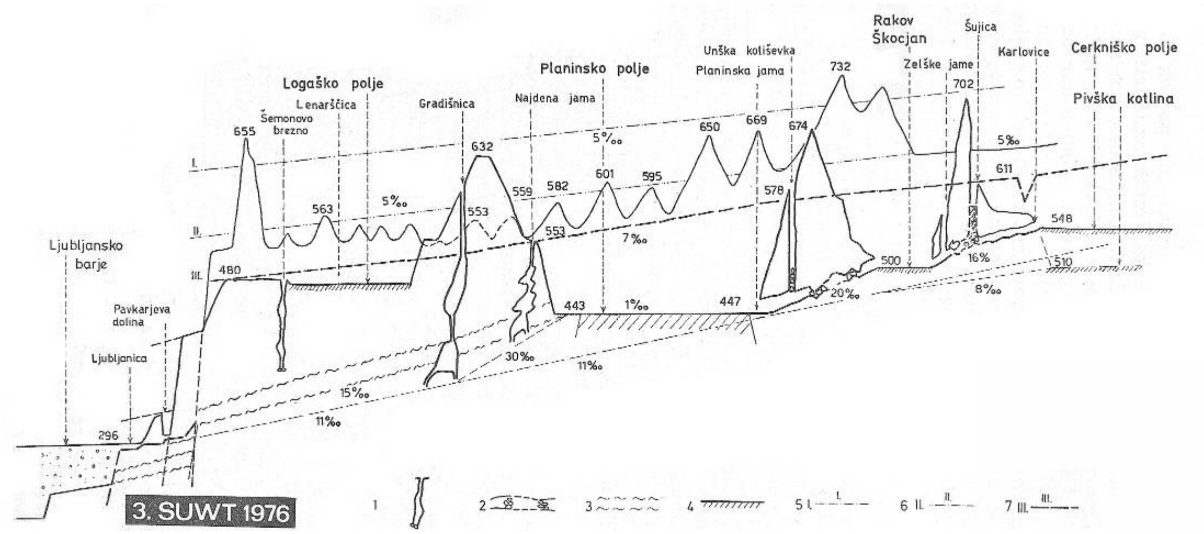


Fig. 37: Longitudinal cross section of Ljubljanica karst river basin. 1 – active cave or pothole, 2 – unknown parts within known active caves. 3 – the supposed zone of former active caves between Planinsko polje and Ljubljansko barje (Ljubljana moor), 4 – karst polje's bottom, 5 – gradišče relief level, 6 – Bodiški vrh relief level, 7 – dolina relief level (Gospodarič & Habič 1976).

Cerknica Polje

Cerknica polje is the largest karst polje in Slovenia. Often it is called just Cerkniško jezero (Lake of Cerknica), because of its regular floods, or intermittent lake. The intermittent lake covers 26 km^2 when is full; it is 10.5 km long and almost 5 km wide. Its hydrological properties caused that already in the beginning of New Age scholars from all round Europe were attracted to it. The lake becomes still more known through the Valvasor's description in 1689.

It is a karst polje developed in the important regional fault zone – Idrija fault. Idrija fault has "Dinaric" direction (NW–SE); in the same fault zone are developed: Planinsko polje, Loško polje and Babno polje. Bottom of Cerkniško polje covers 38 km^2 in elevation of about 550 m. Bottom is formed on Upper Triassic dolomite, which is presented also on the N, E and SE side of the polje, there are some Jurassic dolomites also presented. On W and NW the Cretaceous limestone are presented. Inflows are on E, S and partly on W sides of polje. The largest tributary to polje is Cerkniščica drained the dolomite catchments area. The important karst springs are Žerovnica, Šteberščica and Stržen. Stržen flows on the W side of polje towards the ponors in the middle of the polje, from where water flows directly to Ljubljanica springs, and towards NW side of polje, from where the water flows to Rakov Škocjan. From the foot of Javorniki mountain to the contact with dolomite in the polje bottom is 12 ponor caves. They are connected to Karlovica cave system to which also the highest waters from polje flows. It the system there is more the 7 km of passages. Passages are generally low, because they are filled by alluvia. Thickness of alluvia in Jamski zaliv, before the caves entrances, is about 8–15 m.

During the last centuries a lot of plans for the change of polje hydrology have been made, but not any of them was realised. In 1965 was proposed to make Cerknica polje a permanent lake, in the years 1968 and 1969 entrances to the caves Velika and Mala Karlovica were closed by concrete walls and 30 m long tunnel was made to connect Karlovica with the surface, but small effect of retention in dry period and less moistened years were assessed.

The bottom of Cerkniško polje covers 38 km^2 in elevation of about 550 m. Inflows are on E, S, and partly on W polje's side. There are some small superficial tributaries to polje, the largest is Cerkniščica, with about 45 km^2 of hinterland mostly dolomite.

Flattened bottom of Cerkniško polje is regularly flooded for several months in autumn winter and spring time, at floods it alters to spacious karst lake. Lower waters are sinking mostly in marginal swallow holes and in numerous ground swallow holes and estavellas, which are disposed in central polje's bottom. Principal ponor caves and swallow holes are disposed at NW polje's border.

Next to the polje border, from the foot of the Javorniki to the contact with dolomite in the polje bottom is 12 ponor caves. They are all connected with the system of the Velika and Mala Karlovica cave. Most of caves are short; they get narrow or are blocked by breakdown.

The highest waters run off through the caves Mala and Velika Karlovica, where more than 7 km of passable channels are known.

Outflow from the polje was not oriented to one channel, rather to a mesh of channels, which about 200 m from the edge of polje combine into a couple of larger galleries. They are generally low, because the bottoms are filled with sediments. The sediment fill is at 550 m a.s.l. in all the ponor caves, its thickness is possibly the same as a thickness of alluvia in Jamski zaliv, 8–15 m respectively.

Rakov Škocjan

Rakov Škocjan is a karst depression about 1.5 km long and 200 m wide. It is situated below the N side of Javorniki Mountain at elevation about 500 m between Planinsko and Cerkniško polje. Through the depression flows the permanent river Rak. The Rak springs from Zelške jame cave, bringing water from Cerkniško polje. Zelške jame are about 5 km long; the end of the cave is in huge collapse doline Velika Šujca, where from the other side the Karlovica cave system ends. In Karlovica system is the main outflow from Cerkniško polje. Numerous collapse dolines are situated around the entrance of Zelške jame. In one of them the Small natural bridge is present. Downstream the valley widens and several springs bring additional water to the Rak River. The valley is narrowed at the Great Natural Bridge and afterwards the Rak sinks into Tkalca jama cave from where the water flows towards cave Planinska jama at Planinsko polje. The distance from this point to the springs at Planinsko polje is about 4 km. The connections of the Rak with water from Cerkniško polje and with the Unica springs at Planinsko polje were proved by water tracing. The water regime in the Rak valley is intimately bound to the regime in Cerkniško polje. When Lake Cerknica dries up, the Rak does also.

Before World war I Rakov Škocjan was owned by the Windischgrätz family and was closed as their private park; between 1st and 2nd World war, the Italians also closed the area for the public. From 1949 Rakov Škocjan has been a Landscape Park.

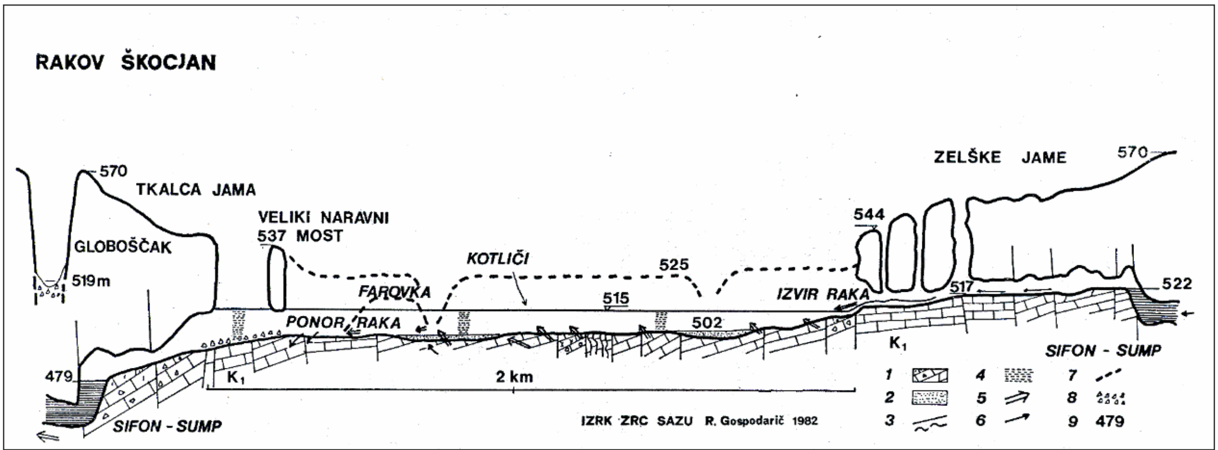


Fig. 38: Cross-section along Rakov Škocjan karst depression between spring at Zelške jame and sink in Tkalca jama. Legend: 1 – rocky bottom, 2 – alluvia, 3- fault zone, 4 – flood in 1982, 5 – karst spring, 6 – water flow directions, 7 – terraces, 8 – boulder rocks, 9 – altitude (Gospodarič et al. 1983)

Planinska jama

Planinska jama is the best known for the easy accessible confluence of relatively large rivers, the Pivka (arriving from Postojnska jama) and the Rak (arriving from Rakov Škocjan), about half a kilometre from the entrance. The former enters the cave through a sump, which has been explored about half a kilometre long and 60m deep, without penetrating on the other side. When Cerkniško polje the polje dries out, the eastern (Rak) branch of the cave receives no inflow and the water body begins to flow towards the Malni spring. The inflow/outflow sump has been explored some hundred meters long, to the very location of bifurcation, which turned out to be extremely dangerous for the divers. Some 30 metres below the water table, the main passage is "crossed" by direct outflow from Javorniki Mountain, draining directly to Malni Springs. The total of all the explored passages in the cave is about 10 km.

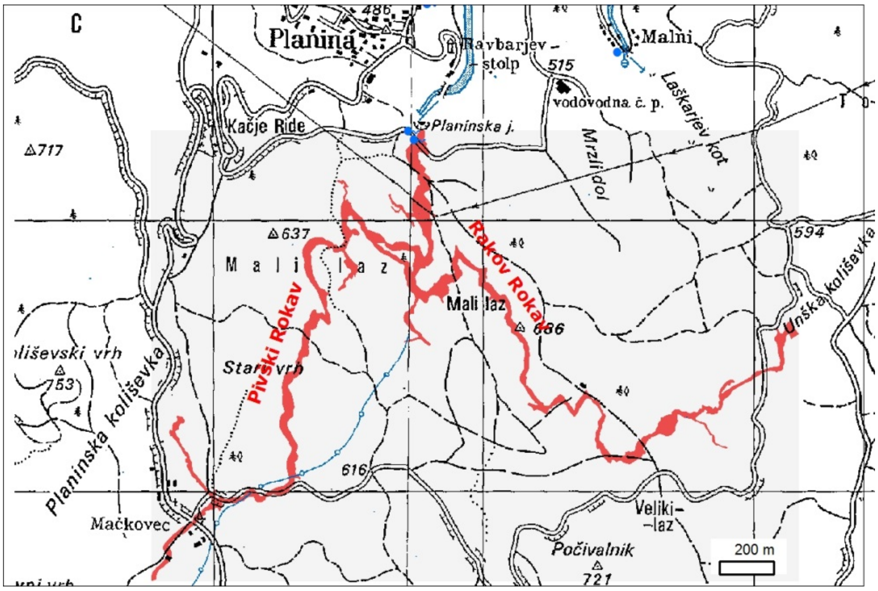


Fig. 39: Ground plan of Planinska jama.

Gradišnica

The cave Gradišnica is one of the largest caves in the Ljubljanica river catchment. 65 m deep entrance shaft with a cross-section of up to 30 m x 40 m, continues with a steep, 120 m long Kraus's gallery, of a similar cross-section. This opens into a Hauer's hall and a 25 m vertical step leading to Putick's hall, 160 m long, about 50 m wide and 55 m high. In 1886, the team led by Viljem Putick used winch to descend Putick to the bottom of the entrance shaft. He reached the step leading to the big hall, which was latter named after him.

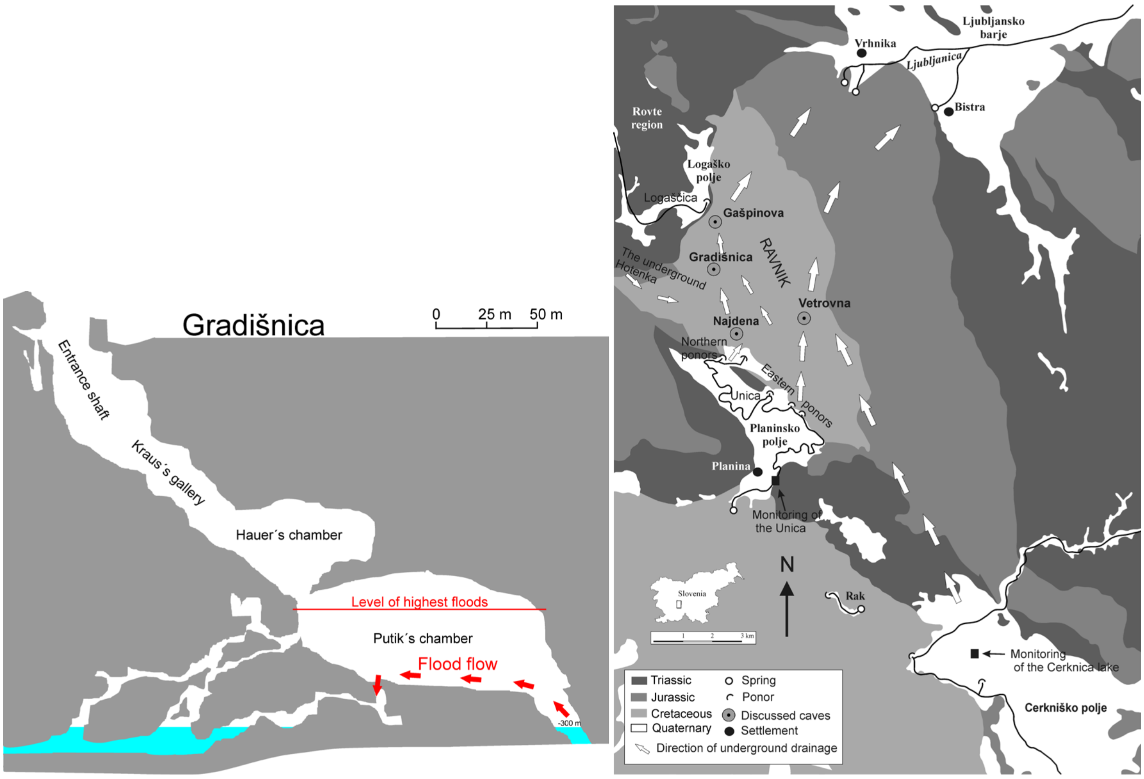


Fig. 40: Left: A generalised map of Gradišnica. The levels of highest floods and flood water flows recorded in 2006-2007 are shown. Right: Generalized geological map of the area between Cerkniško polje and Ljubljana basin. The position of observed caves, surface waters and presumed directions of groundwater flow are marked.

Water level and temperatures were monitored in all active caves between Planinsko polje and Ljubljana basin in years 2006 and 2007, including Gradišnica. During flood events the recorded rise of the water level was up to 40 m. Using temperature as a natural tracer, it has been demonstrated that the flood waters from Planinsko polje reach Gradišnica in about 9 hours. Measurements also show almost uniform water level between Gradišnica and Gašpinova jama, 1 km north from Gradišnica and the last know cave, where one can reach the flow of Ljubljanica.

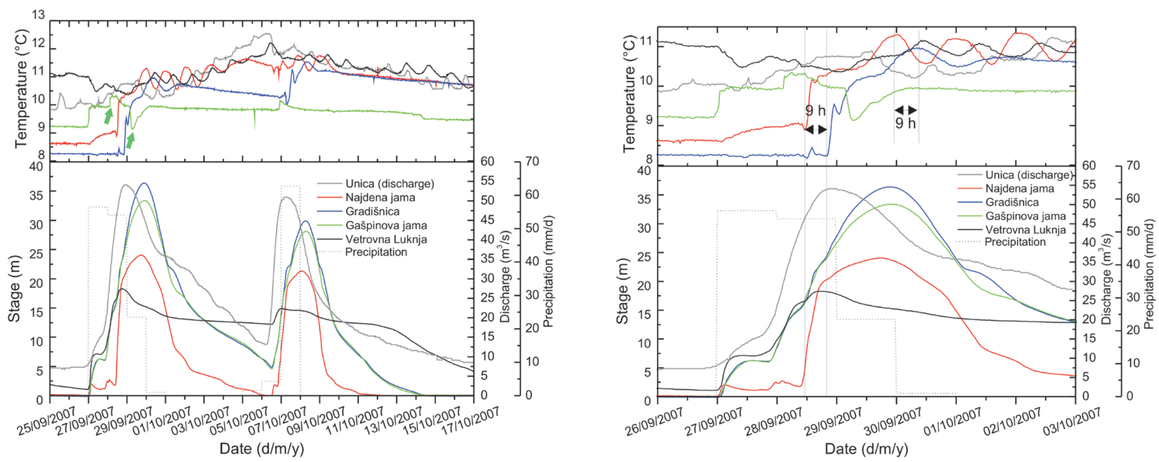


Fig. 41: Water level and temperature hydrograms in caves N from Planinsko polje, during two floo events in autumn, 2007. The right picture shows detail, where 9 h delay between temperature rise in

Najdena jama and Gradišnica was recorded. A detailed look into level hydrogram of Gradišnica Gašpinova jama on the right picture, shows an inflection at 23 m on both limbs. The inflection show the role of large storage capacity of Putick's hall.

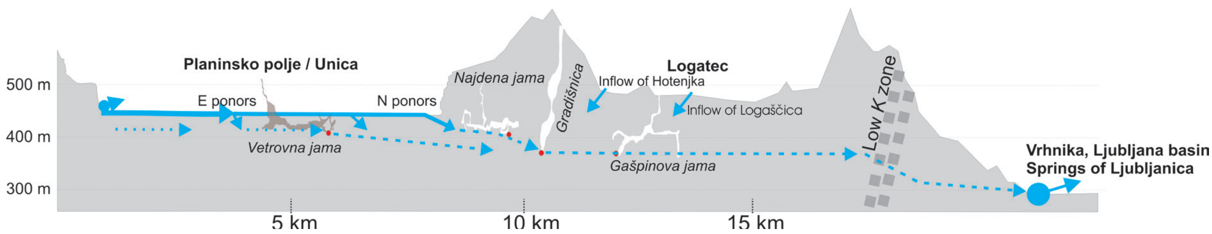


Fig. 42: An elevation profile of the area between Planinsko Polje and Ljubljana Basin approximately in S–N direction. The cross-sections of the caves are generalised and simplified. Vetrovna Jama is shifted to the S, because it would overlap with Najdena Jama if positioned correctly. This way its connection to E ponors is emphasised. Dashed lines show the estimated level and direction of groundwater.

Collapse dolines between Logatec and Vrhnika and in the vicinity of Ljubljanica springs

Between Logatec and Vrhnika,several large collapse dolines formed along the main drainage pathways of underground Ljubljanica river. Table 4 (Stepišnik 2010) lists the bottom elevations, and sizes of the largest.

Name	Bottom elevation (m)	Radius (m)	Average depth (m)	Estimated volume (m^3)
Velika Drnulca	409	157	106	4091107.00
Velika jama	424	143	66	2127419.00
Mala Drnulca	520	101	60	961422.00
Stranski dolec	457	90	69	876405.00
Masletova koliševka	435	89	70	864738.00
Srednja Lovrinova koliševka	443	96	57	816585.00

Tab. 4: Collapse dolines formed along the main pathways of Ljubljanica river (Stepišnik 2010).

Seven collapse dolines are located in immediate vicinity of main Ljubljanica spring (Table 5). The bottoms of are relatively levelled and covered with over 30 m thick loamy sediment . The elevation of bottoms of all these dolines are within 10 meters. Recent floods are observed in Grogarjev dol.

Name	Bottom elevation (m)	Radius (m)	Average depth (m)	Estimated volume (m^3)
Paukarjev dol	297.3	125	55	1337631.00
Meletova dolina	297.7	84	33	358074.00
Grogarjev dol	294	80	35	351858.00
Tomažetov dol	304.4	66	35	241301.00
Babni dol	295	58	27	140223.00
Susmanov dol	298.9	50	18	68722.00
Nagodetov dol	300.8	38	18	38656.00

Tab. 5: Collapse dolines located in the vicinity of main Ljubljanica spring (Stepišnik 2010).

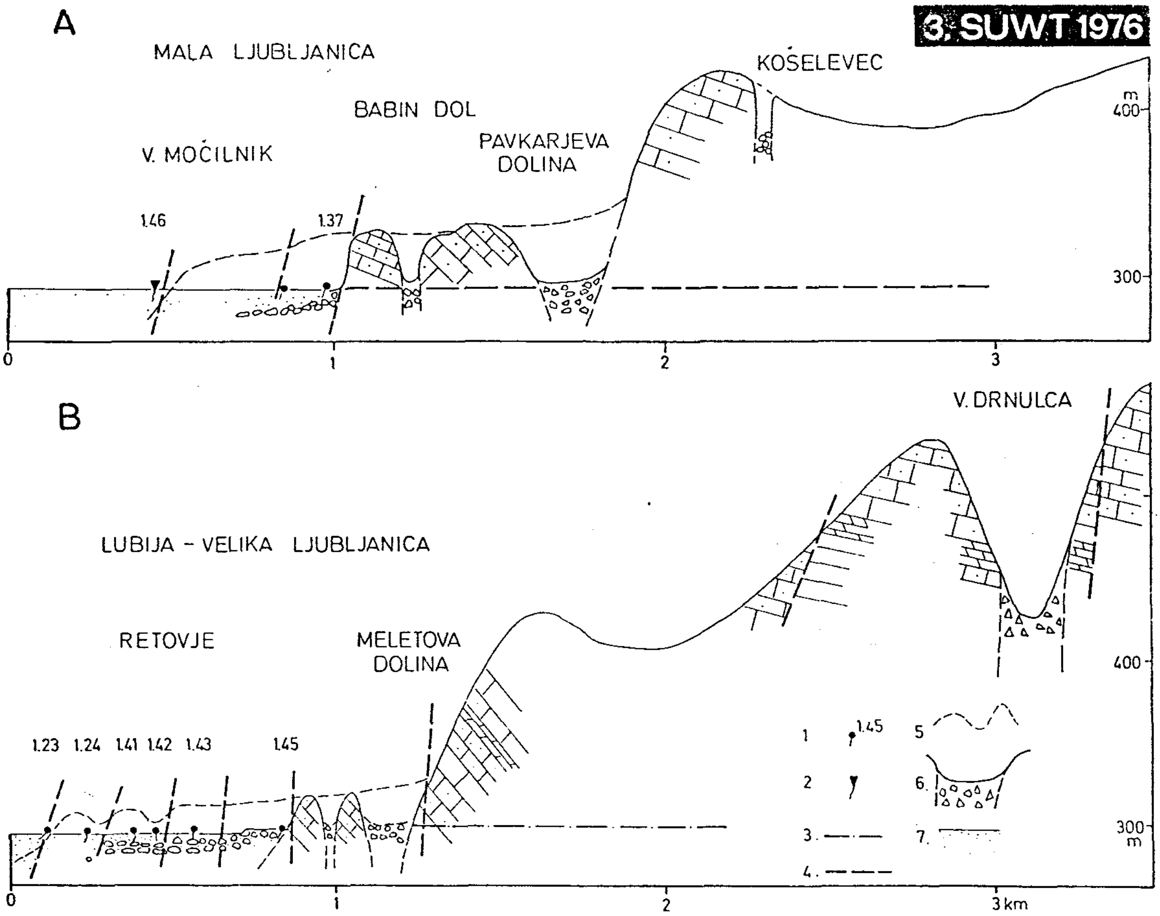


Fig. 43: Ljubljanica springs restricted hinterland cross section. A – Močilnik, B – Retovje.
1 – karst spring wiht number, 2 – thermal spring, 3 – karst water level, 4 – important fault, 5 – sketch of steephead, 6 – collapse doline with breakdown rocks, 7 – Quaternary sediments on Ljubljansko polje (Ljubljana Moor) (Gospodarič & Habič 1976).

