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SCHOOL OF KARST STUDIES PNG
and
KARST RESEARCH INSTITUTE ZRC SAZU



**12th INTERNATIONAL KARSTOLOGICAL SCHOOL
“CLASSICAL KARST”**

DATING OF CAVE SEDIMENTS

Andrej Mihevc & Nadja Zupan Hajna
Guide-booklet for the excursions and abstracts of presentations



Postojna, June 2004

Editorial Board

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Organiser

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Centre of Scientific Research of the
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