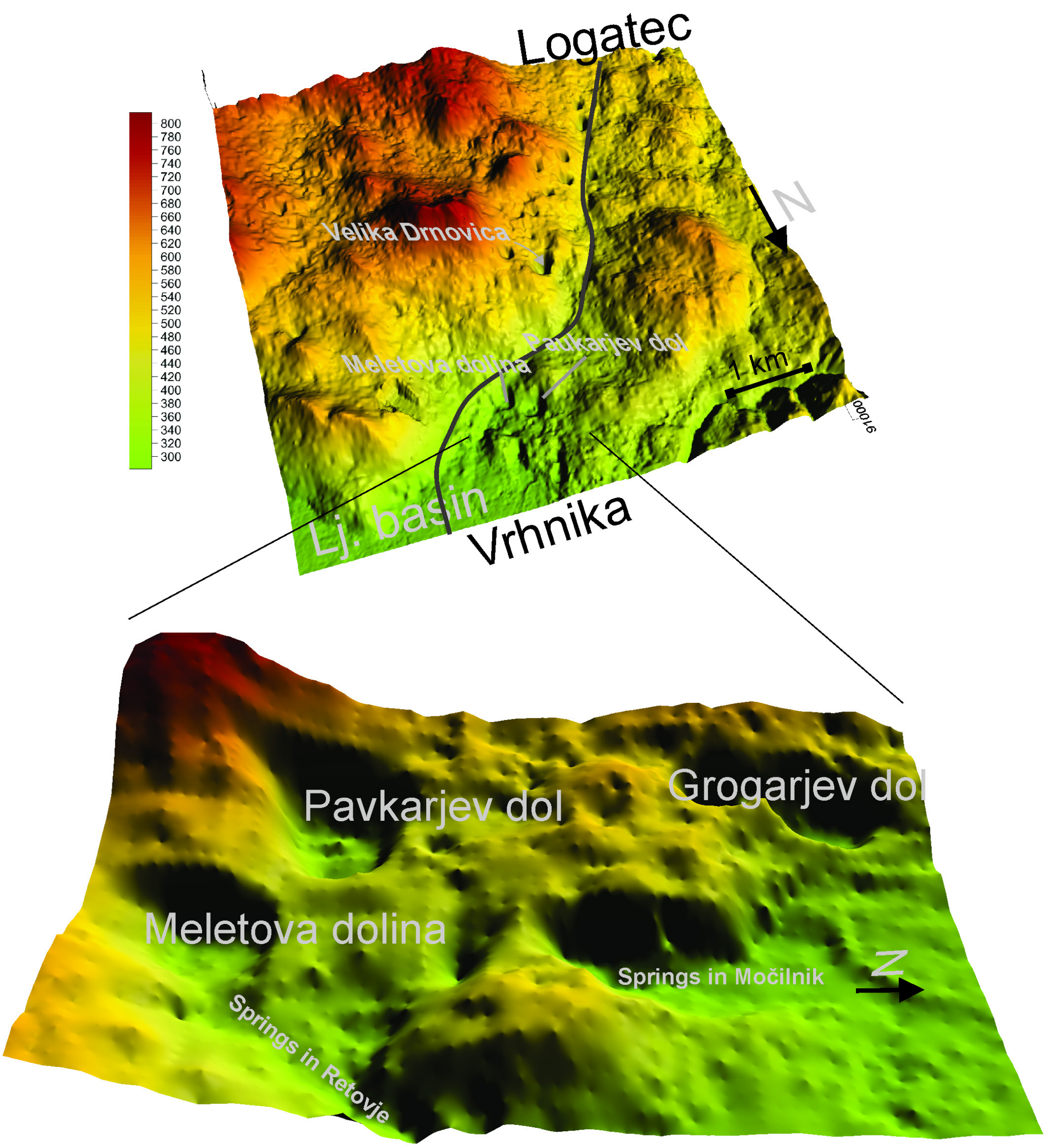


Fig. 44: Above: Line of collapse dolines between Logatec and Vrhnika. Below: About 1 km x 1.5 km excerpt presenting the relief with collapse dolines in the vicinity of Ljubljanica springs.

For more information and detailed data, an interested reader is referred to the work of Stepišnik (2010).

Selected references

Anelli, F. 1941–44. Osservazioni di meteorologia ipogea nelle Grotte di Castel Lueghi presso Postumia. Le Grotte d'Italia serie 2a vol. V, 5–34, Trieste.

Back, W., Hanshaw, B. B., Plumer, L. N., Rahn, P. H., Rightmire, C. T., Rubin, M. 1983. Process and rate of dedolomitization: Mass transfer and ^{14}C dating in a regional carbonate aquifer. Geological Society of America Bulletin, 94, 1415–1429.

Bakalowicz, M.J., Ford, D.C., Miller, T.E., Palmer, A.N., and Palmer, M.V., 1987. Thermal genesis of dissolution caves in the Black Hills, South Dakota: Geolological Society of America Bulletin, v. 99, p. 729–738.

Banner, J.L., Hanson, G.N., 1990. Calculation of simultaneous isotopic and trace element variations during water-rock interaction with applications to carbonate diagenesis: Geochimica et Cosmochimica Acta, v. 54, 3123–3137.

Bosák, P., Hercman, H., Mihevc, A., Pruner, P., 2002. High-resolution magnetostratigraphy of speleothems from Snežna jama, Kamnik-Savinja Alps, Slovenia. Acta Carstologica, 31, 3, p. 15–32.

Bottrell, S.H., Crowley, S., Self, C., 2001. Invasion of a karst aquifer by hydrothermal fluids: evidence from stable isotopic composition of cave mineralization. Geofluids, 1, 103–121.

Culver, D.C., Debevec, B., Knez, M., Kovačič, G., Kranjc, A., Mulec, J., Pipan, T., Prelovšek, M., Ravbar, N., Semeja, A., Slabe, T., Šebela, S., Zupan Hajna, N., 2012. Karstology and development challenges on karst II, Construction, tourism, ecology, protection, ZRC Publishing, 199 pp., Postojna–Ljubljana.

Čadež, F., 1977. Sadra in anhidrit na Idrijskem. Geologija, 20, 289–301.

Čar, J., Šebela, S., 2001. Karst characteristics of thrust contact limestone-dolomite near Predjama. Acta Carsologica 30, 2, 141–156.

Dublyansky, Y.V., 1995. Speleogenetic history of the Hungarian hydrothermal karst. Environmental Geology, 25, 24–35.

Ford, D.C., Takászné, B.K., 1991. Abszolút kormeghatározás és stabil izotóp viszgálatok budai barlangi kalcitmintákon. = U series dating and stable isotope analyses on calcite precipitates from Buda caves. Karszt Barlang, 1–2, 11–18.

Gams, I., 1962. Jama pod Babjim zobom. Proteus, 25, 1, 6–11.

Gams, I., 1974. Kras. Slovenska matica, pp. 360, Ljubljana.

Gospodarič, R., Habič, P., 1976. Underground water tracing : investigations in Slovenia 1972–1975. Third International symposium of underground water tracing, Ljubljana–Bled, 1976. SAZU, Institute for Karst Research SAZU, 309 pp., Postojna.

Gospodarič, R., Kogovšek, J., Luzar, M., 1983. Hidrogeologija in kraški izviri v Rakovem Škocjanu pri Postojni. Acta Carsologica, 11, 19–40.

Grad, K., Ferjančič, L., 1974. Osnovna geološka karta SFRJ, list Kranj, 1:100,000. Zvezni geološki zavod, Beograd.

Habe, F., 1970. Die höhlenwelt von Predjama. Acta Carsologica, 5, 1, 7–94, Ljubljana.

Hajna, J., 1996. Chronological review of the recent discoveries within the Predjama cave system. Naše jame, 38, 40–41.

Klimchouk, A. B., 2007, Hypogene Speleogenesis: Hydrogeological and Morphogenetic Perspective Special Paper no.1, National Cave and Karst Research Institute, Carlsbad, NM, pp. 106.

Knez, M., Slabe, T., 2009. Hydrothermal origin of Zadlaška jama, an acient alpine cave in the Julian Alps, Slovenia. In: Klimchouk, A.B., Ford, D.C. (eds.). Hypogene speleogenesis and karst hydrology of artesian basins: Proceedings of the conference, May 13 through 17, 2009, Chernivtsi, Ukraine, Special paper 1, Ukrainian Institute of Speleology and Karstology, Simferopol, 131–135.

Kranjc, A., 1983. Frequency of Dripstonefall in Golobja Luknja (Slovenia), Predjama. Acta Carsologica, 11, 99–116, Ljubljana.

Lohmann, K.C., 1988. Geochemical patterns of meteoric diagenetic systems and their application to studies of paleokarst. In: James, N.P., Choquette P.W. (eds.). Paleokarst: Springer-Verlag, 58–80.

Martín-Pérez, A., Košir, A., Alonso-Zarza, A.M., Martín-García, R., Otoničar, B., in press. Dolomite speleothems: examples from Spain and Slovenia. 28th IAS Meeting of Sedimentology, Zaragoza (Spain): 5th–8th July, 2011.

Márton, E., Čosović, V., Drobne, K., Moro, A., 2003. Palaeomagnetic evidence for Tertiary counterclockwise rotation of Adria. Tectonophysics, 377, 143–156.

Mihevc, A., 2005. Matjaževe Kamre. In: Knez, M., Prelovšek, M., Slabe, T., Šebela, S. (eds.). 13th International Karstological School "Classical Karst", Postojna 2015. *Karst in various rocks: Guide booklet for the excursions and abstract presentations.* Postojna: Karst Research Institute, Scientific Research Centre of the Slovenian Academy of Sciences and Arts, 13.

Mihevc, A., Horaček, I., Pruner, P., Zupan Hajna, N., Čermák, S., Wagner, J., Bosák, P., 2010. Miopliocenska starost jamskih aluvialnih sedimentov v Snežni jami na Raduhi. In: Košir, A., Horvat, A., Zupan Hajna, N., Otoničar, B. (eds.). Povzetki in ekskurzije, 3. slovenski geološki kongres, Bovec, 16.–18. september 2010, ZRC SAZU, Ljubljana, 34.

Mlakar, I., 1969: Krovna zgradba idrijsko žirovskega ozemlja = Nappe structure of the Idrija-Žiri region. Geologija, 12, 5–72.

Osborne, R.A.L., 2008. Detailed morphologicial studies in Netopirjev rov, Predjama Cave: A hypogene segment of Slovenian Cave. Acta Carsologica, 37, 2–3, 255–272.

Osole, F., 1975. Poselitev Slovenije v Pleistocenu. Arheološka najdišča Slovenije, 43–45.

Otoničar, B., Perne, M., 2010. Hypogene speleogenesis in the foothills of the Jelovica massif (NW Slovenia): examples from Turkovo brezno and Jeralovo brezno caves. In: Mihevc, A., Prelovšek, M., Zupan Hajna, N. (eds.). Dinaric karst: general information, programme, field trips, abstracts: 18th International Karstological School "Classical Karst", Postojna 2010., Karst Research Institute ZRC SAZU, Postojna, 51–53.

Otoničar, B., Tyc, A., Osborne, R.A.L., Bzowska, G. 2012. Mravljetovo brezno v Gošarjevih rupah cave: dissolution of dedolomite In: Mihevc, A. & Gabrovšek, F. (eds.). 20th International Karstological School "Classical Karst", Postojna 2012. *Karst forms and processes : guide book & abstracts*. Postojna: Karst Research Institute, Scientific Research Centre of the Slovenian Academy of Sciences and Arts, 68.

Placer, L., 2008. Principles of the tectonic subdivision of Slovenia = Osnove tektonske razčlenitve Slovenije. Geologija, 51, 2, 205–217.

Schmidl, A., 1854. Die Grotten un Höhlen von Adelsberg, Lueg, Planina und Laas, 1–316, Wien.

Spötl, Ch., Dublyansky, Y., Meyer, M., Mangini, A., 2009. Identifying low-temperature hydrothermal karst and palaeowaters using stable isotopes: a case study from an alpine cave, Entrische Kirche, Austria. International Journal of Earth Sciences (Geologische Rundschau), 98, 665–676.

Stemberk, J., Košťák, B., Cacon, S., 2010. A tectonic pressure pulse and geodynamic activity recorded from long-term monitoring of faults in Europe. Tectonophysics, 487, 1–4, 1–12.

Stepišnik, U., 2010. Udornice v Sloveniji. E-Geograff 1, pp. 118, Univerza v Ljubljani. http://geo.ff.uni-lj.si/sites/default/files/e-GeograFF-1-stepisnik.pdf

Šebela, S., 1991. Površinske geološke strukture in njihov vpliv na oblikovanje Predjame. Master thesis. Fakulteta za naravoslovje in tehnologijo, pp. 115, Ljubljana.

Šebela, S., Čar, J., 1991. Geological setting of collapsed chambers in Vzhodni rov in Predjama cave. Acta Carsologica, 20, 205–222.

Šebela, S., Turk, J., Mulec, J., Košťák, B., Stemberk, J., 2009. Statistical evaluation of the 3D monitoring of displacements of Dinaric Fault Zone in Postojna Cave, Slovenia. Acta Geodyn. Geomater., 6, 2, 163–176.

Šebela, S, Mulec, J., 2011. Activities in karst of Slovenia related to earthquake precoursors. In: *Complex research of earthquake's forecasting possibilities, seismicity and climate change correlations : BlackSeaHazNet Training-Seminar Workshop, 13–16 September, 2011, Tbilisi, Georgia*, (BlackSeaHazNet series, vol. 2). Tbilisi, pp. 147–156.

Šebela, S., Turk, J., 2011. Air temperature characteristics of the Postojna and Predjama cave systems. *Acta geogr. Slov.* 51/1, 43–64, Ljubljana. doi: 10.3986/AGS51102.

Urbanc, J., Kogovšek, J., Pezdič, J., 1990. Izotopska sestava kisika in ogljika v vodi iz Taborske jame. = Isotopic composition of oxygen and carbon in waters from Taborska jama. Acta Carsologica, 19, 157–163.

Urbanc, J., Pezdič, J., Dolenec, T., Perko, S., 1985. O izotopih kisika in ogljika v jamskih vodah in sigah Slovenije = Isotopic composition of oxygen and carbon in cave water and speleothems of Slovenia. Acta Carsologica, 13, 99–112.

Valvasor, J.W., 1689. Die Ehre des Herzogtums Krain, IV. Knjiga, 518-530, Laibach–Nürnberg.

Veizer, J. *et al.*, 1999: Sr-87/Sr-86, delta C-13 and delta O-18 evolution of Phanerozoic seawater. Chemical Geology, 161, 1–3, 59–88.

Vrabec, M., Fodor, L., 2006. Late Cenozoic tectonics of Slovenia: Structural styles at the North-Eastern corner of the Adriatic microplate. In: Pinter, N. *et al.* (eds.) *The Adria Microplate: GPS Geodesy, Tectonics and Hazards.* Proceedings of the NATO Advanced Research Workshop on The Adria Microplate, NATO Sciences Series, VI, Earth and Environmental Sciences, 61, pp. 151–168, Springer.

Weber, J., Vrabec, M., Pavlovčič-Prešeren P., Dixon T., Yan Jiang, Stopar, B., 2010. GPS-derived motion of the Adriatic microplate from Istria Peninsula and Po Plain sites, and geodynamic implication. Tectonophysics, 483, 214–222.

Zupan Hajna, N., Mihevc, A., Pruner, P., Bosák, P., 2008. Palaeomagnetism and magnetostratigraphy of Karst sediments in Slovenia. ZRC publishing, pp. 266. Ljubljana

LECTURE ABSTRACTS

Evidences of hypogenic speleogenesis in Slovenian caves

Bojan Otoničar

Karst Research Institute ZRC SAZU, Titov trg 2, 6230 Postojna, Slovenia, otonicar@zrc-sazu.si

In Slovenia, known as the country of classical karst, thinking about caves of predominantly hypogenic origin have been treated almost as a heresy. Although we may agree that only on the basis of cave morphology and wall rock features parts of some "common" caves especially close to allogenic inflow and past epipheratic zones cannot be simply related to some past hypogenic phase of cave development (e. g. Osborne 2008; Knez & Slabe 2009) some caves in Slovenia host too many features diagnostic for hypogenic, hydrothermal or at least ascending water flow that such interpretations shouldn't be considered.

We will present preliminary studies on caves from different karstic regions of Slovenia where cave morphology, wall rock features, mineralogy, general geological setting of the area and partly hydrogeology and hydrogeochemistry suggest, at least on a level of hypothesis, their partial development with hypogenic processes in a wider sense (*sensu* Palmer 2011). In each of the discussed karstic regions different phenomena diagnostic for some of the hypogenic processes prevails over the others.

In Jelovica high karstic plateau (Julian pre-Alps) and Raduha Mt. (Kamniško-Savinjske Alpe) many caves are locally decorated with big calcite crystals commonly found also as veins on the karstic surface.

The Vrh Svetih Treh Kraljev in Rovtarsko Hribovje, the Pre-alpine region in the western part of central Slovenia, hosts few caves which channels exhibit ramiform and maze like orientation guided by faults and joints with wall rock features characteristic for dissolution with slowly flowing ascending water. A large part of at least one cave is developed in dedolomite while the biggest cave in the area has no known natural entrance. In addition, three wells in the area discharge "sulphuric" water.

In Slovenia many caves show wall rock features that can also be diagnostic for hypogenic speleogenesis or at least to ascending flow. However, such features are most often found in places where high fluctuation of karstic waters mainly with allogenic river inflow occurs. Perhaps some exceptions could be found in the foothills of Jelovica Plateau where especially in one particular maze or anastomotic cave (Jeralovo brezno) no evidence of substantial allogenic inflow occurs although in the lower parts some smaller channels are partly filled by predominately fine grained sandy stream related allogenic deposits.

For more detail information of the above mentioned karstic regions with potential traces of hypogenic spelogenesis see the guidebook of the excursions.

Keywords: hypogenic speleogenesis, calcite crystals, dedolomite, Slovenia

References

Knez, M., and Slabe, T., 2009, Hydrothermal origin of Zadlaška jama, an acient alpine cave in the Julian Alps, Slovenia, in Klimchouk, A.B., and Ford, D.C. (eds.). Hypogene speleogenesis and karst hydrology of artesian basins: Proceedings of the conference, May 13 through 17, 2009, Chernivtsi, Ukraine, Special paper 1, Ukrainian Institute of Speleology and Karstology, Simferopol, 131–135.

Osborne, R. A. L., 2008, Detailed morphologicial studies in Netopirjev rov, Predjama cave: a hypogene segment of a Slovenian cave: Acta Carsologica, 37, 255–272.

Palmer N.P., 2011, Distinction between epigenic and hypogenic maze caves: Geomorphology, 134, 9–22.

Hypogene karst: speleogenetic mechanisms and geochemical methods of diagnostics

Yuri Dublyansky

Innsbruck University, Innrain 52, Innsbruck 6020, Austria, juri.dublyansky@uibk.ac.at

Two features define *hypogene speleogenesis*: (1) recharge of soluble formation from below, independent of recharge from overlying or immediately adjacent surface; and (2) predominance of the deep-seated sources of aggressiveness of karst water, independent of the environment at the overlying or immediately adjacent surface. Many "exotic" types of karst, such as hydrothermal karst or sulfuric acid speleogenesis are varieties of the hypogene speleogenesis.

Two principal types of speleogenetic mechanisms can be distinguished. *Geochemical mechanisms* are those responsible for creation (renewal) of aggressiveness of karst water. *Hydrogeological mechanisms* are those ensuring recharge of soluble formation by aggressive water and eventual removal of matter from the site of karstification.

Specific mechanisms depend on the zone in the Earth's crust where hypogene karst develops. It is convenient to distinguish the following three categories (zones): endokarst, deep-seated hypogene karst, and shallow hypogene karst.

Endokarst zone occurs at depths exceeding 4–5 km, where the total pressure exceeds the strength of the rock, and the pressure of fluid approaches lithostatic values. Solutional porosity of carbonate rocks in endokarstic zone may reach 18–28%, and the porosity of aluminosilicate rocks – 35–30%. Pores and cavities may exist only if they are filled with fluid, which prevents them from failure. Although this type of karst apparently does not produce traversable caves (the size of endokarstic cavities does not normally exceed several centimeters), it may play a significant role in creation of deep-seated reservoirs for hydrocarbons.

Deep-seated (low-gradient) hypogene karst zone covers a range of depths (approximately 0.3 to 4.0 km) where the (geo)thermal gradients are relatively small, pressure is close to hydrostatic, and the influence of the temperature changes at the Earth's surface is practically absent. The water aggressiveness may develop in response to the change in physicochemical parameters of fluids moving toward the surface, such as the decrease in temperature and pressure, due the mixing of different waters, and due to the change in bedrock chemistry/lithology.

Shallow (high-gradient) hypogene karst zone defines the area near the free surface of the hypogene water – both below and above it. In this zone the pressure is relatively low (down to atmospheric) and temperature may range from boiling to ambient. The temperature gradients may be significant, which lead to the appearance of some specific and powerful processes, like thermal convection and condensation corrosion. Also, in this zone upwelling hypogene waters meet oxidized meteoric waters, resulting in strong redox gradients. This may induce specific reactions and processes like H_2S oxidation, mixing corrosion, and cooling corrosion.

Most of the hypogene caves in carbonate rocks are associated with either the CO_2–bearing waters or with waters containing H_2S.

CO_2-RICH WATER

Waters rising from significant depth are commonly thermal and are saturated with CO_2, which may originate from metamorphism of carbonate rocks, igneous activity, or from degradation and oxidation of organic matter. Solubility of CO_2 in water depends on both temperature and pressure. Water saturated with respect to CO_2 at deep crustal levels (e. g., 2–4 km) becomes supersaturated as it moves toward the surface. Hence, CO_2 must exsolve in the gaseous phase and leave the system. Rising carbonic thermal waters also cool down. Due to inverse relationships between carbonate solubility and temperature, they may acquire and maintain aggressiveness – even at decreasing CO_2 levels. The solubility of $CaCO_3$ increases evenly along the ascending fluid path, but near the land surface (water table) it drops drastically. Such nonlinear behavior leads to the appearance of two geochemical zones: a zone of carbonate dissolution at depth and a zone of carbonate precipitation closer to the surface.

OXIDATION OF H_2S

In contrast to carbon dioxide-rich water, aggressiveness of the hydrogen sulphide-rich water is generally limited in the deep-seated settings, but increases dramatically when such water mixes with oxygenated water or contacts with the atmosphere, which results in rapid oxidation of H_2S to H_2SO_4. The effect is attenuated when CO_2 generated by the H_2SO_4-$CaCO_3$ reaction is degassed. Such speleogenetic mechanism, known as Sulfuric Acid Speleogenesis (SAS) tends to occur at shallow levels, both below and above the water table. The second, subaerial setting is characterized by a specific speleogenetic mechanism, involving dissolution and subsequent replacement of calcite by gypsum and its consequent removal (*replacement corrosion*).

Unlike 'pure carbonic acid' hypogene karst, which is a common phenomenon, the sulphuric acid karst is almost always a mixed process. Most natural H_2S-rich groundwaters have also elevated contents of CO_2; additional CO_2 is produced by dissolution of carbonate rocks by sulphuric acid. Under certain circumstances this additional CO_2 could significantly enhance carbonate dissolution.

MIXING OF WATERS (CO_2 AND H_2S)

When waters containing different amounts of dissolved CO_2 or H_2S mix the aggressiveness of the resulting solution is greater than that of each of the initial solutions. Even when mixing waters are saturated with respect to carbonate, the resulting water can be aggressive. Because situations in which waters with varying chemistry mix are rather common in hydrogeology, this process – mixing corrosion – is an important speleogenetic mechanism.

CONDENSATION

Sizable cavities with characteristic solutional morphology can develop above the (hypogene) water table by mechanism of condensation corrosion. Water which evaporates from surface of an underground thermal lake condenses on cooler bedrock. Dissolving CO_2 from the underground atmosphere, condensate becomes aggressive with respect to carbonate. Importantly, this speleogenetic mechanism – condensation corrosion –can operate above the underground lakes of non-karstic (e. g., tectonic) origin, containing non-aggressive or even supersaturated with respect to carbonate bedrock water.

HYPOGENE SPELEOGENESIS IN NONCARBONATE ROCKS

The mechanisms described above pertain to the most common variety of hypogene karst developing in carbonate rocks. Besides, hypogene caves have been reported from silicate rocks (quarzite, scarn, jasperoid, quartz veins), sulfate rocks (gypsum, anhydrite), and rock salt.

GYPSUM AND ANHYDRITE

Hypogene caves in gypsum and anhydrite are the second most-common lythologic type of hypogene karst. The solubility of gypsum in most natural water is roughly 10-20 times that of calcite. The solubility decreases with increasing temperature (retrograde solubility) and increases with increasing pressure. Several chemical and physical factors may considerably increase or renew gypsum solubility: (a) the presence of other salts in water (increasing ionic strength of solution increases gypsum solubility by up to a factor of 3); (b) anaerobic reduction of sulphates in the presence of organic matter; (c) de-dolomitization of dolomite bedrock; and (d) mechanical stress affecting the bedrock. The mechanism of gypsum dissolution by water enriched in CO_2 (which is common in deep-seated waters) is more complex and may involve additional dissolution of gypsum and deposition of calcite.

DIAGNOSTICS OF HYPOGENE KARST

The presence in the cave of water with deep-seated characteristics is the surest indicator of the cave's hypogene origin. Obviously, this criterion applies only to active hypogene karst. Identification of the hypogene character of fossil or paleokarst relies on various indicators which must be applied in conjunction. The primary indicators are macro-, meso-, and micro-morphology of caves. Important insights can be gained by reconstructing the position of the caves in the larger-scale hydrogeological structure.

In this presentation mineralogical and geochemical approaches are discussed. Besides helping to identify the involvement of the hypogene speleogenesis, these approaches help to decipher specific processes that operated during karstification and to reconstruct parameters of hypogene fluids (chemistry, temperature, isotopic composition, gas composition, etc.).

Minerals occurring in hypogene caves can be subdivided in two broad categories: (1) speleogenetic (i.e., whose deposition is directly related to karst process) and (2) non-speleogenetic (whose presence is due to processes other than karst).

Calcite is the most common speleogenetic mineral in carbonate hypogene caves developed in CO_2-dominated systems, and gypsum is the main speleogenetic mineral in caves developed by SAS mechanism. Other speleogenetic minerals reported from SAS caves comprise alunite, natroalunite, dickite, tyuyamunite, metatyuyamunite, aluminite, and hydrobasaluminite. Hypogene caves in gypsum and anhydrite are typically poor in mineralization, represented by primarily by gypsum and calcite.

Non-speleogenetic quartz, barite, fluorite, and various sulfides are commonly reported from the deep-seated carbonate hypogene caves. The list of minerals in ore-related hypogene karst can be quite large.

CHARACTER OF CAVE DEPOSITS

Large euhedral calcite crystals, palisade aggregates, thick crusts, and sediments reflecting stable hydrodynamic conditions are common in deep-seated hypogene caves. The size of individual crystals can be as large as 10-30 and even 100 cm. The crystal morphology is normally simple, dominated by scalenohedra (dogtooth spar). In contrast, the deposits of shallow karst caves commonly reflect a more dynamic environment. Euhedral crystals are rare, and the size of crystals in aggregates ranges from several millimeters to a few centimeters. The dominant crystal morphology is a combination of scalenohedra and prisms with the crystal tip blunted by flat rhombohedra (nailhead spar). Mineral surfaces might be contaminated by clay, which indicate that the paleo waters were dynamic enough to carry the particulate matter. In addition to subaqueous deposits, two more types of speleothems occur in shallow hypogene karst: waterline deposits (rafts, folia, cave cones), and subaerial deposits (e. g., cave popcorn). These two types are also common in cold karst.

GEOCHEMICAL STUDIES OF SECONDARY MINERALS

The presence of secondary minerals in hypogene caves is beneficial, because it opens various avenues for study of hypogene karst process. Fluid inclusions in minerals can be studied in order to determine temperature of mineral-forming waters, their salinity, isotopic composition, and composition of the dissolved gases. Calcite and gypsum can be studied isotopically ($\delta^{18}O$, $\delta^{13}C$, $\delta^{34}S$), providing further insights into the sources of dissolved matter and parameters of fluids. In some cases the minerals can be dated ($U/^{230Th}$, U/Pb and $^{40}Ar/^{39}Ar$ (alunite) methods). It is to be noted that any information obtained from studies of minerals is related to the specific stage of speleogenesis, at which the minerals were deposited.

ISOTOPIC STUDIES OF THE BEDROCK

Hypogene fluids circulating through carbonate bedrock can alter the isotopic composition ($\delta^{18}O$ and $\delta^{13}C$) of the rock. The extent of alteration depends on a number of parameters, such as the diffusive permeability of the rock matrix, difference between isotopic composition of rock and water, temperature, and time. Alteration zones in the walls of the hypogene caves have been found at a number of hypogene karst sites and in some cases the data provided information on the parameters of fluids.

HYDROGEOLOGICAL SETTINGS/MECHANISMS

Hydrogeological speleogenetic mechanisms of the hypogene karst characterize major driving forces which ensure that (a) water reaches the soluble formation and leaves it, carrying the dissolved load, and (b) water acquires or maintains aggressiveness, allowing enlargement of cavities. The flow of groundwater may occur in confined or unconfined regimes and may involve free (buoyant) convection, forced convection, gravity-driven flow, etc. Setting of stratified confined (artesian) aquifer is particularly conductive for the development of cross-formational flows, in the course of which waters with different mineralization mix and acquire additional aggressiveness.

Hydrogeology of the Buda Thermal Karst (Hungary) – new models for the discharge zone

Anita Erőss, Judit Mádl-Szőnyi

Department of Physical and Applied Geology, Institute of Geography and Earth Sciences, Eötvös Loránd University, 1/c Pázmány Péter sétány, 1117 Budapest, Hungary, anita.eross@geology.elte.hu

Europe's largest naturally flowing thermal water system can be found in Budapest. The springs and wells that supply the famous spas of Budapest discharge from a regional Triassic carbonate rock aquifer system. As the result of the interaction of discharging waters, extensive cave systems has developed and still developing today. These caves belong to the group of hypogenic caves, and their special morphology and peculiar minerals make Budapest, beside the city of spas, also "the capital of caves".

According to the recent developments in the speleogenetic theories (Klimchouk 2007, Goldscheider *et al.* 2010), hypogenic karsts and caves are viewed in the regional flow system concept of Tóth (1963), and can be considered as the manifestations of flowing groundwater (Tóth 1999, Tóth 2009, Mádl-Szőnyi & Erőss 2011). As a basic approach of this study, the virtual spring concept of Tóth (2009) was applied, which considers all discharge phenomena together as one single entity in the terminal area of a groundwater flow-system, and the investigation of which plays a crucial role in the understanding of the flow system itself.

In this study the discharge areas of the Buda Thermal Karst were investigated to determine how the discharging fluids and adjoining phenomena (e. g. caves, mineral precipitates) can be telltales of their parent fluid systems, the processes acting along the flow path and operating directly at the vicinity of the discharge zone.

Being a marginal area at the boundary of uplifted carbonates and a sedimentary basin, the Buda Thermal Karst serves as a discharge zone of the regional fluid flow. This implies that it may receive fluid components (karstic and basinal) from several sources resulting in a wide range of discharge features including springs, caves, and mineral precipitates. A comprehensive hydrogeological study was carried out for the investigation of these phenomena and for the characterization of processes acting today at the discharge zone of the Buda Thermal Karst. Methods included hydrogeochemical, mineralogical and microbiological investigations.

Among the results of the study, several processes were identified which can be responsible for cave development and formation of minerals, among them mixing corrosion and microbially mediated sulphuric acid speleogenesis have crucial role. Furthermore, the role of the adjacent sedimentary basin was reevaluated. Based on the results of this study, new, differentiated conceptual flow and process models were developed for the study areas.

These results bring a new insight into the processes acting at a regional discharge zone which could be responsible for hypogenic cave development. It was demonstrated that several processes can be simultaneously active in karst development. These processes are connected to the regional discharge zone as the manifestation of flowing groundwater.

Keywords: hypogenic karst, flow systems, regional discharge area, Buda Thermal Karst

References

Goldscheider, N., Mádl-Szőnyi, J., Erőss, A., Schill, E., 2010, Review: Thermal water resources in carbonate rock aquifers. Hydrogeology Journal, 18: 1303–1318.

Klimchouk, A. B., 2007, Hypogene Speleogenesis: Hydrogeological and Morphogenetic Perspective Special Paper no.1, National Cave and Karst Research Institute, Carlsbad, NM, 106 p.

Mádl-Szőnyi, J., Erőss, A., 2011, Hypogenic karstification processes and products in flow system framework. In: Bertrand, C., Carry, N., Mudry, J., Pronk, M., Zwahlen F. (eds.) Proc. H2Karst, 9th Conference on Limestone Hydrogeology, Besançon (France) ISBN:978-2-7466-3694-1, pp. 315–318.

Tóth, J., 1963, A theoretical analysis of groundwater flow in small drainage basins. Journal of Geophysical Research, 68(16): 4795–4812.

Tóth, J., 1999, Groundwater as a geologic agent: An overview of the causes, processes, and manifestations. Hydrogeology Journal, 7(1): 1–14.

Tóth, J., 2009, Springs seen and interpreted in the context of groundwater flow-systems, GSA Annual Meeting 2009 (18–21 October 2009) Portland, Geological Society of America Abstracts with Programs, 41(7) p. 173.

Hypogene vs epigene caves: the S and O isotope fingerprint

Bogdan P. Onac

University of South Florida, Department of Geology, Tampa, FL, USA, bonac@usf.edu

The classical epigene speleogenetic model in which CO_2 is considered the main source of acidity has been challenged over the last three decades by observations that revealed cave passages unrelated to groundwater drainage routes and surface topography. Most of these passages show unusual morphologies, such are condensation cupolas, floor feeders (i.e., inlets for deep-seated fluids), huge irregular-shaped rooms that terminate abruptly, and without exceptions, contain abundant gypsum deposits, and often a rich and diverse mineral association (sulfate-dominated). This evidence prompted scientists to suggest a new theory (i.e., sulfuric acid speleogenesis, SAS) of cave development. In the hypogenic SAS model, the source of acidity is the sulfuric acid produced by oxidation of H_2S (originating from sulfate reduction or petroleum reservoirs) near or at the water table, where it dissolves the limestone bedrock and precipitates extensive gypsum deposits. SAS is now thoroughly documented from numerous caves around the world, with the best examples coming from the Guadalupe Mountains (NM), Frasassi caves (Italy), selected caves in France, Cueva de Villa Luz (Mexico), and Cerna Valley (SW Romania).

To date, discrimination between epigene and hypogene speleogenetic pathways is made using cave morphology criteria, exotic mineral assemblages, and the predominantly negative $\delta^{34}S$ values for the cave sulfates. This presentation highlights the role sulfur and oxygen stable isotope analyses have in discriminating between epigene and hypogene caves.

Based on a number of case studies in caves of the Cerna Valley (Romania) we found that relatively S-depleted isotopic composition of cave minerals alone does not provide enough information to clearly distinguish SAS from other complex speleogenetic pathways. In fact, $\delta^{34}S$ values of SAS by-products depend not only on the source of the S, but also on the completeness of S redox reactions. Therefore, similar studies to this are needed to precisely diagnose SAS and to provide information on the S cycle in a given karst system.

Integrating cave mineralogy, passage morphology, and geochemical studies may shed light on the interpretation of polygenetic caves, offering clues to processes, mechanisms, and parameters involved in their genesis.

Keywords: sulfur isotopes, mineralogy, geochemistry, hypogene speleogenesis

Folia, calcite rafts, cones and cave clouds: a typical association of hypogenic caves from an evident epigenic setting from Cuba

Ilenia Maria D'Angeli[1], Esteban Ruben Grau Gonzales[2,3,4], Tomaso Bontognali[5], Stefano Torriani[5], Nicola Tisato[4,5], Jo De Waele[1,6]

[1]Department of Biological, Geological and Environmental Sciences, Bologna University, Via Zamboni 67, 40126 Bologna, Italy, ileniamaria.dangeli@studio.unibo.it, jo.dewaele@unibo.it
[2]Comité Espeleológico de Matanzas, Sociedad Espeleologica de Cuba
[3]Fundación Antonio Núñez Jiménez de la Naturaleza y el Hombre – Cuba, matanzas@fanj.cult.cu
[4]La Salle 3D – International Team, Photo, Video and Documentation, www.lasalle3d.com
[5]ETH Zurich, Geological and Integrative Biology Institutes, Soneggstrasse 5, 8092 Zurich, Switzerland, tomaso.bontognali@erdw.ethz.ch, nicola.tisato@erdw.ethz.ch
[6]Associazione di Esplorazioni Geografiche la Venta, Via Priamo Tron 35/F, 31030, Treviso

Santa Catalina Cave, located 20 km East of the city of Matanzas (Cuba), is known for its exceptional association of speleothems. The upper level of this 10 km long cave is characterised by the combined presence of calcite rafts, cones, folia, cave clouds, and mushroom-shaped speleothems. Because of its unique features the cave has been declared National Monument in 1996 and is now protected by the State.

Santa Catalina Cave is developed in the eogenetic Pleistocene coralline limestones of the Yucayo marine terrace, at around 20 m a.s.l., and has many natural entrances formed by the collapse of the roof. The upper level of the cave is horizontal and placed very close (3–6 meters) to the above lying surface.

The general morphology of the cave, with very large passages and interconnected galleries, clearly allows the classification as a flank margin cave. The voids have been formed at the margin of the freshwater lens and the underlying tide-influenced salt water body during a period of sea level highstand. When the sea level dropped, the cave remained isolated from salt water and hosted large bodies of fresh water. The high amount of evaporation, due to the vicinity of the hot land surface and the high air circulation between the many cave entrances, probably caused the water to be oversaturated. This boosted the formation of calcite rafts that deposited on the bottom of the oversaturated lakes and, below dripping points, as cones. Possibly deeper in freshwater bodies oversaturation was lower, producing slow forming cave clouds (mammillary calcite). Close to entrances, organic debris depositing into the cave lakes below may have caused the production of significant amounts of CO_2. This gas was trapped in blind branches of the cave nearby causing condensation-corrosion phenomena and related precipitation of subaqueous calcite close to the water level. The rapid precipitation of calcite at the fluctuating water level and the embedding of floating and sinking calcite rafts have probably allowed the formation of decimeter wide folia.

Keywords: speleothems, coastal cave, subtropics, speleogenesis

Phantom cave development in a thermal environment

Marjan Temovski

Doctorate student at the University of Nova Gorica, Slovenia; Vlado Stojanoski 37a, 7500 Prilep, Macedonia, temovski_m@yahoo.com

Karsi Podot is a small active thermal cave, located slightly above the river bed of Crna Reka in Republic of Macedonia. The cave is mostly developed in Pre-Cambrian dolomitic marbles, and has an active low-temperature thermal water flow. The passages end abruptly in an in-situ dolomitic sediment residue which has preserved the original bedding. The cave is a result of ghost-rock weathering by slowly moving thermal waters, with later backflooding of Crna Reka removing residue and producing phantom cave passages. In this paper we will present the morphology and sediments of the cave, and will discuss the possible mechanism of cave development.

Keywords: thermal cave, phantom cave, dolomitic marble

Regional groundwater flow in the context of karst development

Mihael Brenčič

Department of Hydrogeology, University of Ljubljana, Aškerčeva 12, 1000 Ljubljana, Slovenia, mihael.brencic@ntf.uni-lj.si

Regional groundwater flow is very well developed theoretical concept defined in early publications of Canadian school of hydrogeologists mainly by authors Toth and Freeze. In the terrain where complex topography is developed water infiltration and gravity induce deep water flow with convection cells. They are presenting semicircular or semieliptical flows from the infiltration to the exfiltration point. At the infiltration point flow is predominantly vertically in the downward direction following gravitation forces and at the exfiltration front flow is again predominantly vertical but following upward direction as a consequence of regional hydraulic potential distribution. Mathematical simulations illustrate that such flow at the terminal point can reach depths of several kilometres bellow the surface. Consequently water from the deeper parts of the convection cells has very long retention times and very distinctive physical and chemical characteristics.

Regional groundwater flow concept is very well understood in the regions with relatively isotropic and homogenous soil or rock mass. In the case where rock structure is highly heterogeneous and anisotropic as it is the case in karstic rock the consequences of regional hydraulic distribution are less well understood.

The paper explores interactions between regional groundwater flow and rock heterogeneities and anisotropy typical for karstic rock. It is illustrated that locally sub vertical and even vertical upward flow is possible based only on the gravity driven flow.

Keywords: regional groundwater flow, karst development, deep karst

Hypogenic Speleogenesis: Insights from numerical models

Franci Gabrovšek

Karst Research Institute ZRC SAZU, Titov trg 2, 6230 Postojna, Slovenia, gabrovsek@zrc-sazu.si

Numerical models of speleogenesis couple flow, transport and dissolution to calculate the evolution of porosity along permeable structures in soluble rocks. Many scenarios with different hydrological geochemical and structural conditions have been modelled. Most models discuss the evolution of epigenetic caves, where all aggressivity originates from the atmospheric or soil CO_2. Since the definition of "hypogene" speleogenesis is still a matter of a vivid debate, a review of some modelling results which are potentially related to hypogene speleogenesis is presented. These models primarily include the role of deep CO_2 sources and mixing corrosion in the evolution and resulting geometries of fracture networks. A more provocative scenario in the sense "*is this hypogenic ?*" includes contrast in lithology within the aquifer.

Keywords: speleogenesis, modelling, mixing corrosion

Hypogene cave morphology and speleogenesis, in relation to geological setting

Philippe Audra

Polytech Nice – Sophia, University of Nice - Sophia Antipolis, 930 route des Colles, 06903 Sophia-Antipolis, France & Innovative City – IMREDD, Nice, France, audra@unice.fr

Hypogene caves may develop in several favorable geological settings, mainly in the highest part of deep structures (anticline, horst, overthrust front…). Deep flow lifts up and discharge at windows intersected by valley incision. As a consequence, hypogene caves locate at the intersection between confinements and regional lineaments. The hypogene cave pattern reflects the speleogenetic processes. Processes vary according to the depth in the aquifer, involving mixing corrosion by convergent flux and with meteoric water, cooling, sulfur oxidation, carbon dioxide degassing, and condensation-corrosion. Cave patterns are: Isolated geodes, 2D and 3D multistorey following joints and bedding planes, Giant phreatic shaft, Water table mazes, Isolated chambers, Upwardly dendritic spheres, Water table caves, Smoking shafts.

Ascending speleogenesis in the Czech Republic and Slovakia

Pavel Bosák[1], Pavel Bella[2]

[1]Institute of Geology ASCR, v. v. i., Rozvojová 269, 165 00 Praha 6, Czech Republic & Karst Research Institute ZRC SAZU, Titov trg 2, 6230 Postojna, Slovenia, bosak@gli.cas.cz
[2]State Nature Conservancy of the Slovak Republic, Slovak Caves Administration, Hodžova 11, 031 01 Liptovský Mikuláš & Department of Geography, Pedagogical Faculty, Catholic University, Hrabovská cesta 1, 034 01 Ružomberok, Slovakia, bella@ssj.sk

INTRODUCTION

Several examples of *per ascensum* (ascending) speleogenesis along deep faults (*cf.* also were recently described by Bella & Bosák (2012). The concept of ascending speleogenesis in confined or partly confined conditions connected with deep regional fault was proposed, for the first time on the territory of the past Czechoslovakia, by Bosák (1996, 1997) for the origin of the Koněpruské Caves and some other caves in the Koněprusy Devonian (central Bohemia, Czech Republic). Since that time, number of caves with similar speleogenesis has been studied in more of lesser detail. Most of them were originally described as products of phreatic, epiphreatic and vadose speleogenesis related to the evolution of local water courses, valley incision and river terrace systems usually during Middle to Late Pleistocene climatic changes; eventually with Plio-Quaternary climatic oscillations.

TERMINOLOGY

We use the term of *per ascensum* (ascending) speleogenesis for several reasons: (1) typical features of *hypogenic caves* (in traditional historical sense, see e. g., Ford & Williams 1989, 2007; Palmer 1991, 2007; Dublyansky 2000; Palmer & Palmer 2009) or *hyperkarst* (*sensu* Cigna 1978) are missing nearly in all caves/cave systems mentioned in case studies below; those typical fetures are as follows: caves were formed by water that has derived its solutional capacity (aggressiveness) from sources unrelated to the surface (in depths); waters are of deep-seated origin and/or belong to deep water circulation systems; cave patterns have no relations to (recent) surface karst or recharge; vadose features are generally absent; certain speleothems and minerals are diagnostic; ascending waters are enriched in sulphuric acid, carbon dioxide, hydrocarbons, etc., and increased water temperature is common but not necessary, and (2) a broad concept of *hypogenic caves* sensu Klimchouk (2007 and 2011 and other his contributions on that topics) includes not only real hypogene caves (hyperkarst) but also caves formed by normal circulating meteoric waters in phreatic to bathyphreatic (deep-seated) conditions; such concept is highly incorrect as mixing not connected processes/products.

We apply the term *per ascensum* (ascending) speleogenesis (1) as it represents non-genetic term (from down up) regardless of attempts to understand this term in some modified meanings and (2) to avoid the necessity of repeated explanation, which model of hypogenic speleogenesis is under the consideration.

REVIEW

In the ***Czech Republic***, several examples of real hypogenic karst (hyperkarst) exist. The Zbrašovské Aragonite Caves (central-northern Moravia) represent the classical example = Kunský (1957) defined here the *thermomineral* (later transformed to hydrothermal, see e. g., Dublyansky 2000) karst for the first time in the world karstology literature. Warmer water (16 °C) enriched in juvenile carbon dioxide and helium of upper mantle origin (Meyberg & Rinne 1995) ascends here along deep fault zone from depths over 1,000 m (R. Otava, pers. comm. 2013). The hydrothermal speleogenesis cannot be excluded for the Javorka Cave (Český Karst area between Praha and Beroun cities; Žák 2006) and the lower segments of the Králova Cave and Květnická Chasm (surroundings of Tišnov city, central Moravia; Bosák 1983); both cases probably as a result of LateVariscan (Permian to Triassic) hydrothermal process later corrosionally enlarged by cold waters. Hydrothemal karst in subrecent travertines in the Karlovy Vary city was desribed by Vylita *et al.* (2007). Hydrothermal origin of some of cavities in quartzites in Barrandian area (central Bohemia) was mentioned by Cílek (1988).

Speleogenesis by ascending waters was earlier reported for caves in the Koněprusy Devonian (e. g., Koněpruské Caves; Bohemia /Český/ Karst) by Bosák (1996, 1997) and for Na Pomezí Caves (noprthern Moravia) by Altová & Bosák (2011). Similar speleogenesis is proposed here also for the Mladečské Caves (central Moravia), the outflow system of the regional Třesín aquifer (along deep regional faults) including the Javoříčský and Mladečský Karst (central Moravia) with number of caves/cave systems (e. g., Panoš 1990). The aquifer evolution is clearly related to subsidence/aggradation/erosion history of the Mio-Pleistocene Hornomoravský Basin (continuation of the Labe /Elbe/ Zone; for details see Růžička 1989), causing water ascent along deep marginal faults at least in one of evolution stages. Springs and subsurface occurrence of mineral waters (14–16 ^{o}C enriched in hydrogen sulphide) reported Pospíšil & Řezníček (1973) at Slatinice Spa (between Olomouc city and Javoříčské Caves) or cold mineral waters enriched in carbon dioxide at Horní Moštěnice village (SE from Olomouc city) are related to deep faults of the continuation of the Labe Zone to the East of Mladeč. Also the Arnoldka Cave (Bohemian /Český/ Karst), judging from its dominant speleogens and the general shape highly resembling the Belianská Cave, is proposed here as result of ascending speleogenesis. Very special is the case of the Na Turoldu Cave near city of Mikulov (southern Moravia; Bosák *et al.* 1984); the last studies proved ascending speleogenesis along porous Girvanella horizon in Upper Jurassic limestone (Outer Klippen Belt in the front of Western Carpathian flysh nappes). The oscillations of paleopiezometric level were undoubtedly connected with deep fault systems developed during the evolution of the Vienna Basin. Recent research in the Bozkovské Dolomite Caves (northern Bohemia) strongly indicates ascending speleogenesis by slightly warmer groundwaters. Some of above mentioned caves have increased radon (^{222}Rn) content (Thinova *et al.* 2010) linked with setting on/along deep faults.

Bella *et al.* (2009) and Bella & Gáal (2012) summarized possible occurrences of products of real hypogene (hydrothermal) or ascending speleogenesis in ***Slovakia***. Among hypogene caves, they mentioned caves between Jasov village and Moldava nad Bodvou town where Seneš (1945–1946) expected speleogenesis by warm groundwater and re-modellation by cold karst waters. Number of boreholes in the Slovenský kras (Slovak Karst) and close vicinity uncovered cavities with warm waters (e. g., Orvan 1973). The ascending hydrothermal origin of cave near Sklené Teplice Spa (Štiavnické vrchy Mts., central Slovakia) in metamorphosed Middle Triassic carbonates was related to high-temperature processes during the Late Badenian emplacement of granodiorite subvolcanic bodies or the Late Sarmatian activity of the epithermal system in the Štiavnica Stratovolcano. The typical spherical morphology, host-rocks alterations, large calcite and quartz crystals, and clays point to its hypogene origin (Bella *et al.* 2011). Hydrothermal calcite crystals were found in some old caves cut by younger passages in the Nízke Tatry Mts. (Nová Stanišovská Cave and some nearby caves: Kalcitová and Silvošova diera; Orvošová & Hurai 2008 and references herein). Calcite crystals indicate possible hydrothermal origin of the Drienka Cave in the Silická planina Plateau, Slovak Karst (Gaál 2008) and the Kryštálová Cave in the Malá Fatra Mts. (Janáčik 1959). Flooded bell-shaped shaft, 38 m deep, at Tornaľa town (the eastern part of Rimavská kotlina Basin) is known as Morské oko (Sea eye). It represents the resurgence of slightly warm (16.2 ^{o}C) and highly mineralized water of deep artesian waters along regional faults (see Gaál *et al.* 2007; Gaál 2008). Recently we studied the Skalistý potok Cave with some clear signs of ascending speleogenesis (at least in its subvertical segment) and nearby Drienovská Cave (with possible thermal or sulphuric acid speleogenesis of its upper part); both caves are situated in the southern fault-limited slope of the Jasovská planina Plateau (Slovak Karst).

CASE STUDIES

Na Pomezí Cave System consists of several caves (Panoš 1961) situated on the left bank of the Vidnávka Creek to the north of Lipová-lázně Spas (northern Moravia). Caves with total depth over 100 m are developed in steeply inclined crystalline limestones within metamorphics of the Branná Group (unclear age: Precambrian or Devonian) cut by still tectonically active Marginal Sudetes Fault on the NE. The Na Pomezí Cave is ca 1 km long and 45 m deep. The Rasovna Cave is subvertical, 632 m long and 76 m deep.

Morphology: The system of Na Pomezí–Rasovna caves is arranged in two altitudinal zones. The upper one consists mostly of collapse-modified high, narrow and densely-spaced fissure-like passages with speleogens indicating ascending water flow and strong condensation corrosion. The lower cave zone is characteristic by floor slots and channels leading to ceiling slots in open fractures and leading to the upper cave zone. Rugged phreatic morphology with distinct pendants is characteristic both for upwards narrowing floor and ceiling slots (here also with anastomoses). Wall forms are partly modified by later mixing/condensation corrosion and collapses, and slightly displaced, in places, along fissures. Ceiling channels, often with flat ceiling, are covered by two to three generations of relatively small scallops. Passage walls indicate also vadose speleogens: paragenetically flattened roofs, lateral water-table notches.

Sediments: speleothem crusts at different positions were dated by Th/U dating (H. Hercman, 2008 pers. comm.) from 6.0–9.8 ka to 43.9 up to over 1.2 Ma. Sediments at bottom contain subrecent bat bones and magnetization of sediments is normal (younger than 780 ka; Altová & Bosák 2011).

Evolution: The system Na Pomezí–Rasovna caves is not connected with entrenchment of surface rivers as expected by Král (1958) or Panoš (1959). The age of speleothem crusts indicate the substantial age (over 400 ka and even 1.2 Ma) and the origin of cavities as early as in Pliocene (Panoš 1961). The system was formed in phreatic to deep phreatic conditions by ascending water of deep circulation along the Marginbal Sudetic Fault. Cave spaces were later partly re-modelled in epiphreatic conditions following the incision of the Vidnávka Valley and movements along the Marginal Sudetic Fault. The system, especially its lower zone was several times completely filled with allogenic clastic sediments and subsequently exhumed partially or completely. The Rasovna Cave is vertical outlet part connecting the cave system, or its part, with the surface. Original surface outlet forms were completely destroyed by the intensive Quaternary geomorphic processes.

Belianska Cave. The cave is situated in the eastern part of the Belianske Tatry Mts. at the right bank of the Biela River. It is developed in the Middle Triassic limestones. Steep NE-inclined fault in the area of the cave morphologically separates the easternmost middle-mountain part of the Belianske Tatry Mts. from their principal high-mountainous monoclinal ridge in the W. The cave is 3,829 m long and 168 m deep.

Morphology: cave consists of two principal inclined branches connecting subhorizontal passages in upper and lower cave segments with corrosion domes and inclined extensive passages passing into them; deep corrosion cupolas in ceilings; assymetric scallops, indicating ascending water flow; corrosion oblique smooth facets in the lower part of halls or passages; lateral water-table notches between subhorizontal passages. Morphostratigraphically, older phreatic corrosion domes and inclined passages are cut by horizontal water-table notches at several altitudes.

Sediments: fine-grained clastics (clays to silts) represent the insoluble residua of the selective dissolution of dolomitic host rocks and contain up to 90 % of dolomite (Zimák *et al.* 2003). They were deposited in stagnant or slowly moving water. In upper parts of some of sedimentary profiles, clastic allogenic sandy admixture and local autogenic conglomerate bodies occur. Subaerial flowstone crusts covering most of profiles are older than 1.25 Ma (U-series dating; Bella *et al.* 2007a) and those in the lower part of the Dlhá chodba Passage contains *Nyssa* sp. pollen grains typical for Miocene/Lower Pliocene (Bella *et al.* 2011). Fine-grained residua are older than Lower Pliocene, which is indicated also by paleomagnetic data (Pruner *et al.* 2000).

Evolution: the beginning and principal phase of phreatic cave development can be linked with the ascent of deep waters along the fault, which dissected Sarmatian–Early Pannonian surface (Głazek *et al.* 2004; Bella *et al.* 2011). Groundwaters infiltrating in areas of bare Mesozoic carbonate rocks partly penetrated below Central Carpathian Paleogene strata and ascended along fault separating more uplifted Tatry Mts. from less uplifted eastern marginal part of the Belianske Tatry Mts. Groundwater penetrated along steeply inclined bedding planes dissected by the fault(s). The slow water ascent (Bella & Osborne 2008) and intensive corrosion of the host rock can be dated to Miocene (?Upper Miocene) by Lower Pliocene subaerial flowstones (Bella *et al.* 2007a, 2011). Subhorizontal epiphreatic passages and re-modellation developed during stagnant phases of groundwater level following distinctive stages of the Biela River Valley entrenchment (Bella & Pavlarčík 2002). The upper subhorizontal passages can be linked with the former slightly oscillating piezometric level developed during the lateral planation of (?)Pontian pediment (Bella *et al.* 2011).

Jasovská Cave. The cave is situated in eastern part of the Jasovská planina Plateau (the NE part of the Slovak Karst) at the Jasov village. The cave is developed in Middle Triassic limestones and dolomites. The Bodva Valley north of Moldava nad Bodvou town follows the N–S-trending continuation of the Budulov Fault. Karst surface on limestone blocks sunkened in respect to the rest of the eastern segment of the Jasovská planina Plateau are exhumed along the Bodva River (a.o. Jakál 1975; Liška 1994). The cave is 2,811 m long and 55 m deep.

Morphology: irregular inclined and step-like spaces, different cupola and sponge-like cavities, domes and passages with cupolas in lower part of the cave; lateral water-table notches and flat ceilings in different altitudes; cupolas and cupola- and chimney-shaped hollows (see Bella & Urata 2002) in the lower and middle cave segments. Middle and upper cave segments differ from the lower one: smaller or larger domes, ceiling channels, numerous huge pendants, some of them are perforated by ascending waters.

Sediments: passages of the lower segment are filled by fine-grained sediments, sometimes completely up to flat ceilings. They deposited from very slow water flows and/or floods. Sediments are younger than 780 ka (Bella *et al.* 2007b). Coarse-grained fluvial sediments are absent.

Evolution: the evolution of original phreatic cave morphology can be explained only by slowly ascending water flow. The Upper Pliocene and Quaternary evolution phases re-modelled the original phreatic morphology in epiphreatic conditions with the origin of cave levels in relation to evolution of the Bodva Valley and stabilizations of the groundwater table (Bella 2000).

Caves at Plavecké Podhradie. Plavecká Cave and Plavecká Shaft are situated on the western slope of the Malé Karpaty Mts. under the Plavecký hrad Castle in Triassic limestones along marginal fault zone of the Malé Karpaty Mts. Fault separates the horst from the northeastern part of Miocene Vienna Basin. The Plavecká Cave is 837 m long and 33 m deep. The Plavecká Shaft is 70 m deep and about 130 m long.

Waters: karst spring below the Plavecký hrad Castle with water temperature of 11.6–13.6 °C influences the air temperature in the Plavecká Cave (11 °C). Underground lake in the Plavecká Shaft has temperature of 13.0–13.1 °C increasing temperature in cave to 12.7–12.8 °C (Košel 2005). Extensive travertine accumulation up to 550 m wide has been deposited from slightly warmer and highly mineralized waters at the fault-limited foothill of the Plavecký Castle Hill (Hanzel *et al.* 2001).

Morphology: phreatic speleogens: chimneys with asymmetric large scallops illustrating ascending water flow, ceiling cupolas and irregular corrosion hollows; oval halftubes along steep tectonic lines (ceiling slots); floor slots (feeders) along faults. Epiphreatic remodellation: passages and domes developed along the groundwater table in two evolution levels with lateral water-table notches (Bella 2010).

Sediments: any cave sediments have been discovered in both caves.

Evolution: slightly warmer groundwaters slowly ascended along the fault zone. Epiphreatic re-modellation was connected with altitude stabilization of karst resurgences.

Liskovská Cave. The cave is situated in the eastern suburb of the Ružomberok city in the eastern side of the Mních Horst (the western part of the Liptovská kotlina Basin) built of Triassic limestones limited by two systems of faults. The cave is 4,250 m long and 72 m deep.

Morphology: the 3D maze, oval and mostly irregular corrosion morphology dominates; cupolas, smaller spherical and sponge-like hollows developed in walls; upward scalloped channels and local steeply inclined slots along faults (Bella *et al.* 2009).

Sediments: no river sediments (sand, gravels) occur in spite of the fact that the cave is situated directly on the right bank of the Váh River, and low accumulation terrace is nearby.

Evolution: the cave was formed by predominant corrosion in slowly moving water of the the deep karst circulation in the phreatic zone (Bella 2005). Ascending waters were drained from cave into the alluvium of the Váh River. The piezometric level of karst groundwater later followed the incision of the river bed and evolution of river terraces, which is reflected in epiphreatic re-modellation of pre-existing 3D maze with origin of horizontal cave levels by slowly flowing to stagnant waters (Bella 2005) or by injected flood waters of the Váh River.

Zápoľná Cave. The cave is situated in the right bank of the Čierny Váh River in the Važecký chrbát Ridge along the tectonic boundary of Kráľova hoľa area (Nízke Tatry Mts.) and the western part of the Kozie chrbty Mts. The cave is developed mostly in Middle Triassic limestones. The cave is 1,813 m long and 59 m deep with sumps 20 m below the river bed.

Morphology: cave with unlevelled longitudinal section consists of more or less iregular inclined passages, shafts, chimneys and connecting tubes forming sponge- to maze-like system; parallel passages are often separated by rock walls thick only several centimeters; cupolas in places; smaller half-spheric hollows (ceiling pockets).

Sediments: no fluvial sediments can be found in the cave.

Evolution: The cave was formed in the phreatic zone with slow water flow and convection (Bella & Holúbek 2002). Waters ascended along fault pre-disposing the nearby segment of the Čierny Váh River Valley. Lateral water-table notches and local flat ceilings indicate phases of water level stagnation and drawning during younger cave evolution phases.

CONCLUSIONS

Caves presented in case studies represent products of ascending speleogenesis in zones of deep regional faults/fault zones. Any of described caves contains clear diagnostic features of real hypogene caves or hyperkarst (as defined before the concept of Klimchouk 2007), expressed e. g., by specific mineral assemblages. On the other hand, number of speleogens can be attributed to phreatic and deep phreatic speleogenesis related to slowly rising water flow (e. g., Osborne 2004; Audra *et al.*

2009b); some of them are often expected as typical for hypogenic speleogenesis (*sensu* Klimchouk 2007) or hyperkarst (*sensu* Cigna 1978). The reasons for ascending speleogenesis in most caves mentioned here can be related to the evolution of tectonic basins and river valleys, i. e. subsidence and deep erosion was followed by basin fill or fluvial aggradation due to change of tectonic regime and/or related to transgressions.

Decribed case studies (and some of mentioned in the review) have several common characteristics, especially: (1) caves developed along or in close vicinity of deep faults/fault zones, commonly of regional importance; (2) the groundwater ascended due to deep faults/fault systems mostly as results of deep regional circulation of meteoric waters from adjacent karst or nonkarst areas; (3) the 3D mazes and labyrinths dominate in cave morphologies; (4) certain speleogens (e. g., cupolas, slots, ceiling channels, spongework, rugged phreatic morphology especially along slots) indicate ascending speleogenesis in deep phreatic to phreatic environments; (5) strong epiphreatic re-modelling is common in general (e. g., subhorizontal passages arranged in cave levels, water-table flat ceilings and notches) and related to the evolution of the recent landscape; (6) caves exhibit poor relation to the present landscape; in some of them fluvial sediments are completely missing in spite of surface rivers/streams in the direct vicinity; (7) recharge structures and correlate surface precipitates are poorly preserved or completely missing (denuded) on the present surface in spite of fact that recent recharges broadly precipitate travertines; (8) caves can be, and some of them are, substantially older than the recent landscape; (9) most of other caves are relic (paleokarst *s.l.*) with fragmentary preserved drainage pattern (Koněpruské Caves), unknown drainage pattern (Na Pomezí Caves) or depending on very deep groundwater circulation on long distances with hardly tracable paths (most of Slovak case studies), and (10) caves were formed in conditions of slow water ascent, which differentiate the process from faster *vauclusian ascending speleogenetical* models (Audra *et al.* 2004, 2009a; Mocochain *et al.* 2011) through well-organized conduit drains and vauclusian water outflow to springs due to base level rise by sediment aggradation.

Acknowledgements

The study is result of Grant Project of Ministry of Education of the Slovak Republic VEGA No. 1/0030/12 Hypogene caves in Slovakia: speleogenesis and morphogenetic types; Grant Project of the Grant Agency of the Academy of Sciences of the Czech Republic No. IAA300130701 Paleomagnetic research of karst sediments: paleotectonic and geomorphological implications, and the Institutional Research Plan of the Institute of Geology AS CR, v. v. i. No. CEZ AV0Z30130516.

References

Altová, V. & P. Bosák, 2011: Karst of Eastern Sudetes and its importace for the study of relief evolution in the Rychlebské hory Mts.- Research Reports 2009. Institute of Geology AS CR, v. v. i., 54–55, Praha.

Audra, Ph., Mocochain, L. & J.-Y. Bigot, 2009a: Base level rise and *per ascendum* model of speleogenesis (PAMS), interpretation of deep phreatic karsts, Vauclusian springs and chimney-shafts.- In: W.B. White (ed.) *Proceedings of the 15th International Congress of Speleology*, 2, 788–794, Kerrville, Texas, USA.

Audra, Ph., Mocochain, L., Bigot, J.-Y. & J.-C. Nobécourt, 2009b: Morphological indicators of speleogenesis: hypogenic speleogens.- Ukrainian Institute of Speleology and Karstology, Special Paper, 1, 23–32.

Audra, Ph., Mocochain, L., Camus, H., Gilli, É., Clauzon, G. & J.-Y. Bigot, 2004: The effect of the Messinian Deep Stage on karst development around the Mediterranean Sea. Examples from Southern France.- Geodinamica Acta, 17, 6, 27–38.

Bella, P., 2000: Principal morphologic and genetic features of the Jasov Cave (in Slovak).- In: P. Bella (ed.) *Výskum, využívanie a ochrana jaskýň, zborník referátov z 2. vedeckej konferencie, Demänovská Dolina, 16. –19. 11. 1999*. Správa slovenských jaskýň, pp. 42–51, Liptovský Mikuláš.

Bella, P., 2005: On the morphology and genesis of Liskovská Cave (in Slovak).- Slovenský kras, 43, 37–52.
Bella, P., 2010: Formation of caves by waters ascending along a marginal fault of Malé Karpaty Mts. near Plavecké Podhradie, Western Slovakia – hydrogeological conditions and morphological features (in Slovak).- Aragonit, 15, 2, 65–70.
Bella, P. & P. Bosák P., 2012: Speleogenesis along deep regional faults by ascending waters: case studies from Slovakia and Czech Republic.- Acta Carsologica, 41, 2–3, 169–192.
Bella, P., Bosák, P., Głazek, J., Hercman, H., Kadlec, J., Kicińska, D., Komar, M., Kučera, M. & P. Pruner, 2007a: Dating of cave fills in the Belianska Cave: geochronologic records of its genesis (in Slovak).- Aragonit, 12, 127–128.
Bella, P., Bosák, P., Pruner, P., Głazek, J. & H. Hercman, 2011: The development of the River Biela Valley in relation to the genesis of the Belianska Cave (in Slovak).- Geografický časopis, 63, 4, 369–387.
Bella, P., Bosák, P., Pruner, P., Hochmuth, Z. & H. Hercman, 2007b: Magnetostratigraphy of cave deposits and speleogenesis of the Moldava and Jasov Cave (in Slovak).- Slovenský kras, 45, 15–42.
Bella, P. & Ľ. Gaál, 2012: Hypogenic caves in Slovakia: current knowledge and research objectives.- Geomorphologia Slovaca et Bohemica, 12, 1, 38–50.
Bella, P., Gaál, Ľ. & P. Bosák, 2009: Conditions and indications of evolution of hypogenic caves in Slovakia (in Slovak).- Aragonit, 14, 2, 159–161.
Bella, P. & P. Holúbek, 2002: Principal morphologic and genetic features of the Zápoľná Cave in the Čierny Váh Valley (Kozie chrbty Mts.) (in Slovak).- Slovenský kras, 40, 31–40.
Bella, P. & A. Osborne, 2008: Corrosion facets and their morphogenetic features in relation to the speleogenesis of Belianska Cave, Slovakia (in Slovak).- Slovenský kras, 46, 1, 75–86.
Bella, P. & S. Pavlarčík, 2002: Morphology and genesis problems of the Belianska Cave (in Slovak).- In: P. Bella (ed.) *Výskum, využívanie a ochrana jaskýň, zborník referátov z 3. vedeckej konferencie, Stará Lesná, 14.–16. 11. 2001*. Správa slovenských jaskýň, pp. 22-35, Liptovský Mikuláš.
Bella, P., Šucha, V., Gaál, Ľ. & P. Koděra, 2011: The First Karst Cave in the Štiavnické vrchy Mts., Central Slovakia – hydrothermal speleogenesis in basement carbonates of the Miocene stratovolcano.- Slovenský kras, 49, 1, 5–21.
Bella, P. & K. Urata, 2002: Oval ceiling cupola- and chimney-like hollows in the Jasov Cave.- Aragonit, 7, 4–7.
Bosák, P., 1983: Polycyclic development of karst phenomena in the Tišnov area (Western Moravia, Czechoslovakia).- In: *Proceedings. European Regional Conference on Speleology,* 2, pp. 253–256, Sofia.
Bosák, P., Čadek, J., Horáček, I., Ložek, V., Tůma, S. & J. Ulrych, 1984: Karst phenomena of the Turold Hill at Mikulov (in Czech).- Studie ČSAV, 5, 1–108.
Bosák, P., 1996: The evolution of karst and caves in the Koněprusy region (Bohemian Karst, Czech Republic) and paleohydrologic model.- Acta Carsologica, 25, 57–67.
Bosák, P., 1997: Paleokarst of the Bohemian Massif in the Czech Republic: an overwiev and synthesis.- International Journal of Speleology, 24(1995), 1–2, 3–40.
Cigna, A.A., 1978: A Classification of Karstic Phenomena.- International Journal of Speleology, 10, 1, 3–9.
Cílek, V., 1988: The karstification of Barrandian quartzites (in Czech).- Český kras, XIV, 58–62.
Dublyansky, Y.V., 2000: Hydrothermal Speleogenesis – Its Settings and Peculiar Features.- In: A.B. Klimchouk, C.D. Ford, A.N. Palmer & W. Dreybrodt (eds.) *Speleogenesis. Evolution of Karst Aquifers*. National Speleological Society, pp. 292–297, Huntsville, Alabama.
Ford, D.C. & P.W. Williams, 1989: *Karst Geomorphology and Hydrology*.- Unwin Hyman, 601 pp., London–Boston–Sydney–Wellington.
Ford, D.C. & P.W. Williams, 2007: *Karst Hydrogeology and Geomorphology*.- Wiley, 562 pp., Chichester.

Gaál, Ľ., 2008: *Geodynamics and evolution of caves of the Slovak Karst* (in Slovak).- Štátna ochrana prírody Slovenskej republiky, Správa Slovenských jaskýň, 168 pp., Žilina.

Gaál, Ľ., Balciar, I., Belanová, E., Megela, M., Papáč, V. & H. Vaněková, 2007: The flooded chasm Morské oko in Rimava Basin (in Slovak).- Aragonit, 12, 4–9.

Głazek, J., Bella, P., Bosák, P., Hercman, H. & P. Pruner, 2004: Genesis and age of the Bielanská Cave (in Polish).- In: *Materialy 38. Sympozjum Speleologicznego, Zakopane, 7.–10. 10. 2004*. Sekcja Speleologiczna PTP, pp. 41-42, Kraków.

Hanzel, V., Vrana, K. & S. Kúšiková, 2001: Hydrogeological map of the Pezinok Carpathian Mts. at the scale of 1:50 000 (in Slovak).- In: P. Malík (ed.) *Hydrogeologické a hydrogeochemické mapy v mierke 1:50 000, regióny: južná časť Záhorskej (Borskej) nížiny, Pezinské Karpaty, SV časť Podunajskej nížiny, východná časť Veľkej Fatry, severná časť Spišsko-gemerského rudohoria, Ľubovnianksa vrchovina a Pieniny, Čierna hora* [CD-Rom]. Ministry of Environment of the Slovak Republic and the State Geological Institute of Dionýz Štúr, Bratislava.

Jakál, J., 1975: *Karst of the Silica Plateau* (in Slovak).- Osveta, 152 pp., Martin.

Janáčik, P., 1959: Contribution to karst phenomena of the Malá Fatra Mts. (in Slovak).- Slovenský kras, 2, 55–67.

Klimchouk, A., 2007: *Hypogene Speleogenesis: Hydrological and Morphogenetic Perspective*.- National Cave Karst Research Institute, Special Paper, 1, 106 pp.

Klimchouk, A., 2011: *Hypogene Speleogenesis: Hydrological and Morphogenetic Perspective*.- National Cave Karst Research Institute, Special Paper, 1 (2nd ed.), 106 pp.

Košel, V., 2005: Which is the warmest? (in Slovak)- Spravodaj speleologickej spoločnosti, 36, 4, 29-30.

Král, V., 1958: Karst and caves of Eastern Sudetes (in Czech).- Acta Universitatis Carolinae, Geologica, 2, 105–159.

Kunský, J., 1957: Thermomineral Karst and Caves of Zbrašov, Northern Moravia.- Sborník Československé společnosti zeměpisné, 62, 4, 306–351.

Liška, M., 1994: Surface (in Slovak).- In: Rozložník, M. & E. Karasová (eds.) *Chránená krajinná oblasť – Biosférická rezervácia Slovenský kras*. Osveta, pp. 22–36, Martin.

Meyberg, M. & B. Rinne, 1995: Messung des $^{3}He/^{4}He$-Isotopenverhältnisses im Hranicka Propast (Tschechische Republik).- Die Höhle, 45, 1, 5–-8.

Mocochain, L., Audra, Ph. & J.-Y. Bigot, 2011: Base level rise and Per Ascensum model of speleogenesis (PAMS). Interpretation of deep phreatic karsts, vauclusian springs and chimney-shafts.- Bulletin de la Société géologique de France, 182, 2, 87–93.

Orvan, J., 1973: Hydrogeological situation of the Rimavská Basin (in Slovak).- Mineralia slovaca, 5, 3, 271–278.

Orvošová, M. & V. Hurai, 2008: Calcite crystals in Kacitová 1 and 2 caves in Poludnica, Low Tatras Mountains (in Slovak).- Slovenský kras, 46, 1, 87–97.

Osborne, R. A. L., 2004: The troubles with cupolas.- Acta Carsologica, 33, 2, 9–36.

Palmer, A.N., 1991: Origin and morphology of limestone caves.- Geological Society of America Bulletin, 103, 1, 1–21.

Palmer, A.N., 2007: *Cave Geology*.- Cave Books, pp. 454, Dayton.

Palmer, A.N. & M.V. Palmer, 2009: Geologic Overview.- In: A.N. Palmer & M.V. Palmer (eds.) *Caves and Karst of the USA.* National Speleological Society, pp. 1–16, Huntsville.

Panoš, V., 1959: Contribution to knowledge of geomoprphology of karst area Na Pomezí in the Rychlebské hory Mts. (in Czech).- Sborník Vlastivědného ústavu v Olomouci, Oddělelní A, Přírodní vědy, IV, 33–85, Olomouc.

Panoš, V., 1961: Periglacial destruction forms of relief in the Rychlebské hory Mts. (in Czech).- Přírodovědný časopis slezský, 22, 1, 105–119, Opava.

Panoš, V., 1990: Třesín karst aquifer at the eastern margin of the Bohemian Massif and problem of its racional exploitation and protection (in Czech).- Československý kras, 41, 55–70.

Pospíšil, Z. & V. Řezníček, 1973: Mineral waters of karst structures in Moravia (in Czech).- Geologický průzkum, 7/1973, 200–202.

Pruner, P., Bosák, P., Kadlec, J., Venhodová, D. & P. Bella, 2000: Paleomagnetic research of sedimentary fill of selected caves in Slovakia (in Czech).- In: P. Bella (ed.) *Výskum, ochrana a využívanie jaskýň, zborník referátov z 2. vedeckej konferencie,* Demänovská Dolina, 16. - 19. 11. 1999. Správa slovenských jaskýň, pp. 13-25, Liptovský Mikuláš.

Růžička, M., 1989: Pliocene of the Hornomoravský úval and Mohelnická brázda (in Czech).- Sborník geologických věd, Anthropozoikum, 19, 129–151. Praha.

Seneš, J., 1945–1946. Research in the South-Slovakian Karst (in Slovak).- Krásy Slovenska, 23, 6, 128–132.

Thinova, L., Rovenska, K. & P. Otahal, 2010: Environmental and radon measurements in the underground workplaces in the Czech Republic. – Nukleonika, 55, 4, 491–493.

Vylita, T., Žák, K., Cílek, V., Hercman, H. & L. Miklíková, 2007: Evolution of hot-spring travertine accummulation in Karlovy VaryúCarlsbad (Czech Republic) and its significance for the evolution of Teplá valley and Ohře/Eger rift.- Zeitschrift für Geomorphologie, 51, 4, 427–442.

Žák, K., 2006: Geological and karstological description of the Na Javorce Cave (in Czech).- Speleofórum, 25 (2006), 19–20, Praha.

Zimák, J., Štelcl, J., Zelinka, J. & J. Hlaváč, 2003: Natural radioactivity of rocks in the Belianská Cave (in Czech).- Aragonit, 8, 2–29.

Morphogenetic types of caves on Klassical Karst

Andrej Mihevc*

Karst Research Institute ZRC SAZU, Titov trg 2, 6230 Postojna, Slovenia, mihevc@zrc-sazu.si

Classical karst is loosely defined area between the springs of Ljubljanica at the edge of Ljubljana basin and Trieste bay and is the most NW part of Dinaric karst. It includes different types of karst morphologies, both surface and underground, which depend on geological structure and geomorphic evolution of the area. Basically we can distinguish two types of relief: levelled surfaces and the high karst plateaus. There are no horizontal passages in high karst plateaus.

Karstification of Classical Karst started in Oligocene, but that relief and caves were already consumed by karst denudation since. The oldest cave sediments in unroofed caves were dated to 4–5 M years. Active caves, relict ones and those, which were exposed by karst erosion, coexist in today's karst. They pass in time through different conditions and that reflects in their morphology.

Data from Cave register, professional literature and my own observations of about 500 caves from the area were used. On that territory that covers around 3,500 km^2 is 4,650 caves known with total length of 375 km. Majority of the caves is small so average length is only 42 m and the depth of the caves is 24 m and are representing only small segments of cave systems.

Most numerous caves are simple, 10–30 m deep shafts. They could be both formed in vadose or phreatic conditions. Vadose morphology is clear for those formed in high karst relief. Deeper ones have pitch/ramp morphology following faults and narrow canyons with phreatic upper parts following dip of strata mostly. Most prominent example is Velika ledena jama v Paradani. But also in these caves there are segments of passages with phreatic morphology.

On the levelled surfaces the origin of shafts in not clear. In majority of shafts phreatic morphology is mixed or modified with vadose elements. In some shafts important oscillations of water level occur. In Gabranca oscillation of water is 214 m. In caves of the sinking river Reka that flows about 40 km underground oscillations are around 100 m. Most likely 180 m deep entrance pit to Kačna jama is also phreatic. In Ljubljanica river catchment area oscillations are generally smaller, in Brezno v Grudnovi dolini about 70 m, phreatic morphology of pits at edges of poljes is visible in Šemonovo brezno and in Brezno na Repišah.

The longest horizontal caves, there are 45 caves longer than 1 km, are developed in levelled surfaces or between karst poljes and there are no horizontal passages in high karst plateaus. Caves formed in the areas of contact karst were transformed by paragenesis due to sediments of sinking rivers. In Škocjanske jame there are traces of phreatic tubes and shafts, paragenetic levels and vadose entrenchments. Postojnska jama shows several phases of infill and is in great part paragenetic.

Phreatic caves or passages are less common. Most prominent phreatic caves are Jazbina v Rovnjah, developed in levelled surface and water caves on the edges of high karst plateaus.

There are no traces in cave morphology, pattern or cave sediments that would indicate hypogene origin of caves in the area.

Keywords: vadose, phreatic, epiphreatic, cave, Kras

Hypogene caves in Austria

Lukas Plan[1], Yuri Dublyansky[2], Andreas Roncat[3], Christoph Spötl[2], Rudolf Pavuza[1]

[1]Naturhistorisches Museum Wien, Karst- und Höhlenkundliche Abteilung, Museumsplatz 1/10, A-1070 Vienna, Austria, lukas.plan@nhm-wien.ac.at, rudolf.pavuza@nhm-wien.ac.at

[2]Universität Innsbruck, Institut für Geologie und Paläontologie, Innrain 52, A- 6020 Innsbruck, Austria, christoph.spoetl@uibk.ac.at, juri.dublyanski@uibk.ac.at

[3]Vienna University of Technology, Department of Geodesy and Geoinformation, Research Group Photogrammetry and Remote Sensing, Gußhausstraße 27 - 29, 1040 Vienna, Austria ar@ipf.tuwien.ac.at

Among the ca. 14,500 registered caves of Austria approximately 100 have been attributed to hypogene speleogenesis. This paper provides an overview of hypogene caves in Austria. Most of the hypogene caves cluster around the Vienna Basin. Some of these caves, such as *Eisensteinhöhle* and *Nasser Schacht*, show a thermally anomalous microclimate and are associated with thermal springs. Other caves are inactive, but their morphology and deposits are suggestive of a hypogene origin. Morphologic observations suggest a sulfuric acid speleogenesis for *Stephanshöhle* and other caves near Bad Deutsch Altenburg and for small parts of Güntherhöhle. In the Northern Calcareous Alps, which host the majority of caves in Austria, only very few have been identified as hypogene (e. g., *Märchenhöhle, Wasserhöhle, Torsteinhöhle-Nord*), but the number of such caves is likely to increase in the future. For Märchenhöhle and Wasserhöhle 3d-laserscans were applied to analyse the peculiar hypogene morphologies. Also, "normal" (epigenetic) cave systems sometimes show morphological evidence suggestive of a hypogene origin, but a conclusive proof is lacking. The only Austrian cave where a sulfuric acid speleogenesis is well documented is *Kraushöhle*. In marbles of the Central Alps lukewarm and thermal springs are present and cavities of likely hypogene origin were encountered during a tunnel construction near Lend. In a nearby cave, *Entrische Kirche*, isotopic evidence of marble alteration by warm paleowaters was recently identified. Extensive calcite deposits are also known from nearby *Stegbachgraben*, and ongoing isotopic and fluid-inclusion studies strongly suggest hypogene water-rock interaction at lukewarm (<40°C) temperatures there. A few caves in the Southern Calcareous Alps also show morphological evidence of a hypogene origin (e. g. *Kozakhöhle*), which is U/Th-dated to older than ca. 144 ky. CO_2-rich springs discharge nearby.

Determining a strong relation between hypogenism and hydrothermal water circulation in Greek caves

Markos Vaxevanopoulos[1], Angeliki Reizopoulou[1], Tatjana Bakran-Petricioli[2]

[1]Volos Natural History Museum, Giannitson 5, 38334 Volos, Thessaly, Greece, vaxevanopoulos@hotmail.com, reizopoulou@gmail.com
[2]University of Zagreb, Faculty of Science, Department of Biology, Zagreb, Croatia, tatjana.bakran-petricioli@zg.t-com.hr

A significant number of Greek caves considered as epigenic are recently studied under the prism of hypogenism. Most of them comprise morphological features (patterns and meso-morphology) indicative of their origin. Their hypogenic past it’s very difficult to be defined because of the epigenic overprint.

At the present study, 10 different cave systems in Greek mainland are presented and their hypogenetic features are described. They are all located in highly tectonically uplifted areas with the presence of hydrothermal activity.

Fluid inclusion studies in selected calcite spars from the caves show elevated temperatures of formation due to circulating hydrothermal fluids serving an unquestionable argument about their hypogenic origin and its relation with hydrothermal water circulation.

Keywords: hypogenism, hydrothermal caves, fluid inclusions, Greece

Convergence of hypogene and epigene small-scale solution features in caves (examples from central Europe and eastern Australia)

Andrzej Tyc

Department of Geomorphology, University of Silesia, ul. Bedzinska 60, 41-200 Sosnowiec, Poland, andrzej.tyc@us.edu.pl

Hypogene (or hypogenic) speleogenesis is recently discussed by many authors. Broad definitions of hypegenic processes and related features have been presented by Klimchouk (2007) and Audra *et al*. (2009). Hypogenic caves and correspodning speleogens are present in cave and karst textbooks (e.g. Palmer 2006 or Ford & Williams 2007), too. As we can distinguish distinctive hypogenic processes and cave mineralogy, unique small-scale solution features for hypogene speleogenesis recognition are not present. Convergence of hypogene and epigene speleogens is quite common. Solution pockets, cupolas or rising wall channels, as example, are present in both genetic cave types. Cave morphology resulted from *per ascensum* water circulation, dissolution on a contact between fine grain sediments and cave wall or condensation corrosion can occur both in hypogene and epigene caves. In case of some complex caves early hypogenic processes have provided pathways for surface waters and have allowed development of later epigenic features. As a consequence hypogene small-scale solution features can be overprinted by epigene one. Convergence of speleogens cause necessity of complex cave studies, especially in case of multiprocess and multiphase caves with possible hypogene origin, but without any active hypogenic processes or presence of specific minerals.

Examples from different caves of central Europe and eastern Australia have been used to demonstarte arguments of the paper. The research leading to these results has received funding from the [European Community’s] Seventh Framework Programme [FP/2007-2013] under grant agreement n°247616. Author wish to thanks participants of the HYPOCAVE project, realised according to mentioned EC funding, for kind cooperation in the field and discussion.

Keywords: hypogene caves, caves morphology, cave rocky relief

References:
Audra P, Mocochain L, Bigot J-Y, Nobecourt J-C, 2009. Morphological indicators of speleogenesis: Hypogenic speleogens. In: AB Klimchouk and DC Ford (eds.). Hypogene speleogenesis and karst hydrogeology of artesian basins. Ukrainian Institute of Speleology and Karstology, Special Paper 1, Simferopol, pp. 17–22.
Ford DC, Williams P, 2007. Karst hydrogeology and geomorphology. John Wiley & Sons, Ltd, Chichester.
Klimchouk A, 2007. Hypogene speleogenesis. Hydrogeological and morphogenetic perspective. NCKRI Special Paper Series, vol. 1, National Cave and Karst Research Institute, Carlsbad.
Palmer AN, 2006. Cave geology. Cave Books, Dayton.

Hypogene speleogenesis – cases from Italy

Marco Menichetti

Department of Earth, Life and Environmental Sciences Urbino University - 61029 Urbino, Italy, marco.menichetti@uniurb.it

The karst/speleogenesis is a morphological process resulting by the removing mass from a host rock operated by aggressiveness of a chemical agent that flows through it transported by a fluid vector. The exogenous soil derived CO_2 is the chemical agent for the epigenic limestone caves formation, while endogenic agents operate the corrosion in the hypogenic caves speleogenesis (chemical or physical or both like CO_2, H_2S, cooling, mixing, etc.). The fluid vector flowing through the rock mass could be the water or a gas. The main differences between epi & hypo speleogenesis are exclusively related to the origin of the corrosive agents. The geological and the structural features of the area, the hydrology and the modalities of the groundwater flow, lead the development of different caves morphologies. The epigenic speleogenesis of carbonate karst system is a process that propagates downward from the surface to depth through the drainage network. While the hypogene speleogenesis is related to the upward flow of deep-seated solutional generated at depths below the surface.

In the last decades there has been a renewed interest in hypogenic cave speleogenesis studies using different approaches that explore the presence of processes endogenically driven aggressiveness (*sensu* Palmer, 2007 and reference therein) and the roles of deep seated hydrogeological recharge (transverse hypogenic cave origin of Klimchouk, 2007 and reference therein). Hypogenic caves are well known in Europe and in different parts of the world, from Central Asia to North and South America and especially the underground fossil system in Guadalupe Mountains in New Mexico and Texas (DuChene *et al.* 2000).

Through more than one century of speleological research in Italy, many hypogenic limestone caves have been explored, mapped and studied (Galdenzi & Menichetti 1989; 1995). These caves are characterized by a variety of patterns and morphological sizes including three-dimensional maze systems and deep shafts, with both endogenic CO_2 vents and active sulfuric streams. An integrate approach taking in account geological, hydrological and geochemical settings permit to recognize the main hypogenic speleogenetic process. The H_2S oxidation to sulfuric acid, by oxygen-rich groundwaters as well as in the atmosphere is the main hypogenic cave-forming processes. Both phreatic and vadose corrosion reactions involve chemotropic microbial activity, with sulfur-redox bacterial communities that generate sulfuric acid as metabolic product (Engel *et al.* 2004; Macalady *et al.* 2006). The bedrock corrosion produce sulfate ions in the phreatic zone and gypsum replacement in the limestone walls of the vadose sectors of the caves. The caves are characterized by both fossil and active passages in which water rich in H_2S as well as endogenic CO_2 plays a determinant role in speleogenesis. Although sulfuric acid-related speleogenesis typically produces gypsum deposits, in caves where the karstification processes are driven by subterranean CO_2 sources, voids and speleothems are the only final products.

In Italy all the end-members of the karst processes can be found, from solution caves to outcrop of carbonate travertine; moreover volcanic, crustal and mantle-derived CO_2 and H_2S emissions are known along the Peninsula. The hypogenic caves are concentrate for largest and both fossils and active systems in the Tuscany, Umbria, Marche and Latium regions (Menichetti, 2009). These consist of few tens of kilometers of solutional passages with galleries and shafts, which are characterized by large rooms, cupola and blind pits, anastomotic passages, bubble trails roof pendants, knife edges, and phreatic passages. In many cases, the caves are developed at several levels related to the evolution of external hydrographic networks. Active smaller karst systems are known in Southern Italy in Apulia, Campania and Sicily, related to the geothermal anomaly associated with CO_2 and H_2S degassing (Menichetti 1994). The smaller karst systems have a ramiform pattern of several large rooms with wide ceilings that end abruptly in narrow passages or fissures. Phreatic passages, often anastomotic, are also spread over large parts of the cave, where they constitute some network zones. The geological characterization of the hypogenic cave formation needs to consider the great variety and unusual characteristics of Italy's underground landscape. The karst in the region is not homogeneously distributed and a relationship between the cave development and the regional geomorphic events is not well established and many caves are suspected to have an hypogenic origin in all Italian Regions. A more dynamic view of cave pattern development and evolution in space and time that will take into account the general altimetric variations of the regional water table together with episodic gas emissions needs to be considered.

Central Italy is probably the world's best location to observe both the active and fossil hypogenic speleogenesis processes in different geological contexts (Menichetti 2011). In the Umbria-Marche Apennines region, the presence of important hypogenic caves has been well documented by several decades of researches and explorations of the vertical karst system of M.Cucco and Faggeto Tondo and the maze systems of the still active Frasassi Gorge and Acquasanta Terme caves. Analyses of the different morphological aspects of these karst systems have allowed the identification of the primary formation processes within a geological and hydrogeochemical framework. The hypogenic processes can be linked to the oxidation of the H_2S to sulfuric acid as the oxygen-rich groundwaters mix. The cave morphologies show that the oxidation zone of H_2S is not restricted to the shallow groundwater levels but can be extended the deeper sections of the aquifer to which input of fresh water via a complex regional hydrogeological circuit could occur.

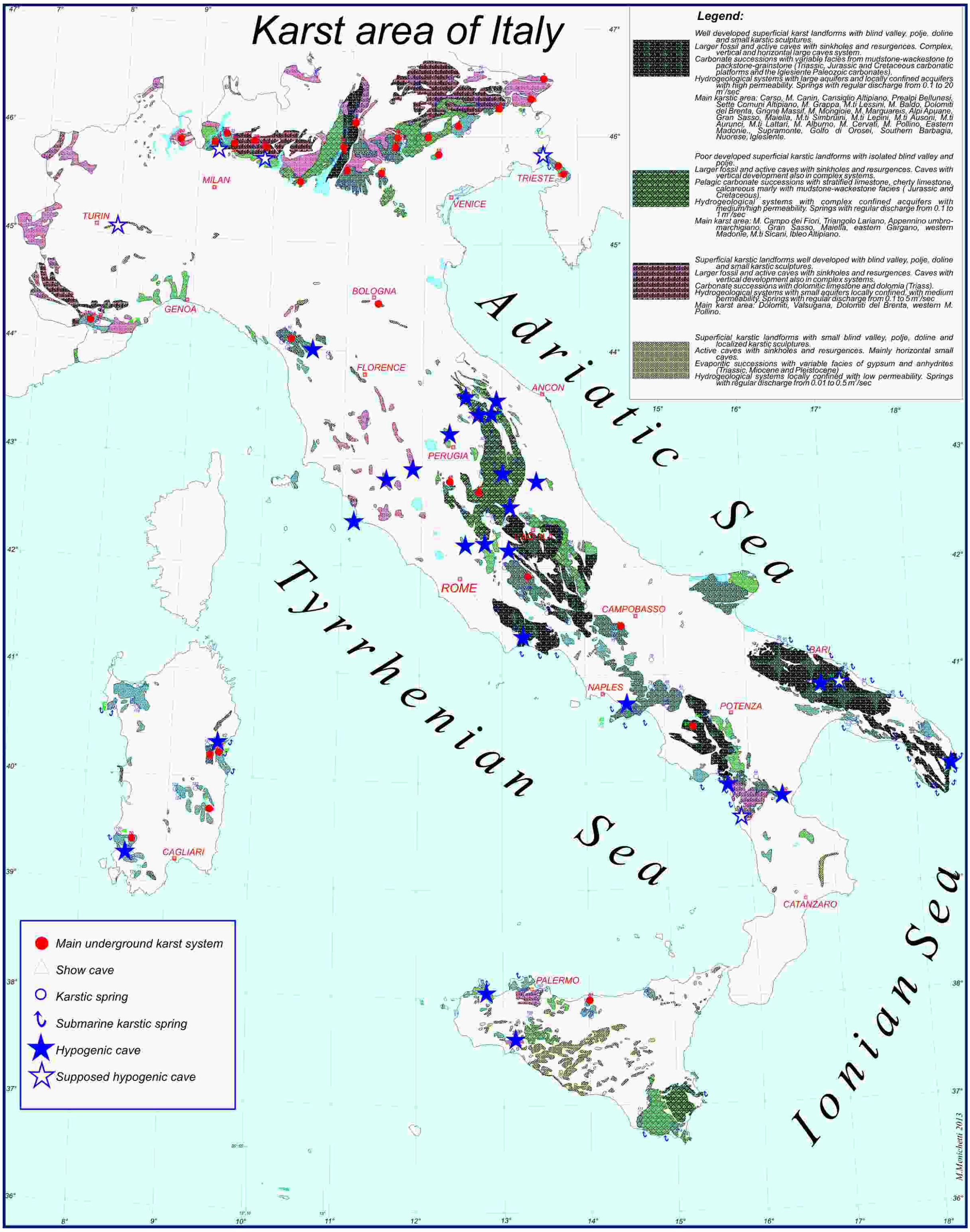
Many low temperature CO_2 gas emissions are known in Central/Southern Italy, with flow rates estimated at 10^{11} mol yr^{-1} in proximity to the main outcrops of travertine deposits. The origin of the gases is still debated since both CO_2 and H_2S are often associated with CH_4 and He.

The pCO_2 values of the groundwater in peninsular Italy range from 0.03 to 0.1 atm increasing the solubility of $CaCO_3$ by an order of magnitude with respect to the normal karstic waters. The breakthrough mechanism of progressive fracture widening by epigenic CO_2 corrosion is modified to a homogeneous widening of the fracture walls along their complete length by the presence of endogenic CO_2. An increase in pCO_2 of 0.002 atm from a continuous volcanic input is sufficient to reduce the breakthrough time for a fracture aperture by about half (Gabrovšek *et al.* 2000). Additionally, there is a positive feedback between the H_2S oxidation and the release of CO_2 in the shallower groundwater providing supplementary aggressiveness to the carbonate.

The travertine deposits represent the other end member of these karst processes. They form as a result of degassing of surfacing carbon dioxide-rich groundwater containing >2 mmol L^{-1} calcium. In order for this to occur, the dissolution of previously deep seated carbonate rocks by corrosive, CO_2-rich groundwater is necessary. The origin and evolution of a cave, within a travertine deposit where H_2S action has been linked to primary gypsum deposition, leaves open several questions related to the timing of the speleogenesis.

Geothermal anomalies are known in the Southern Alps as well as along the Italia peninsula especially in the Tyrrhenian side. The cooling of thermal water during its ascent along conduits increases the CO_2 aggressiveness with corrosion acting almost uniformly along the surfaces with producing a dramatic increase in the hydrologic flow and karst void development (Andre & Rajaram 2005).

Even though the general speleogenetic reactions are known, the precise geological, hydrogeological and geochemical conditions of their occurrence need to be documented. In particular the reactions at the gas/water interface (H_2S, CO_2) and above all the role played by organic matter require more detailed study.



References

Andre B.J., Rajaram H., 2005: Dissolution of limestone fractures by cooling waters: wearly development of hypogene karst systems. Water Resour. Res., 41, w01015, doi 10.1029/2004WR03331.

DuChene, H.R., Hill, C.A., Hose, L.D., Pisarowicz, J.A., 2000: The caves of the Guadalupe Mountains research symposium. Journal of Cave and Karst Studies, 62, 2, 1–159.

Engel A.S., Stern L.A., Bennet P.C., 2004 : Microbial contributions to cave formation: new insights into sulfur acid speleogenesis. Geology, 32, 5, 369–372.

Gabrovšek, F., Menne, B. and Dreybrodt, W., 2000: A model of early evolution of karst conduits affected by subterranean CO2 sources. Environmental Geology 39, 531–543.

Galdenzi S., Menichetti M., 1989: Evolution of underground kasrt systems in the umbria-marche Appennines in Central Italy. In *Proceedings, International Congress of Speleology, 10th,* Hazslinszky, T. & Takacsne B.K. (eds.), Budapest, 3, 745–747.

Galdenzi, S., Menichetti, M., 1995: Occurrence of hypogenic caves in a karst region: Examples from central Italy. Environmental Geology, 26, 39–47.

Klimchouck A., 2007: Hypogene speleogenesis: hydrogeological and morphogenetic perspective. Nat. Cave and Karst Research Institute, Carlsbad N.M. USA, SP.1, 106 p.

Macalady J.L., Lyon E.H., Koffman B., Albertson L.K., Meyer K., Galdenzi S., Mariani M., 2006: Dominant microbial populations in limestone-corroding stream biofilms, Frasassi cave system, Italy. Appl. Environ. Microbiol.72, 5596–5609.

Menichetti M., 1994: Grotte ipogeniche. SpeleoCAI, Costacciaro - Perugia, 5, 13, 34–37.

Menichetti, M., 2009: Speleogenesis of the hypogenic caves in Central Italy. Proceedings of the 15th Int. Cong.of Speleology, 909–915, Kerville.

Menichetti M., 2011: Hypogenic cave in Western Umbria (Central Italy). Acta Carsologica, 40/1, 129–145.

Palmer A.N., 2007: Cave Geology . Cave book Ed., Dayton, O.H. USA, 453 p.

"Classical Karst" caves, to be or not to be hypogenic?

Nadja Zupan Hajna

Karst Research Institute ZRC SAZU, Titov trg 2, 6230 Postojna, Slovenia, zupan@zrc-sazu.si

Lately numerous authors published papers on hypogene speleogenesis all around the world, even for some caves of Dinaric karst. The problem is that there exists different understanding of the same term between the authors.

What hypogen actually means? From dictionaries hypogene and phreatic have very similar meanings. Hypogene means formed underground and phreatic means relating to ground water, occurring below the water table.

Caves studies of Guadalupe Mountains of New Mexico and the Black Hills of South Dakota in last decades have revealed hypogene processes involving upward migrating fluids, some of them at high temperatures or carrying sulfuric acid in addition or carbonic acid (Ford & Williams 1989, 2007; Hill 2000; Palmer & Palmer 2012).

Palmer (1991) defined hypogene caves as caves formed by acids of deep-seated origin or epigenic rejuvenated by deep-seated processes and after Palmer (2000, 2009) defined hypogenic caves as those formed by water in which aggressiveness has been produced at depth beneath the surface, independent of surface or soil CO_2 or other near surface acid sources. With this clear description and definition there is no doubt what is hypogenic.

Klimchouk (2000, 2007, 2009) definition instead of on aggressiveness refer on source of ground water (deep waters); in sense of lack of genetic relation with ground water recharge from overlying surface. After many papers (e.g. Osborne 2008, De Waele & Forti 2009, Audra 2009, Palmer 2011) term hypogenic refer to the caves which were formed by the action of rising (ascending) waters and its circulation in the phreatic and epiphreatic zone. In this case, the dissolution proceeds from the inside towards the external surface of the rock mass. To deal with the use of the term hypogene in this sense, arise several questions:

1.) Are all ascending waters hypogenic and how deep originally meteoric waters have to circulate to be no more epigenic? To highlight the question, are submarine springs (e.g. vrulje on Adriatic coast below Velebit mountain) hypogenic?
There are also problems with interpretation of genesis of cave rocky features and lack of coarse grained clastic sediments if you follow Klimchouk (2009): characteristic cave features which attributed to rising groundwater are: floor slots, wall grooves, ceiling channels, cupolas, etc.; lack of coarse grained sediments …

2.) There is a question how to recognize the process from the forms on the cave walls if specific rocky feature can form by various processes (e.g. cupolas). For instance, below the clastic sediments (Slabe 1995) or in sea-coast caves in poorly lithified limestones which have never been in confined settings or exposed to rising groundwater (Mylroie & Mylroie 2009, Birmingham *et al.* 2011), most or all of the features described as hypogene features can be find?

3.) In the caves in which we can't find pebbles or sands, because they were washed away or caves are faraway from the source of allogenic sinking waters, such as many caves in Kras plateau or in karst of Matarsko Podolje; are all those caves hypogenic in origin?

If the answer is yes, a lot of "classical" Dinaric karst caves become hypogenic and that just because of the use of the term hypogenic in newer, much broader sense (Klimchouk 2000, 2007, 2009; Ford 2006; Palmer 2011), which tells less information on the genesis and source of aggressiveness than original meaning of the term (Ford & Williams 1989; Palmer 1991); but if we don't play with the terminology: "Classical Karst" caves in Slovenia are still "classical" and they are epigenic in origin according to origin of clastic sediments.

References

Audra, P., Mocochain, L., Bigot, J.-Y., Nobecourt, J.-C., 2009a. Hypogene cave patterns. In:Klimchouk, A., Ford, D. (eds.), Hypogene Speleogenesis and Karst Hydrogeology of Artesian Basins. Special Paper, 1. Ukrainian Institute of Speleology and Karstology, 17–22.

Audra, P., Mocochain, L., Bigot, J.-Y., Nobecourt, J.-C., 2009b. Morphological indicators of speleogenesis: hypogenic speleogens. In: Klimchouk, A., Ford, D. (eds.), Hypogene Speleogenesis and Karst Hydrogeology of Artesian Basins. Special Paper, 1. Ukrainian Institute of Speleology and Karstology, 23–32.

Birmingham, A. N., Mylroie J. R., Mylroie, J. E. , M.J., Lace, 2011. Bell Hole Origin: Constraints on Developmental Mechanisms, Crooked Island, Bahamas. Speleogenesis and Evolution of Karst Aquifers, Issue 10, online scientific journal www.journal.speleogenesis.info/journal.

De Waele J. , P. Forti, 2009. Hypogenic caves. In: Teaching resources for Speleology and Karst 2009, CD Società Speleologica Italiana.

Ford, D.C., 2006. Karst geomorphology, caves and cave deposits: A review of North American contributions during the past half century. In: Harmon, R.S.,Wicks, C.W., (eds.). Perspectives on Karst Geomorphology, Hydrology, and Geochemistry, Geological Society of America Special Paper 404, Boulder, Colorado, 1–14.

Ford D.C., Williams P.W., 1989: Karst geomorphology and hydrology. Unwin Hyman, pp. 601, London.

Ford D., Williams P., 2007. Karst Hydrogeology and Geomorphology. Wiley, pp. 562, Chichester.

Hill, C.A. , 2000. Sulfuric acid hypogene karst in the Guadalupe Mountains of Klimchouk, Alexander, Ford, D.C., Palmer, A.N., Dreybrodt, Wolfgang, 2000, Speleogenesis-Evolution of karst aquifers: National Speleological Society, Huntsville, Alabama, 309–316.

Klimchouk, A., 2000b. Speleogenesis under deep-seated and confined conditions, in Klimchouk, A., Ford, D.C., Palmer, A.N., Dreybrodt, W. (eds.). Speleogenesis: Evolution of Karst Aquifers. National Speleological Society, Inc., Huntsville, AL, 244–260.

Klimchouk, A., 2007. Hypogene Speleogenesis: Hydrogeological and Morphometric Perspective. National Cave and Karst Research Institute, Special Paper No. 1, Carlsbad, NM, 106.

Klimchouk, A.B., 2009. Principal features of hypogene speleogenesis. In: Klimchouk, A.B., Ford, D.C.(eds.). Hypogene Speleogenesis and Karst Hydrogeology of Artesian Basins. Special Paper 1, Ukrainian Institute of Speleology, 7–16.

Mylroie, J.E., Mylroie, J.R., 2009: Diagnostic features of hypogenic karst: is confined flow necessary? In: Stafford, K., Land, L., Veni, G. (eds.). Advances in Hypogene Karst Studies. Symposium, 1. National Cave and Karst Research Institute, Carlsbad, NM, 12–26.

Osborne, R. A. L., 2008: Detailed morphological studies in Netopirjev rov, Predjama Cave. Acta Carsologica, 37, 2/3, 255–272.

Palmer, A.N., 1991. Origin and morphology of limestone caves. Geol. Soc. Amer. Bull. 103, 1–21.

Palmer, A.N., 2011. Distinction between epigenic and hypogenic maze caves. Geomorphology 134, 9–22. doi:10.1016/j.geomorph.2011.03.014.

Palmer, A. N., Palmer M. V. 2000. Speleogenesis of the Black Hills maze caves, South Dakota, USA.- Speleogenesis. Evolution of karst aquifers, 274–281. Klimchouk A., Ford D. C., Palmer A. N., Dreybrodt W. (eds.), National Speleological Society, Huntsville.

Palmer, M. V., Palmer, A. N., 2012. Petrographic and isotopic evidence for late-stage processes in sulfuric acid caves of the Guadalupe Mountains, New Mexico, USA. International Journal of Speleology, 41, 231–250.

Slabe, T., 1995. Cave rocky relief and its speleogenetical significance. Zbirka ZRC, 10. Ljubljana:ZRC SAZU, 128 pp.

El-Balayza Caves: The first Hypogene Caves in the Nile Valley of Egypt

Ashraf Aboul-Fetooh Mostafa

Assiut University, Faculty of Arts, Department of Geography, Assiut, Egypt, ashraffetooh74@yahoo.com

Most of the Messinian Nile valley of Egypt has been sculptured in the Eocene limestone. Sides of this valley are rich with two main kinds of the caves: dissolution and man-made caves. El-Balayza area, which is located on the western side of the middle Nile Valley at Assiut Governorate, distinguished by different hypogene Speleothems. The preliminary observations of five caves suggest hypogenic origin. Several geomorphological and sedimentlogical evidences have been recognized, such as: rift-like features, wall and ceiling channel, ceiling cupolas, euhedral calcite spar. Ca, Si, Fe, Al, K, Zn, P, Cu, and S are the most predominant minerals in some of these caves. The present study suggests that these caves may have been originated during the extraordinary hydrothermal activity of Oligocene-Pliocene period. The presence of this kind of caves in the Nile Valley has proposed to reconsider the factors affecting its inception.

Keywords: karst, hypogene, The Nile Valley, Assiut, Egypt.

Cueva Bellamar, a hypogenic cave in Cuba

Cailhol Didier

Université de Savoie EDYTEM, Centre Interdisciplinaire Scientifique de la Montagne, Bourget du Lac, France, didier.cailhol@univ-savoie.fr

On February 2012, a team of European cavers in collaboration with the Sociedad Espelelogica of Cuba, come in Matanzas area to explore, survey and make pictures in several caves.
Bellemar cave system is 24 km long with 3 parallel networks linked and 9 different levels.
Bellamar cave was explored in 1861, a few many years later a show cave was installed inside because of formations.

The galleries are mainly covered with gypsum formations and we find hydrothermal calcite in different places.

This is a single conduit cave type, with several horizontal galleries, parallel to the successive steps of the evolution of the water table.

This presentation propose to describe how H_2S in contact with the air over the water table, install the gallery formed by the condensation corrosion, and how the different variations of sea level during Quaternary had organized the succession of levels and the linked system in a context of marine terrace.

Keywords: H_2S corrosion, water table, variations of sea level

Scientific research in the Cave system Lukina jama – Trojama (-1421) on the Velebit karst massif (Croatia)

Dalibor Paar[1,9], Andrej Stroj[2,9], Nenad Buzjak[3], Darko Bakšić[4,9], Damir Lacković[5,9], Magdalena Ujević Bošnjak[6], Vanja Radolić[7], Dubravka Kljajo[8]

[1]University of Zagreb, Faculty of Science, Department of Physics, Bijenička 32, HR-10002 Zagreb, Croatia, dpaar@phy.hr
[2]Croatian Geological Survey, Sachsova 2, HR-10000 Zagreb, Croatia
[3]University of Zagreb, Faculty of Science, Department of Geography, Marulićev trg 19/II, HR-10000 Zagreb, Croatia
[4]University of Zagreb, Faculty of Forestry, Svetošimunska 25, HR-10 000 Zagreb, Croatia
[5]Croatian Natural History Museum, Demetrova 1, Zagreb, Croatia
[6]Croatian National Institute of Public Health, Rockefellerova 7, HR-10 000 Zagreb, Croatia
[7]Department of Physics, University of Osijek, P.O. Box 125, HR-31 000 Osijek, Croatia
[8]Northern Velebit National Park, Krasno 96, HR-53 274 Krasno, Croatia
[9]Speleological Society Velebit, Radićeva 23, HR-10 000 Zagreb, Croatia; Speleological Committee of the Croatian Mountaineering Association, Kozarčeva 22, HR-10 000, Zagreb, Croatia

The objective of this study is to present the first results of scientific research conducted in the 1421 m deep cave system Lukina Jama–Trojama during 2010 and 2011. The cave is situated in the area of Hajdučki kukovi in Northern Velebit National Park (Croatia) and is the deepest cave system in the Dinaric karst. Deep pits of Mt. Velebit provide excellent way of gathering new insights on the geology, geomorphology, hydrology, physical processes and other properties of karst underground. Therefore, the aim of scientific research is to gather as much information on those properties. In situ measurements of microclimate parameters and radon concentrations were performed at 20 measuring points for one year. The air temperature in the cave ranges from 0°C in the upper part where permanent snow and ice are noted, to 5°C at a depth of 1368 m next to lake/siphon. Two temperature gradients were detected. The change of sign of temperature gradient is 100 m deeper than in 1026 m deep Cave system Velebita that was previously explored in Northern Velebit. The difference is probably due ice and snow dynamics that influenced microclimate parameters to a depth of 200 m. Mean radon concentrations changed with depth, from 200–600 Bq/m^3 in the upper cave sections, up to 1139 Bq/m^3 in the lower sections. This increase is in correlation with the partial pressure of carbon dioxide. Microclimate conditions below a depth of 220 m to the bottom are very stable, so speleothems are good candidates for further paleoclimate investigation. Lithostratigraphic and chronostratigraphic research was conducted. Geological profile of the Velebit massif underground was reconstructed based on the research results. At that time hydrological research was also taken up in the bottom syphon of the Cave. In the period of one year water level, temperature and electrical conductivity were measured in the entrance pool of the syphon. Measured data provide insight in the hydrogeological properties of the massif in its central part, between main sinkholes on the east and coastal springs on the west. Water in the pit is circumneutral to slightly alkaline, with pH ranging from 7.65 to 8.27. Temperature ranges from 0.8 to 4.7°C. Observed changes of water conductivity and TDS through the pit reflect impact of the lithology, geomorphology and mixing of the waters from different flows on the water chemistry . According to the analyses of major cations and anions for three water samples from the pit, concentration of Ca^{2+} largely exceeds that of Mg^{2+}, Na^{+} and K^{+}. The predominant anion is HCO_3- so water in the cave is Ca-HCO_3 type as a result of dissolution of carbonate rocks – limestone. Even if dolomite can be present too due to short water-rock interaction time Mg concentration are low. However, slightly higher Mg concentration was observed in the sample from -1368 m which present syphon and longer water-rock interaction period.

This research was supported by Northern Velebit National Park and Croatian Environmental Protection and Energy Efficiency Fund.

Keywords: geology, hydrology, cave climate, radon, speleology, Dinaric karst, Croatia

Determining environmental conditions that shape shallow, partly submerged coastal cave today – case of Y-cave, Dugi otok, Croatia

Mirko Radolović[1], Tatjana Bakran-Petricioli[1], Dražen Perica[2], Donat Petricioli[3], Maša Surić[4]

[1]University of Zagreb, Faculty of Science, Department of Biology, Rooseveltov trg 6, 10000 Zagreb, Croatia
[2]University of Zadar, Department of Geography, Trg kneza Višeslava 9, 23000 Zadar, Croatia
[3]D.I.I.V. Ltd, 23281 Sali, Croatia, tatjana.bakran-petricioli@zg.t-com.hr
[4]University of Zadar, Department of Geography, Ulica dr. Franje Tuđmana 24i, 23000 Zadar, Croatia, msuric@unizd.hr

Last late Pleistocene–Holocene sea transgression submerged hundreds of caves of Dinaridic Classical karst along the Croatian coast. From the total number of >235 investigated caves, more than half host completely marine conditions (euhaline) with the belonging biocenoses (b. of semidark caves and b. of caves and ducts in total darkness) whilst other (mainly coastal) experience different environmental conditions depending on the depth, tide and seaward freshwater discharge, and there species of organisms and biocenoses are distributed accordingly. One of such is Y-cave, shallow (down to -12 m), over 80 m long horizontal cave developed in Turonian (K_2) limestone, located on Dugi otok Island (Croatia), where impact of these different environmental conditions could be recognised within only a few tens of meters distance.
Geochemical condition produced by the interaction of freshwater and seawater, known as mixing corrosion, is responsible for dissolutional effects that influence the cave carbonate regardless if it is secondary deposited flowstone or limestone bedrock. Since pronounced dissolution and freshwater influence (corroded speleothems and bedrock, lack of sessile marine organisms) were visually noticed only in particular areas of the Y-cave, sets of limestone tablets coupled with temperature data loggers were placed along the cave and left exposed for 1 year, in order to asses dissolutional effect within different cave conditions. Results obtained by measuring the mass difference of carbonate tablets coincide with organisms' distribution and abundance. Moreover, the results, although preliminary, indicate that in spite of submarine position, the environment in particular areas of the cave is not saturated with respect to $CaCO_3$, as expected in the shallow sea, but aggressive. The distribution of living communities along the cave together with the results of measured abiotic parameters clearly reflects complex environmental conditions that shape this shallow, partly submerged coastal cave today.
Hypogene caves are lately defined as structures dissolutionally enlarged by the upwelling flow, independent from the surface influence, i.e. the most pronounced is hydrogeological aspect. But if we take into consideration geochemical aspect of the cave formation being induced not only by meteoric freshwater, but by the other sources as well (seawater in this case), Y-cave can be regarded as a cave with at least one phase of speleogenesis ascribed to hypogene settings.

POSTER ABSTRACTS

Environmental Problems Associated With Water Aquifer in Bahariya Oasis, the Western Desert of Egypt

Mahmoud Abdel-Fattah Anbar

Assistant Lecturer, Geography Department, Faculty of Arts, Cairo University, Egypt, mahfattah@yahoo.com

The depression of Al-Bahariya Oasis is located 150 km westward of the Nile Valley, covering an area of 2000 km^2. This depression had about 500 springs, either mineral, warm sulfur or cold water. Due to the over pumping, most of these spring dried out. The groundwater is the main source of water supply in the area of study, where there is almost no rainfall or surface runoff. Therefore, the population depends here heavily on the groundwater in their various activities.

The current paper aims to shed some lights on the characteristics of the aquifer in Al-Bahariya Oasis depression, especially: levels and movement of the groundwater, the geographical distribution of springs and wells, the quality and validity of the groundwater for the human use, as well as to identify the most important environmental problems associated with groundwater, such as: the soil salinization and water-logging, and finally how to preserve the underground water storage as a non-renewable natural resource.

This work depends on analyzing various kinds of historical and recent topographic maps, remotely sensed data and successive field trips.

Keywords: paleokarst, drylands, Egypt

Nekovci cave

Sami Behrami[1], Fadil Bajraktari[1], Ramiz Krasniqi[2]

[1]Kosovo Environment Protection Agency, Pristina, Kosovo, sami_behrami@yahoo.com, fadilbajraktari@yahoo.com

[2]Independent Commission for Mines and Minerals, Pristina, Kosovo, ramiz.krasniqi@kosovo.mining.org

Nekovci cave is located at the edge of the mountain range of Drenica, in the southwest of the municipality of Drenas, at the entrance to the gorge, "Përroni i Thatë". The cave is located in the altitude of 800 m, above the sea level. Cave is known by people as "Peshterr" but properly it would be known as Nekovci cave. Nekovci cave is located in the right side (north-east) of the gorge "Përroni i Thatë"about 190 m over the water flow. The cave's entrance is located about 40 m, under the limestone rock. The locality where the cave is located is composed of limestones, volcanogenic-sedimentary series and serpentinites whereas the pond of Drenica River is located in the eastern part where delluviums and alluviums dominate. Karstic erosion processes are present in the locality above the cave and in the vicinity of the cave, where the falling of limestone exchanges. Also large factures of limestone rocks are seen above the cave. The cave has natural entrance with width of 7 m and height of about 4 m. In the west entrance of the cave there are two small entrances which communicate with each other. From the entrance to about 20 m in deepness it is located a great gallery, with width of about 15 m, and the height from 2 m to about 30 m. After 20 m from the entrance, the cave is derived in two small and narrow corridors, one continues to north-east whereas the other to north-west of the cave. The considerable number of bats live in the cave that have polluted the floors and the walls of cave. The cave in the first part is not rich with cave ornaments, stalactites and stalagmites. Several chimneys are in the main hall of the cave that communicate with

the spaces above the cave that indicates whistles of air current. This cave has not been explored to date by the researchers of central institutions neither by the speleological associations. It is assumed that this locality is cave settlement of the years 3200–2800 BC, where late neolithic and early etnolithic tracks are discovered. Nekovci cave has scientific, geological, geomorphological, archaeological, education and tourism values.
Keywords: cave, Nekovc, corridors, gallery, etc.

The problem of determining of the karst polje edges – example of Korenica and Bijelo polje, Dinaric karst, Croatia

Neven Bočić, Ana Vujaković

University of Zagreb, Faculty of Science, Department of Geography, Subdepartment of Physical Geography, Zagreb, Croatia, nbocic@geog.pmf.hr

During geomorphological studies of karst poljes there is the problem of defining their exact boundaries. The edges of the karst poljes are not uniform and vary from polje to polje, but also within a single karst polje. In this work geomorphological research of Korenica and Bijelo Polje in Croatia was carried out by using the methods of digital terrain analysis, field research and mapping. In this research we try to defined four possibilities to determine the edges of the karst polje areas: border of the bottom of the polje, the highest closed contour, orographic basin edge and the edge of the theoretical surface drainage basin.

It was concluded that for defining the karst polje area the best is to take two parameters: border of the bottom of the polje and orographic basin edge. In addition, we tried to define the basic types of these boundaries. The edge of the bottom of the karst polje can be one of these main types: clearly defined, covered and transition edge. Also, orographic basin edge can be: defined, undefined and transition edge. Using so-defined edges different morphographic and morphometric parameters can be accurately measured and compare for multiple poljes.
Keywords: karst geomorphology, karst polje, Dinaric karst, Korenica polje, Croatia

Hydrochemical and geochemical research of Bistrac spring (Croatia)

Nenad Buzjak[1], Krešimir Maldini[2], Damir Tomas[2], Simana Milović[2], Natalija Matić[3]

[1]University of Zagreb, Faculty of Science, Department of Geography, Zagreb, Croatia, nbuzjak@geog.pmf.hr
[2]Hrvatske Vode, Central water management laboratory (CWML), Zagreb, Croatia
[3]Hrvatske Vode, EU Unit, Zagreb, Croatia

Bistrac karst spring is located in Samobor karst area in NE part of Samoborsko gorje hills (NW Croatia). It is a Vauclusian spring type in a karst system developed in Neogene limestone beds overlying less permeable Triassic beds. Due to the intense urbanization the whole area is under strong anthropogenic pressure resulting in nature degradation. Since it is unique for this part of Croatia, due to its geomorphological and ecological importance Bistrac spring and upper part of its valley is planned to be protected as a geomorphosite. Therefore geomorphological, hydrochemical and geochemical research are in progress to determine its characteristics and vulnerability. Concentrations of 21 elements, dissolved organic carbon, nutrients and ions, mineral oil, physical and chemical indicators were measured in water samples. Their concentrations were low - more than few orders of magnitude less than allowed by the Croatian regulations EQS for Inland surface water (environmental quality standard). According to concentrations of anions and cations dissolved in

water it is classified as Ca-HCO_3 type of water. Higher amount of Ca^{2+} (>70%) and lesser amount of Mg^{2+} (<30%) showing that water is under the higher influence of carbonate hinterland (limestones). Water from Jazbinščak stream that is connected with Bistrac has somehow higher amount of sodium, potassium and chloride. The mass fractions of 21 elements were determined in representative spring sediment by ICP MS. Sediment samples were also investigated using standard sieves 125 µm and 63 µm diameter. Highest concentrations of some metals in sediments are discussed.
Keywords: karst spring, trace elements, water quality, sediment

Coastal and submarine springs of Rovanjska – Modrič area (Croatia)

Nenad Buzjak[1], Maša Surić[2], Krešo Maldini[3], Robert Lončarić[2], Petra Kovač Konrad[4]

[1]University of Zagreb, Faculty of Science, Department of Geography, Zagreb, Croatia, nbuzjak@geog.pmf.hr
[2]University of Zadar, Department of Geography, Center for Karst and Coastal Researches, Zadar, Croatia, msuric@unizd.hr, rloncar@unizd.hr
[3]Hrvatske vode, Central water management laboratory (CWML), Zagreb, Croatia
[4]Karst Research Society Freatik, Zagreb, Croatia

Croatian Adriatic coastal belt is mostly built of intense karstified carbonate beds with well developed karst drainage systems and various types of karst aquifers well connected with hinterland. Along the coast there are zones with intense groundwater-seawater interactions marked by: a) groundwater discharge into the sea in the form of submarine and coastal springs, b) seawater penetration into karst aquifers, c) development of unique geomorphosites and habitats of high vulnerability to natural hazards and climate change. Their development and characteristics were mainly controlled by lithological composition, tectonic events, hydrogeological conditions, Late Pleistocene/Holocene sea level change and climate. Recently there is also quite aggressive anthropogenic impact in some restricted areas. In the conditions of recent climate variations and increased demands for fresh water, especially during the tourist season, the multidisciplinary researches of karst aquifers needs more attention by scientific, environmental, economic and government sector.
The area of Rovanjska - Modrič in northern Dalmatia is well known for very well developed coastal karst aquifer with submarine springs (local terms: vrulja, jezero) and numerous coastal springs. It was developed in karstified Crecateous and Paleogene-Neogene carbonate beds (mainly limestone and breccia). The development of the aquifer was determined by conditions of a mixed autogenic-allogenic system. The main inputs of fresh water are from: a) the hinterland (Lika region) in the form of sinking streams flowing underground towards the coast and b) the high precipitation in Velebit Mt. area. The largest submarine springs are Vrulja Modrič and Vrulja Zečica. Using speleodiving techniques in Vrulja Zečica 197 m of submerged passages were mapped (of about 650 m of known passages till the depth of 43 m). In Vrulja Modrič there was about 500 m of passage explored (up to 27 m deep). Both are characterized by seasonal water outflow and by well developed, spacious passages. During inactivity period seawater intrusion and anchialine conditions were recorded. In the area there are also three zones with high concentration of coastal springs. Research project in 2012 was aimed to their mapping and water sampling using field measurements and lab analysis. Concentrations of 16 elements, nutrients, physical and chemical indicators were determined. According to the first results there is no pollution of anthropogenic origin recorded.
Keywords: coastal aquifer, submarine spring, coastal spring, trace elements

Hypogenic caves in Italy: a review

Jo De Waele[1], Giuliana Madonia[2], Marco Menichetti[3], Mario Parise[4], Leonardo Piccini[5], Laura Sanna[6], Francesco Sauro[1], Marco Vattano[2], Bartolomeo Vigna[7]

[1]Department of Biological, Geological and Environmental Sciences, University of Bologna, Italy, jo.dewaele@unibo.it, cescosauro@gmail.com
[2]Department of Earth and Marine Sciences, University of Palermo, Italy, marco.vattano@unipa.it
[3]Department of Earth, Life and Environmental Sciences, University of Urbino (Italy)
[4]CNR-IRPI, Bari, Italy
[5]Department of Earth Sciences, University of Firenze, Italy
[6]Department of Science for Natural and Environmental Resources, University of Sassari, Italy, speleokikers@tiscali.it
[7]Department of Territorial Engineering, of the Environment and of Geotechnologies, Politechnical University of Turin, Italy

Although hypogenic cave systems have been described since the beginning of the XXth century, the importance of ascending fluids that acquired their aggressiveness from in-depth sources in speleogenesis has been realised in the last decades. Aggressiveness of waters can be related to carbonic and sulphuric acids and the related corrosion-dissolution processes give rise to different types of caves and underground morphologies.
The abundance of hydrothermal springs and associated travertine deposits, and the widespread interaction between volcanic or sub-volcanic phenomena and karst in many sectors of the Italian peninsula are a clear evidence of hypogene speleogenesis. Also researches on secondary minerals have allowed to discover hypogenic caves formed by highly acidic vapors in a subaerial environment, also showing that most of these caves have extremely rich mineral associations.
Despite this, until the late 80s the only known important cave system of clear hypogenic origin in Italy was considered to be the Frasassi Canyon and Monte Cucco cave cave systems, in which important gypsum deposits clearly showed that sulphuric acid played an important role in the creation of voids. Afterwards many other caves were categorized as formed by the sulphuric acid speleogenesis throughout the entire Apennines. Following the broad definition of hypogenic caves by Palmer in 1991, and the even more general one of Klimchouk in the last decade, the number of caves considered of hypogene origin in Italy has grown rapidly.
More recently, in a few of these caves detailed studies have been carried out including geomorphology, mineralogy, and geochemistry. Sulphuric acid caves are known from many regions along the Apennine chain (Tuscany, Umbria, Marche, Latium, Calabria), but also from Apulia, Sicily and Sardinia. In this last region ascending fluids have also formed a hypogenic sulphuric acid cave in quartzite rock. Oxidation of sulphides can locally create hypogenic cave morphologies in dominantly epigenic caves, such as in the Venetian forealps. Ascending fluids have also created large solution voids in Messinian gypsum beds in Piedmont, and these can be defined hypogenic caves according to the definition of Klimchouk.
At almost twenty years distance from the first review paper on hypogenic cave systems in Central Italy by Galdenzi and Menichetti, we will give a review on the state of the art knowledge on hypogenic caves actually known from the whole of Italy.
Keywords: hypogene caves, review

Types, characteristics and spatial distribution of caves in Zadar County

Fran Domazetović

University of Zadar, Department of Geography, Zadar, Croatia, frandomazet@gmail.com

Zadar County abounds with various speleological objects, which have been systematically investigated for many years. These objects differ greatly in their main characteristics (depth, length, hydrological and geological features, etc.). So far, a systematic statistical and spatial analysis of the data collected has not been done. The main objective of this paper is to create a digital database of the explored caves in order to conduct a spatial analysis. The aim is to determine and analyze the spatial distribution of caves in Zadar County in respect to geological and hydrological characteristics of this research area, and to infer which types of caves dominate in this area. Research is based on statistical analysis of the existing data on explored caves in Zadar County which are obtained from the archives of Speleological section Liburnija, and on the use of modern information systems, primarily ArcGIS. As the result, various maps of general settings and spatial distribution of caves in Zadar County are made. All caves were formed in well-stratified Cretaceous limestones. Characteristics of caves are given through their basic geological, hydrological and morphological types, together with the observation that derived from the conducted research.An interrelation between regional tectonic stress and hydrologic characteristics of the area on the distribution and types of caves is perceived.

Keywords: cave types, distribution, GIS, statistical analysis, spatial analysis, Zadar County, Croatia

Cave microclimate of Northern Velebit Mt. (Croatia)

Vinka Dubovečak[1,4], Nenad Buzjak[2,5], Dalibor Paar[3,4], Marko Kovač[6]

[1]Trakošćanska 42, Lepoglava, vinka.dubovecak@gmail.com
[2]University of Zagreb, Faculty of Science, Department of Geography, Croatia, nbuzjak@geog.pmf.hr
[3]University of Zagreb, Faculty of Science, Department of Physics, Croatia, dpaar@phy.hr
[4]Speleological society Velebit, Croatia
[5]Caving club Samobor, Croatia
[6]VijenacFraneGotovca 1, Zagreb, marko.kovac7@gmail.com

The Northern Velebit area is known by its many caves. In the last 22 years, 348 caves were explored, 3 of which are deeper than 1000 m, 5 are deeper than 500 m, 9 are deeper than 200 m and 27 are deeper than 100 m. Development of the deep karst system is the result of a complex geological structures and hydrogeological conditions. The characteristic climate diversity of Velebit Mt. is the result of its geographical position between the Adriatic Sea and Pannonian Basin, its altitude and its stretch in NW–SE direction. Not only does the increase of the altitude decrease the temperature, but it also significantly increases the amount of precipitation, and that is very important for the physical processes observed in caves.

As the result of the favorable climatic conditions, numerous caves of Velebit Mt. have perennial ice and snow deposits. One of them is the Ice pit in Lomska duliba (Ledena jama u Lomskoj dulibi). At its entrance significant deposits of ice and snow are accumulated due to the following micro-location factors: vertical entrance (perimeter 50 x 60 m), altitude of entrance (1235 m a.s.l.), location in the karst depression with frequent negative temperature gradient and abundant precipitation with significant amounts of snow. For the more detailed analysis of the conditions in snow accumulation and ice genesis, the data made in previous measurements (temperature and relative humidity) is used. This data is compared with the microclimate data of Lomska duliba and the main meteorological station Zavižan (1594 m a.s.l.). Since in the last 20 years deposits of snow and ice have been significantly changed, there are new microclimate researches in the progress.

Measurements are being managed with the help of data loggers on a different depths from September 2012. to September 2013. In addition to the air parameters, the rock temperature is also measured. Same measurements are also managed in Patuljak cave (1582 m a.s.l.) and 281 m deep collapsed sinkhole of the Sirena pit, (1543 m a.s.l.), situated in Rožanski kukovi area.
Keywords: cave microclimate, Ice pit (Ledena jama), Lomska duliba

Evidences of Paleo Karst from the Egyptian Deserts

Saleh R. Eisa[1], Ali M. Tamam[2], Atef M.Abdel-Hamid[2]

[1]Geography Department, Faculty of Arts, Minya University, Egypt, salehgeo@yahoo.co
[2]Geography Department, Faculty of Arts, Cairo University, Egypt, atefoov@gmail.com

The very dry Deserts in Egypt nowadays had been enjoying a humid climate during the past geological ages. Many limestone rocks has exposed to intermittent periods of paleo rain system, began in Oligocene and extends across the Miocene and Pliocene to successive periods during the Pleistocene. These old wet periods gave good opportunities to the development of paleo karst landforms, such as springs, caves, solution pans, dolines, Karren, and many pseudo karst landforms.
Most of the paleo karst landforms analyzed in this paper belongs to the Eocene age in Sinai & the Eastern Desert, and to Cretaceous-Paleocene in the Western Desert. Although the current climatic conditions have nothing to do with the origin of Karst, since they are hyper-arid, the study of these relic landforms is very important in reconstructing the landscape evolution of the Egyptian environment.
The aim of this paper is to shed lights on some of the prominent examples of plaeo-karst system in selected regions of the Egyptian deserts, especially: hot springs in Sinai, dry valleys (wadies) in Eastern Desert, and the White Desert in Farafra Depression (Western Desert of Egypt). The research depends on field survey, interpretation of remotely sensed data and geomorphological mapping.
Keywords: paleokarst, drylands, Egypt

Isotopic tracers as a tool to recognize water circulation pattern in a karst system – a case study from the Niedźwiedzia Cave (Sudetes, Poland)

Michał Gąsiorowski, Helena Hercman, Bartosz Galbarczyk-Gąsiorowski

Institute of Geological Sciences Polish Academy of Sciences, Twarda 51/55, PL-00818, Warszawa, Poland, mgasior@twarda.pan.pl

The Niedźwiedzia Cave, with the length of known passages over 4000 m, is the biggest cave in the Polish part of Sudety Mountains. The system has 3 levels of passages and chambers connected by several fissures and chimneys. Middle level of the system is a show cave with over 80,000 visitors every year. In general, the Niedźwiedzia Cave karst system is fed by direct infiltration of precipitation, infiltration from the surface stream and inflow by fissures from the surrounding rocks. The cave is drained by system of karst springs in the Kleśnica stream valley, but some part of water flows across border ridge and occurs in Morava stream valley, Czech Republic.
From 2010 to 2013 we have been doing a monitoring program of cave air temperature and humidity, drip rate, stable and radiogenic isotopes composition of water inside the cave and in its vicinity. The major aim of the project was to verified a general (and simplified) model of water circulation in the cave and to develop a new methodology of water circulation study using isotopic tracers.
Changes in dripping rate at upper level of the cave were well correlated with precipitation. However, a response of dripping to rainfall depends on former precipitation frequency and intensity – during

the humid period the dripping points reacted immediately and after long dry period dripping responded with a two-weeks delay. In the upper level, stable isotope composition in drip water are located close to the local meteoritic water line (LMWL- this line characterized the relation between $\delta^{18}O$ and δD in the region) and varied during the year similar to stable isotope composition of precipitation (i.e. low $\delta^{18}O$ values during winters and higher $\delta^{18}O$ during summers).
There is no direct correlation between precipitation frequency and amount of drip water in the lower level of the cave system. Also stable isotope composition of drip water shown no variation during a year. It suggests relatively long time of infiltration down to the cave lower level. Tritium dating of this water indicated an age of 1.4+/-0.3 year.
The “oldest” water was found in karst spring draining the cave system. The estimated transit time is 3–4 years and suggest admixture of some “old” water that was not sampled in the cave.
This study is funded by the National Science Centre and Higher Education grant no. N N306 131038.
Keywords: stable isotopes, Tritium, karst water, drip rate

Morphometric analysis of dolines Mt. Jahorina based On digital terrain analysis

Jelena Golijanin

University of East Sarajevo, Faculty of Philosophy – Department of Geography, Bosnia and Herzegovina, jelenagolijanin@gmail.com

Mt. Jahorina is located southeast of Sarajevo, at the border between Eastern to Central Bosnia. It is a part of the central Dinarides with typical Dinaric direction of NW–SE. The highest peak is Ogorjelica (1916 m) and towers above the shallow segmented karst plateau with an average height of 1300–1400 m. Of the total area of Jahorina (387 km^2) karst covers approximately 160 km^2, or 41% of the area. Karst plateau is built mainly of anisian stage limestone and lesser amount of dolomite, which are faulted and dissected by multiple faults with mainly Dinaric direction. Turbulent tectonics caused high levels of fissuration of limestone, which has contributed to the development of karst process. Dolines are the most dominant and the most numerous karst forms in this area.
In this paper an morphometric analysis of dolines of Mt. Jahorina is conducted, the most dominant karst forms. Also, an analysis of the evolution of dolines and their factors such as bedrock, relief and geotectonic conditions, using GIS methodology. Based on 1:25,000 topographic maps, and digitized contour lines the digital elevation model (DEM) of the study area was made, which served as basis for carrying out morphometric analysis of dolines.
Keywords: doline, karst, morphometrical analysis, Jahorina Mt., GIS

Slovenian legislation and Karst phenomena

Katarina Kosič

University of Nova Gorica, Križ 66, 6210 Sežana, Slovenia, katarinakosic84@gmail.com

Slovenia is one of the countries with the most developed legislation regarding protection of Karst and it`s phenomena. Slovenian protection policies could be the foundation for common European Union Karst protection policies, which are almost inevitable for the future preservation of Karst and the most important part of it, the ground waters. Which are an important source of drinkable water for the European Union.
Keywords: Karst, groundwater, protection

Paleo- Karst in El Ma'aza plateau, Eastern Desert of Egypt

Mohamed Ebrahim Khatab

Cairo University, Faculty of Arts, Geography Department, Cairo, Egypt, khattab_mohammed80@yahoo.com

The study area is a part of the Ma'aza Limestone plateau, which is located in the Eastern Desert – Egypt, covering an area about 1250 km^2, it's a semi-flat surface, and its elevation ranges between 60–513 m, the area is dissected by numerous incised dry valleys, these valleys have very steep sides, and very narrow bottom, the rock exposed in the area is limestone, and it belongs to lower Eocene , which consists mainly of medium to thick bedded limestone and chalky limestone with very thin beds of marl and shale, moreover numerous chert bands and flint nodules. Structurally, the Eocene strata have a gentle regional dip, and there are a lot of faults, joints, and drag folds.

The area has exposed to eras and periods of paleo rain system, begins in Oligocene to the Pontic pluvial in upper Miocene, in addition to two or three periods in the Pleistocene. This old wet periods, hosted by the geological characteristics, gave very good chances to the development of paleo karst landforms, as caves, solution Pans, collapse sinkholes, calcite veins and many pseudo karst landforms.

There are nearby 102 caves, with differences in sizes, shapes and distributed at different altitudes and different beds. Furthermore, the research recorded 308 solution pans, which has an area of 2.13 km^2, and its size ranging between 40–200 thousand m^2, and there are 2 collapse sinkholes, excess 5 m in depth, and about 2000 m^2 in area. There are countless of calcite veins, which spread over the surface of the region, and record heights more than 1 m, and take a multiple directions depending on the trends of the joints. The study based on the reading and interpretation of the Ikonos Images, field studies, topographic maps scale 1: 50,000, and geological maps scale 1: 100,000.

Hypogenically-formed dedolomite bodies in the mid-Cretaceous dolomite of the Povir Formation (Kras, Slovenia)

Adrijan Košir[1], Andrea Martín-Pérez[1] & Bojan Otoničar[2]

[1]Paleontološki institute Ivan Rakovec ZRC SAZU, Novi trg 2, 1000 Ljubljana, Slovenia, adrijan@zrc-sazu.si
[2]Karst Research Institute ZRC SAZU, Titov trg 2, 6230 Postojna, Slovenia, otonicar@zrc-sazu.si

Extensive road-cuts in Cretaceous carbonate succession exposed along the motorway near Sežana (Kras, Slovenia) revealed remarkable, decametre-size yellow to red rock bodies crosscutting dark grey bedded dolomite and forming sheet-like structures parallel to the bedding. The bodies appear to be limited to the massive and laminated bituminous dolomite of the Albian-Cenomanian Povir Formation and form a 3-dimensional network pattern, likely predisposed with intersecting vertical fractures and bedding-plane partings. XRD and petrographic analysis shows calcite composition of the yellow-red rock and indicates its formation predominantly through dedolomitisation and replacement of the host dolomite. Typically, dedolomites have chalky appearance and high microporosity. The fabric includes hypidiotopic mosaics where dolomite rhombs show calcitic rims and cloudy dolomitic centres, microsparitic mosaics, pseudospherulitic fibrous calcite and abundant blocky and drusy cements. Preliminary informational isotopic analyses of few samples suggest that dedolomitization was taking place in meteoric conditions. The stratigraphic unit of bituminous dolomite with dedolomite is underlain by a thick succession of dolomite, interbedded with irregular, several metres thick beds of dolomite breccia. Composition, structure and geometry of the breccia beds indicate that they most probably formed by the collapse associated with dissolution and complete removal of evaporites (Ca sulphates), originally present in the dolomite succession. We hypothesise that the dedolomite and collapse breccia are two closely related phenomena, namely, that the dedolomitisation resulted from upward recharge of Ca sulphate-rich solution formed by dissolution of evaporates in meteoric conditions.

Water chemistry and microbiological studies in a thermal cave in Hungary (Molnár János Cave)

Gabriella Köblös[1], Klaudia Kiss[2], Tibor Szili-Kovács[3], György Czuppon[4], Krisztina Kármán[5]

[1]Agricultural Institute, Centre For Agricultural Research, Hungarian Academy of Sciences, H-1022 Budapest, 15 Herman Ottó street, Hungary, koblos.gabriella@agrar.mta.hu
[2]Geographical Institute, Research Centre For Astronomy and Earth Sciences, Hungarian Academy of Sciences, H-1112 Budapest, 45 Budaörsi street, Hungary, kissklau7@gmail.com
[3]Institute For Soil Sciences and Agricultural Chemistry, Centre For Agricultural Research, Hungarian Academy of Sciences,H-1022 Budapest, 15 Herman Ottó street, Hungary
[4]Institute For Geological and Geochemical Research, Research Centre For Astronomy and Earth Sciences, Hungarian Academy of Sciences, H-1112 Budapest, 45 Budaörsi street, Hungary
[5]Institute For Geological and Geochemical Research, Research Centre For Astronomy and Earth Sciences, Hungarian Academy of Sciences, H-1112 Budapest, 45 Budaörsi street, Hungary

Molnár János Cave is an active hydrothermal cave located in Budapest on the karstic erosional base level (Danube). This means that waters from different origin mixing at the Danube line play(ed) important role in the development of the cave (so-called mixing corrosion). The mixing waters originate from karstic infiltration, intermedier and regional flows. They have different temperature (17–27°C) and dissolved ion concentration (electrical conductivity of the springs in the cave are between 900 and 1200 µS/cm, EC of dripping waters: 1100–2200 µS/cm).
The aim of our study is to examine and compare the chemical quality and microbiological properties of spring waters and to obtain infromation about their origin.
For the analyses four sampling points were established representing the water-cavity passages. The samples were collected with the help of divers in winter-time, 2013. To detect the short-time fluctuation of the water quality the examination was repeated four times (weekly). For all samples pH, electrical conductivity, HCO^{3-}, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, NH^{4+}, SO_4^{2-}, Cl^{-}, NO_3^{-}, NO_2^{-}, PO_4^{3-}, stable oxygen ($\delta^{18}O$)and hydrogen (δD) isotope were measured. The phylogenetic diversity of bacterial communities of the waters was investigated by novel methods (different culturing conditions, DNS extraction).
In our work we show the results of the initial measurements. We plan to do the same series of measurement in summer-time to examine temporal changes of the spring waters.
Keywords: hydrothermal cave, water chemistry, bacterial communities

Stable isotope composition of recent cave calcite precipitates and its relation to DIC in drip water from Postojna Cave, Slovenia

Magda Mandić[1], Ines Krajcar Bronić[2], Andrej Mihevc[3], Albrecht Leis[4]

[1]Physics Department, University of Rijeka, Rijeka, Croatia, mmandic@phy.uniri.hr
[2]Ruđer Bošković Institute, Zagreb, Croatia, krajcar@irb.hr
[3]Karst Research Institute ZRC SAZU, Titov trg 2, 6230 Postojna, Slovenia, mihevc@zrc-sazu.si
[4]Joanneum Research, RESOURCES - Institute for Water, Energy and Sustainability, Graz, Austria

Modern approach to the application of stalagmites for paleoclimate investigation recommends first studies of younger actively growing samples as well as cave drip water and cave environment monitoring undertaken for at least one climatic year.
In the period from March 2010 to April 2011 such program has been performed in Postojna Cave. Environmental parameters (air and water temperature, pCO_2 and geochemical parameters of drip water) have been monitored and stable isotopic composition ($\delta^{13}C$ and $\delta^{18}O$) of water and recent (soda straw and carbonate precipitated on watch glasses) has been determined, as well as stable isotopic composition of old carbonates. Monitoring has been performed on nine locations along the longitudinal profile of Postojna cave. Locations were chosen in order to cover different conditions of cave environment. Drip rate has been measured at each site. Glass plates were exposed for eight months at each location for recent carbonate precipitate sampling. The analysis of carbon ($\delta^{13}C$) and oxygen ($\delta^{18}O$) isotope ratios from cave drip water and fresh calcite precipitates from watch glasses has been done. Here we present the obtained results.
The $\delta^{13}C$ values of carbonates precipitated on watch glasses are close to the corresponding $\delta^{13}C$ DIC values (≈-12 to -13‰). The values of $\delta^{13}C$ for "soda straws" vary from -7.84‰ to -10.58‰. The $\delta^{13}C$ of DIC and carbonates precipitated on watch glasses at location 05 – Podrti kapnik, -9.90 ‰ and -9.95 ‰, respectively, differ significantly from the corresponding data at other locations. The reason of such behavior could be in assumed prior calcite precipitation (PCP).
The highest $\delta^{18}O$ value of soda straw samples is -4.84‰ and the lowest is -7.84‰. The $\delta^{18}O$ values of carbonates precipitated on watch glasses range from -3.07‰ to -4.67‰. The $\delta^{18}O$ values of carbonates on watch glasses are therefore more positive/less negative than $\delta^{18}O$ of "soda straws".
Keywords: Postojna cave, stable isoropes, precipitated carbonates, PCP

Natural bridges of Zlatibor mountain massif

Dejan Milenić*, Nenad Doroslovac, Bojan Dončev, Marina Jovanović,

University of Belgrade, Faculty of Mining and Geology , Department of Hydrogeology
**e-mail:dmilenic@yahoo.ie, tel:0113346000*

The Zlatibor mountain massif spreads over the area of three municipalities in the southwestern part of Serbia: Čajetina, Užice and Nova Varoš. It stretches along the northwest-southeast direction covering an area of about 1000 km^2.The Zlatibor mountain massif is mostly made of Mesozoic age rocks within which there can be singled out a diabase-chert formation and the carbonate rock complex of Triassic age.
Natural bridges are rare and specific forms of karst relief. In the region, they are called prerast (parast). When the genesis is in question, there is not a universal way of their formation. Natural bridges are formed in karst terrains by the collapse of cave ceilings above strong underground streams or above shallow caverns.
The most distinctive natural bridge of the Zlatibor mountain massif (the southern margin of Zlatibor Mt.) is certainly the prerast in Dobroselica situated in the area of the village of Dobroselica. The area of the Tornik peak where the prerast is situated belongs to an ultramaphite complex while the very natural bridge is formed in Triassic reef limestone.

Another natural bridge in the region of Zlatibor Mt. is situated in the village of Tripkovo immediately above the Sušičko spring. The Sušičko spring is one of karst springs of the highest yield in the western part of Serbia. The total precipitation occurring on the carbonate complex of Zlatibor, owing to karst terrain, sinks and occurs in the Sušičko spring. Therefore it is considered that groundwater has participated in the genesis of this karst phenomenon.
Key words: natural bridge, Zlatibor mountain massif.

Subthermal karst occurrences in eastern part of Zlatibor mountain massif

Dejan Milenić*, Ana Vranješ, Đuro Milanković, Nevena Savić,

University of Belgrade, Faculty of Mining and Geology , Department of Hydrogeology
**e-mail:dmilenic@yahoo.ie, tel:0113346000*

The Zlatibor mountain massif is situated in southwestern part of the Republic of Serbia and, administratively, belongs to the Zlatibor County. It stretches along the municipality territories of Čajetina, Nova Varoš and Užice. The rivers Uvac and Veliki Rzav represent its southern and eastern borders, while, in the west, it borders with Bosnia (Mokra Gora, Semegnjevo and Jablanica). The altitude in the study area ranges from 900 to 1200 MASL. The mean annual air temperature for the period from 1981 to 2010 amounts 7.7 ºC while the values of geothermal gradient amount 20 to 30 °C/km. From the hydrographic point of view, the Zlatibor region belongs to the Black Sea watershed.
The study area is made mainly of rocks of Mesozoic age where ultramaphite rocks, a diabase–chert formation and the carbonate complex of Triassic age can be singled out. The Banja Vapa Spa and the spring on the right bank of the River Katušnica can be distinguished as subthermal karst occurrences in eastern part of the Zlatibor mountain massif. Groundwaters run towards water streams representing local erosive bases where their discharge occurs. The movement directions of these waters are predisposed by tectonic texture of the terrain. The discharge of the subthermal water of the Banja Vapa Spa is related to the fault structure by which the watercourse of River Prištevica is predisposed. The subthermal spring Banja Vapa drains the limestone of Middle Triassic age. It is tapped in the way that subthermal water from a catchment reservoir discharges into four catchment areas having two pipes each. The total yield of this spring amounts 2 l/s. The water temperature is about 18 °C at the air temperature of 21.7 °C. Results obtained by a chemical analysis point out that hydro carbonate ion (378.57 mg/l), prevails in the anion composition, while among cations, calcium ion (109.42 mg/l) prevails. The water from the Banja Vapa Spa Spring has total mineralization of 342 mg/l, and general hardness of 17.92 °dH. The discharge of the spring on the right bank of the River Katušnica is related to the contact between the Middle Triassic limestone and the Lower Triassic conglomerate. This spring is of the ascending type according to the mechanism of discharge. It is tapped in a primitive way. The yield of the spring is 0.0002 m^3/s.The water temperature amounts17.6 °C at the air temperature of 14.8 °C. The brief chemical analysis points out that the water from this spring is a mild mineralized (312 mg/l) type, of a hydro carbonate group(332 mg/l), a calcium class (98.2 mg/l), with the pH value of 7.46 and the general hardness of 14.84 °dH. The potential use of this water could be multi-purpose, first of all for wellness and spa programmes (balneological and sports recreation aspects) as well as for the heating and cooling of facilities.
Key words: Zlatibor mountain massif, groundwater, sub thermal karst occurrence.

A genetic classification of caves in Lower Austria, focused on hypogene caves

Pauline Oberender, Lukas Plan

[1]Karst and Cave Research Group, Natural History Museum Vienna, Museumsplatz 1/10, A-1070 Vienna, Austria, paulob06@uni-bonn.de, lukas.plan@nhm-wien.at

Based on existing cave classifications we developed a classification scheme focusing on the main genetic process, which we defined as the one that was responsible for most of the cave volume. Caves can develop due to various processes whereupon we differentiate the following types:
Corrosional caves which were subdivided in *epigene* and *hypogene caves*. The *epigene caves* were distinguished in *vadose* and *phreatic* caves while the *hypogene* ones were split in *hydrothermal* and *sulphuric acid caves*.
Weathering and erosional caves which were subdivided into *frost weathering caves*, *spherical weathering caves*, *talus caves*, *crevice caves*, *river side caves*, *piping caves* and some others.
This scheme was applied to the 4849 known caves of Lower Austria and some neighbouring areas (ca. 23,000 km²). This area comprises most major tectonic units of the Eastern Alps which results in a highly diverse landscape ranging from high alpine karst plateaus (up to 2079 m a.s.l.) over low mountains and hills to extended lowlands.
In geomorphology it is a common approach to reconstruct the process from morphologic observations. Therefore we set up a key of characteristic attributes for each cave type considering overall cave morphology and pattern, micro morphologic features (scallops etc.), cave sediments, and the relation of the cave to the surface and to hydrology. Besides some direct field observations (some hundred caves) these attributes were deduced from cave maps, descriptions, photographs, topographic maps (including a high resolution laser scan and discussion with speleologists).
For 93% of the 4849 caves a classification was possible but for 15% of them classification is somewhat uncertain. 45% of the classified caves are corrosional caves, out of these 68.2% are epigene caves, 3.2% are hypogene ones and 28.5% cannot be further differentiated. The epigene ones split up into 33.1% of mainly vadose origin, 30.9% are phreatic and 4.2% show both hydrologic regimes to a significant extend.
A total of 67 caves (20 with some uncertainty) were classified as hypogene in origin which make up 1.4% of the total number of caves in the study area. Out of these for 9 caves a sulphuric acid speleogenesis was attributed. All these hypogene caves are located at or near the margin of the Vienna Basin, which is a Miocene pull apart basin where hydrothermal water rises along major faults. The sulphuric acid ones only occur near Bad Deutsch Altenburg which also shows an active sulphuric spring.

Chemical analysis of water samples from wells and springs of Rovte region, W Slovenia: an assesment of ongoing dedolomitisation

Sven Philipp[1], Bojan Otoničar[2], Franci Gabrovšek[2], Stephan Kempe[1]
[1] Institute for Applied Geoscience, TU Darmstadt, Schnittspahnstraße 9, 64287 Darmstadt, Hessen, Germany, sven.philipp@stud.tu-darmstadt.de
[2]Karst Research Institute ZRC SAZU, Titov trg 2, 6230 Postojna, Slovenia, otonicar@zrc-sazu.si

Speleological and geological research in the area of Rovte (W Slovenia) revealed potential hypogenic origin of several caves. Among other processes dedolomitization seems to have played important role in speleogenesis. To assess if the dedolomitization is still active, we have sampled and analysed water from three deep wells and two springs. As the wells penetrate gypsum strata at the depth of several hundred meters, water from wells shows high SO_4^{2-} concentration and very low Mg/Ca ratio. On the other hand, the concentration of nitrates is much higher in surface springs indicating impact

from the surface. Calculation of saturation indexes with PHREEQC showed, that most samples from the wells were supersaturated with respect to calcite and undersaturated with respect to dolomite, which points to conclusion that dedolomitization can still be an ongoing process. However, before more firm conclusions will be possible, more sampling and further analyses are needed.
Keywords: Dedolomitization, PHREEQC, ground water chemistry, deep wells

Geochemistry and Mineralogy of the speleothems from caves on Mt.Velebit (Croatia)

Srđan Pichler[1], Stanislav Frančišković-Bilinski[2], Krešimir Maldini[3], Dalibor Paar[4]

[1]Heinzelova 7 a, HR-10000 Zagreb, Croatia, spichler@irb.hr
[2]Ruđer Bošković Insitute, Bijenička c. 54, HR-10002 Zagreb, Croatia, francis@irb.hr
[3]Croatian waters, Vukovarska 220, HR-10000 Zagreb, Croatia, kresimir.maldini@voda.hr
[4]University of Zagreb, Faculty of Science, Department of Physics, Bijenička c. 32, HR-10002 Zagreb, Croatia, dpaar@phy.hr

The aim of this study is to estimate a possibility of using trace elements as paleoclimate proxies in speleothems from some of the deepest caves of Dinaric karst located on Mt. Velebit (depth up to 1421 m). It is well known that there is an relationship between trace element content in speleothems and environmental conditions that can vary due to differences in climatic conditions on a surface, vegetation, chemical composition of bedrock, groundwater movement etc.
Methods used in analysis are semiquantitative mineralogical analysis using X-ray powder diffraction to determine mineralogical composition, inductively coupled plasma mass spectrometry ICP-MS and atomic absorption spectrometry (AAS) to determine geochemical composition. Differences in geochemical and mineralogical content show us possibility of using trace elements and mineralogical composition in analysis of palaeoenvironmental changes in Dinaric karst.
Keywords: X-ray, ICP-MS, AAS, speleothems, Mt. Velebit

Karst in Upper Cretaceous carbonate sediments in Bukovinian part of the Dniester Valley

Oles Ridush

Department of Physical Geography and Natural Management, Chernivtsi "Yuri Fedkovych" National University, Ukraine, olesridush@gmail.com

The region of Western Ukraine is famous mostly with karst developed in Neogene sulphate sediments (gypsum). It the same time there are other karstified sediments above and below the gypsum strata. Particularly, since the beginning of 20th century karst was described in the Cretaceous carbonate sediments (sandy limestone and carbonate sandstone). The karst forms in these rocks were described just as caverns and small cavities (up to 0.5m). Our research of fossil karst cavities in Cretaceous sediments in the Bukovinian part of the Dniester valley shows that sometime they may reach up to 5 m in diameter.
Cretaceous sediments in the region are characterized with great lithofacial variability even within each geological stage. Cavities size is controlled by the thickness of layers with prevailing of carboniferous material. The residual deposits in such cavities are represented with quartz sand.
Being overlying with thick pack of Neogene deposits, Cretaceous sediments could be influenced only by underground water. Therefore karst in these deposits could be only of hypogenic origin. This is confirmed by complex of indicator forms inside cavities.
Due to the presence of many karst springs with discharge up to 1 m^3/sec, associated with Cretaceous sediments, the karst processes in these strata are still active.

Keywords: Bukovyna, Cretaceous, sandy limestone, hypogenic karst

Concurrency of the lowest points of drainage basins with distribution of the caves in Zadar County

Krešimir Samodol[1], Nina Lončar[1, 2]

[1]University of Zadar, Department of Geography, Croatia, ksamodol8@gmail.com, nloncar@unizd.hr
[2]Speleological section Liburnija, Zadar, Croatia

This paper deals with concurrency/overlapping of caves with the lowest points of drainage basins (sink points) in Zadar County area. The goal is to establish are there any overlaps and in which degree do they occur and to test what are the possibilities of studying karst areas, from the aspect of sink analysis tool. The study area is divided on area with low relief energy (Ravni Kotari, Zadar County) and with high relief energy (Bojinac Velebit, Zadar County), in order to check whether there are differences in concordance of caves and sink points with regard to energy relief. Spatial analyzes were made in ArcGis 10.1. In order to perform the analyses, locations of caves were georeferenced, geological map of the area was digitalized and digital elevation model (DEM) was created based on the topographic maps of Zadar County. DEM is used to analyze the settings of the slopes on which caves occur and to create drainage basins, flow directions and sink points inside the studied area.
Keywords: cave distribution, drainage basins, GIS analysis, Zadar County, Croatia

Multidisciplinary study of the caves of Naica (Mexico): a review

Laura Sanna[1], Paolo Forti[2]

[1]Institute of Biometeorology, National Research Council, Italy, speleokikers@tiscali.it
[2]Italian Institute of Speleology, University of Bologna, Italy, paolo.forti@unibo.it

The caves of the Naica Mine (Chihuahua, Mexico) contain some of the World's most impressive secondary hypogene speleologenetic processes actually mainly known for their gypsum crystals that in the last ten years have attracted attention of scientific community.
In fact, the Naica cave patterns are not interpreted as strictly hypogene, but could have formed in a first stage by dissolution in meteoric water conditions along fractures, faults and bedding plains affecting the carbonate massif and, only later, superimposed by hypogenic features related to the mobilization of the polysulphide mineralization that filled the karst voids.
The ore deposits in Naica is of hydrothermal origin, resulted from the presence of a magmatic activity that took place about 26 million years ago, probably corresponding with the last magmatic stages in the Sierra Madre Occidental. Intrusion of this body and interaction with connate water of the sedimentary sequence created a hydrothermal system with high metal transport capacity brines. The interaction between hot water of meteoric origin (rising along main fault of Sierra de Naica mountain) and anhydrite lens, formed in the limestone during later stage of ore body formation, led to the formation of rare and complex speleothems.
For these reasons, since 2006 Naica caves are part of a multidisciplinary research project that covers main research fields, such as geology, physics, biology, and more recently, detailed studies have been carried out including mineralogy, geochemistry and hydrogeology.
A review on the state of the art knowledge on hypogenic features of Naica caves is presented.
Keywords: hypogene features, speleothems, gypsum crystals, Naica, Mexico

Hermannshöhle (Lower Austria): A probably non-hypogean 3D-maze cave

Andrea Schober

University of Vienna, Vienna, Austria, andreaschober@gmx.at

The app. 5 km-long Hermannshöhlen system (located in Kirchberg/Wechsel, Lower Austria) is the largest cave in the Lower Austroalpine Unit. It is developed in an isolated block of carbonate marble, taking up only 200 x 200 m of ground area and 80 m of elevation difference. The cave is unusual in several respects: (a) its dense network of corridors is arranged in a three-dimensional maze, (b) corridors are often developed as canyons that clearly lack any vadose influence, and (c) clastic sediment fills as well as speleothemes are abundant throughout the cave.
Besides some vadose dripwater the cave is dry today. A conspicuous feature is the lack of a single water path and instead a maze with multiple flow paths formed. Another interesting feature is that one part of the cave developed below the nearby Ramsbach brook but is still dry. Speleothems are abundant throughout the cave comprising flowstones, dripstones, helictites, popcorn, calcite rafts, a shield, and moonmilk. Even though most passages are canyon-shaped, the cave shows exclusively phreatic features. Sediment fills are abundant as well, mostly covering the floor of passages to an unknown depth, containing mainly allochthonous material, i.e. schists and gneisses.
The aim of this study was to enlighten the speleogenesis as well as the palaeohydrology of this cave using morphological and sedimentological observations as well as U/Th dating of speleothems. First results show that the prominent sediment fills played a crucial part in the evolution of the Hermannshöhlen system. Recent cave features seem to be primarily related to paragenetic development of corridors, meaning an upwards solution of host rock due to less erodible sediment fills. Furthermore the palaeo-environment and the hydrologic setting of the Hermannshöhle were drastically different from today. Undersaturated water sourced from nearby non-karstic gneisses and schists gave rise to well-developed contact karst features. Surprisingly the palaeo flow direction deduced from indicators like scallops and sediment structures was opposite to the flow direction of the present nearby brooks (Rams- and Feistrizbach). Following pulses of clastic sediment input a distinct system of paragenetic canyons developed creating the unique maze character of the cave.
Even though the cave is located close to prominent fault zones which could have been the source of rising waters there is no evidence for a hypogean speleogenesis: Almost all macro and micro morphologic features can be related to an epigean phreatic speleogenesis with a dynamic palaeo flow regime and sediments (neither clastic nor chemical ones) do not indicate a hydrothermal influence. Only few cupola-like features leave some doubts about a pure epigean speleogenesis.
Keywords: maze cave, contact karst, epigean, paragenesis

Challenges in monitoring and sampling for the palaeoclimate studies of caves in Zadar region

Maša Surić[1], Robert Lončarić[1], Nina Lončar[1], Nenad. Buzjak[2]

[1]Department of Geography, Center for Karst and Coastal Researches, University of Zadar, Croatia, msuric@unizd.hr, rloncar@unizd.hr, nloncar@unizd.hr
[2]Department of Geography, Division of Physical Geography, Faculty of Science, University of Zagreb, Croatia, nbuzjak@geog.pmf.hr

In July 2012, scientific project Reconstruction of the regional palaeoclimate change – speleothem records from the North Dalmatia (Croatia) started, encompassing 3 caves on the transect from Dalmatian islands to Velebit Mt. peaks: Strašna peć Cave on Dugi otok Island (70 m a.s.l.), Manita peć Cave in Velika Paklenica canyon (Velebit Mt., 570 m a.s.l.) and Spilja u Zubu Buljme Cave (Velebit Mt., 1305 m a.s.l.). The main goal of this study is reconstruction of palaeoenvironmental settings that were recorded in speleothem carbonate, with the intention to assess i) the extent to which climatic

conditions in the region varied during the late Quaternary and ii) the likely impact of future climatic changes. The growth history of speleothems within the cave itself offers a first-order palaeoclimate signal, since deposition occurs only when the effective precipitation is sufficient to sustain recharge into the vadose zone. Moreover, in combination with the stable isotope data, palaeoenvironmental changes can be revealed. Stable isotope analyses will be undertaken on sub-samples drilled along the central growth axes of the U-series dated stalagmites to provide a time-series stable isotope record.
The first leg of this 3-year project consists exclusively of the field work, monitoring and sampling. Temperature and relative humidity will be monitored for 2 years at the selected sites within all three caves. Four drip-loggers have been installed to record the response of the drip water to the rain events on the surface i.e. to characterize hydrological behavior at the different drip sites, two of which fed the sampled stalagmites. Water samples for stable isotope analyses will be collected monthly for 1 year, as follows: i) rainwater from above the each cave, ii) drip water from each cave, iii) drip water from drip-logger sites in Manita peć Cave. As for the speleothems sampling, two actively growing stalagmites were collected from Manita peć Cave.
In spite of relatively simple monitoring and sampling protocol, we encountered several problems caused by natural forces, technical limitations of the equipment and by human interference. Weather conditions such as severe summer drought, autumn precipitation extreme by amount and intensity, and winter snow drifts caused different setbacks, fortunately with no significant damage. Furthermore, at one location very sensitive drip-logger has been threatened by extremely intensive calcification from the drip water, while at two other locations some periods were not recorded because of too big and too small distances between the feeding drip site and the logger. The most evident negative human impact was experienced while collecting the speleothem samples from Manita peć Cave. Namely, in the past when the cave was not protected by the gate almost all of the stalagmites were broken and dislocated. Lately, part of our equipment disappeared probably also because of the irresponsible individuals, in spite of the visible sign of ongoing scientific experiment.
In this initial phase of the project, along with collecting samples, a valuable experience was gained, and regardless of few disruptions forthcoming measurements and analyses are expected to be fruitful, offering novel and genuine data and insight into palaeoenvironmental settings of the North Dalmatia.
Keywords: speleothems, palaeoclimate, palaeoenvironmental changes, Croatia

Tectonic control of caves development in the upper part of the Mała Łąka Valley (Western Tatra Mts., Poland)

Jacek Szczygieł

Department of Fundamental Geology, Faculty of Earth Sciences, University of Silesia, Sosnowiec, Poland, j_szczygiel@tlen.pl

The Tatra Mts. are characterized by a geological structure typical to fold-and-thrust alpine belt with post-glacial geomorphology. The biggest caves in Tatra Mts. have been explored in the Czerwone Wierchy Massif, for the last 50 years: Wielka Śnieżna System (denivelation: 824 m, length: 23,723 m) and Śnieżna Studnia (denivelation: 763 m; length: 12,050 m). Both caves are located on western slope of the Mała Łąka Valley – eastern side of the Małołączniak. Four other caves deeper than 100 m are located there. Concurrently, on the oppositeslope of the valley – western side of the Kopa Kondracka, the biggest cave, LodowaMałołącka, has 50 m of depth and 300 m of length.
Structural research including geometrical structural analyses of measurements from caves of eastern slopes of the Małołączniak (Śnieżna Studnia, Wielka Śnieżna, Małołącka) and of western slopes of Kopa Kondracka (Pomarańczarnia Cave, Mnichowa Studnia Wyżnia, Lodowa Małołącka Cave, Koprowa Studnia, Świstacza Cave). Structural plans of the caves were drown too.

Caves in the E slopes of the Małołączniak were developed primarily on the steep bedding. At this planes a tectoglyphs were observed what indicates a flexular slip. Movment on bedding planes predisposing them for speleogenesis. Faults other than flexluar slip have a mostly local influence on the course of these caves.

Caves on the western slopes of Kopa Kondracka developed mailnly on the discontinuities. Studied caves in this region has the general course of W–E. These caves are developed mostly on fractures and faults. Strike directions of those discontinuaties are housed in a range NW–SW.

Differences in the development of caves on both sides of the Mała Łąka Valley are due to differences in the geological structure of two parts of the massif. The western part of the valley is composed of steep strata toward S, only locally deformed by second-rate faults and folds. As a result, the waterflow was held by bedding planes which are long, steep and without bigger obstacles, further facilitated by loosening due flexular slip.

In the eastern part of the valley a dip of bedding is 20 to 40^o. There are many steep and very steep fractures and faults, included faults of the long displacements. These features demonstrate a stronger tectonic deformation of the eastern slopes of the valley than the western. The stronger deformation was reflected in a number of discontinuities.

Absence of large caves in the area of western slopes of the Kopa Kondracka is the result of great numbers of tectonic deformations in this area, especially the discontinuities. For water penetrating the massif, a better migration conditions offer steep and very steep discontinuity planes than gently inclined bedding planes. Discontinuities are hindering the concentrated flow for a long distance, which prevented the development of long passages.

Keywords: tectonics, cave development, geology, Alpine karst, Tatra Mts.

Predjama Cave microclimate (2009 – 2012)

Stanka Šebela, Janez Turk

Karst Research Institute ZRC SAZU, Titov trg 2, 6230 Postojna, Slovenia, sebela@zrc-sazu.si

In the fourth longest karst cave in Slovenia (Predjama Cave, 13 km long) continuous monitoring of cave air temperature at two locations (Konjski Hlev and Velika Dvorana) is organized since August 2009. The study is part of climatic monitoring within the short-term programme (2009 –2013) on the use of natural asset. The aim of the 5-year-long research is to formulate natural protection precautions based on the results of cave climate and fauna monitoring. Predjama Cave as a show cave receives about 6000 visitors per year and their impact on cave microclimate have minor influence. Both monitoring sites inside the cave have much stronger influence on external climate conditions. In the period 2009 to 2012 a gentle rise of cave air temperature is observed what is in accordance with outside climate. Konjski Hlev monitoring site, which is situated near the cave entrance, shows very similar air temperature changes as outside conditions. At Velika Dvorana monitoring site winter influence is strong, but summer influence is not as strongly expressed as at Konjski Hlev. In fact summer air temperature at Velika Dvorana is equilibrated at 9°C, showing specific cave microclimate conditions. The study is important to perceive outside climatic changes in longer period (5-years) and their influence on cave climate.

Keywords: cave microclimate, air temperature, Predjama Cave, Slovenia

Geomorfological characteristics of pocket valleys in Slovenia and France

Jure Tičar

Caving club Brežice, Slovenija, jure.ticar@gmail.com

Pocket valleys are typical landforms of outflow part of contact karst. They are developed in the area of karst springs, where water emerges from carbonate rocks. In a process of headward erosion, springs are cutting into a karst surface and eventually valley like landforms are developed. Above the spring in the beginning of pocket valley, steep walls are developed, known also as cirques.

The lack of geomorphological studies on this field of karstology is one of the reasons for the shortage of widely accepted definition of pocket valleys. The results conducted with the study of literature and field work present the basis for further study on this topic. The geomorphological characteristics of pocket valleys are also revealing some general characteristics of the regional karst.

Based on the wide range literature review and field work, the thesis summarizes detailed morphographic, morphometric and speleological analyses of pocket valleys. The main objectives are (1) to describe the geological, hydrological and speleological characteristics of pocket valleys, (2) to define the morphogenesis of pocket valleys and (3) to define different types of pocket valleys according to their form and genesis.

Twenty-six typical examples of pocket valleys were identified and geomorphologicaly examined in detail. Field work in Slovenia included geomorphological analyses of the rims of Ljubljana Moor, Planina Polje, and Krka River Basin, whereas in France field work included areas of Vaucluse Mountains, Jura Mountains, plateau of Causse de Gramat, and the Alps of High Provence.

Detailed geomorphological examination and morphogenetic interpretation confirmed the influence of lithology, geological structure, characteristics of waterflow discharge, formation of cave systems in the rim of pocket valley and the level of regional surface landforms above which pocket valleys are situated on the development of pocket valleys. Pocket valleys are sometimes merged with other karstic landforms such as dolines and collapsed dolines. Existance of linear pocket valleys, which are developing in one cirque and existance of detritical pocket valleys, which are developing in multiple cirques and are highly branched was confirmed. Identified polygenetic development of pocket valleys led to the typification of pocket valleys on: erosional pocket valleys, phreatic pocket valleys, epiphreatic pocket valleys and glacial pocket valleys.

Keywords: geomorphology, karstology, contact karst, pocket valley, morphogenesis, Slovenia, France

Two giant phreatic shafts of Southern Ural

Elena Trofimova

Institute of Geography, Russian Academy of Sciences, Moscow, Russia, e.trofimova1@gmail.com

The region explored is situated on the Southern Ural (Bashkortostan, Russia), in 150 km to NE from the provincial capital Ufa. The territory researched belongs to the southern part of Ufimskoe plateau (380–460 m a.s.l.), dissected by the valleys of Ufa, Urusanie and Ay Rivers. Geologically the plateau consists of carbonate rocks (limestones, dolomites, more rarely, marlstones) dated from the Lower Permian, having a thickness till 200 m outcrop.

Two giant shafts, formed by the deep circulation zone ground water leakage, are wide known here. There are the largest vauclusian springs of Southern Ural. First one, Krasny Kluch, includes two pits with the deep to 38 m with the diameter in the central part to 22 m. Second one – Sarva, achieves the depth of 49 m, at 12 m in diameter in the central part of the shaft. The annual discharges of spring waters achieve 12.5 m^3/s for Krasny Kluch and 10.1 m^3/s for Sarva. The annual cavity's increase of giant vauclusian springs Krasny Kluch and Sarva is estimated accordingly to 25,475 m^3 and 14,086 m^3.

Keywords: phreatic shafts, Krasny Kluch, Sarva, Southern Ural

Appendix to analysis of stream in groundwater flow of karst springs

Emir Trožić, Edin Smajić

Mašinski fakultet, Univerzitet Sarajevo, Bosnia and Herzegovina, emirtrozic@yahoo.com

The position of the tectonic plates and the chemical composition of the rock mass resulted in various forms of underground openings through which water flows. Applying of empirical equations with known dimensions of openings, one can calculate the speed of flow. On the basis of historical data about the weather, the concentration and the intensity of fluorescence of the solution are determined by relating the daily fluctuations in flow rate, average daily value and the amount of color that appeared. Applying empirical formula known positions and dimensions of underground openings is determined changes in flow and velocity in different cross sections of underground flow. On the basis of diver speolog are known cross section, position and direction, at least 800 meters of the output of the underground stream, karst springs. Based on the discussion of the assumed changes in flow velocity in the concrete conditions and daily values and the amount of color that appeared in the spring will be determined the difference between the results obtained on the basis of the estimated and actual parameters.
Keywords: underground opening, the speed of flow, fluorescent solution, underground streams

Dependence of water supply, surface water table, the temporary surface storage and bandwidth ponors depression

Emir Trožić, Edin Smajić

Mašinski fakultet, Univerzitet Sarajevo, Bosnia and Herzegovina, emirtrozic@yahoo.com

After the water emerges from estavelles Oko, at a level that is below 400 m a.s.l. and plunges at a level that is below 370 meters above sea level filled with water, crooked trough from which the water is poured, creating, temporary, involuntary, surface accumulation. Straight-line distance is about 4,000 meters of water to the appearance of sinking, while the developed length Winding bed was about 1.5 times more. Throughput ponors depression was reduced because of the closing pieces of stone blocks and other materials located at the entrance to ponors depression. Because of the surface layer, which closed the entrance to the abyss depression, it is not possible to estimate the actual size, shape and direction inputs, or runoff. Estimated bandwidth, entrance ponors depression, can be determined, using empirical formula, calculating the area of water surface and volume temporarily stored water. The amount of continuous flow and the islands of the temporary accumulation are determined depending on the duration and the change in the quantity of water in the reservoir. Through discussion analyzes the results of changing parameters and flow of water in the reservoir with a constant parameter runoff accumulation in ponors depression. In conclusion, on the basis of the estimated value and the flow of water in the reservoir, determine the amount of runoff from the accumulation of ponors depression.
Keywords: estavelles, ponors depression, reservoirs, water feature

Inference from the formation of a small cave in Epikarst zone, Velika Pasica Cave, Central Slovenia

llen Wei Liu

National Institute of Biology, Ljubljana,Slovenia, allen.wei.liu@nib.si

The Velika Pasica cave is located 20 km south of Ljubljana, at an elevation of 662 m a.s.l. The geological condition of the cave area is thinly bed Norian-Retian dolomite from the Upper Triassic period, and the strata inclines to the north at 10-15^{o}. The cave features a 126 m long horizontal gallery in the south-north direction rich in decorations of flowstone, which were derived from a conglomerate and clay mixed layer lying across the middle of the cave. The entrance to the cave is at the bottom of a 10 m deep circular depression with a diameter of 15 m. From the surface, a large doline has occurred in the extend direction toward the entrance, while in the opposite direction, there is another cave known as “Mala Pasica Cave”. All the evidence indicates that the conglomerate and clay mixed layer was eroded easily, distributed along a line and it was the initiator of the cave formation, which also provides the paleo-sedimentary environment.

Keywords: epikarst, cave formation, conglomerate and clay mixed layer.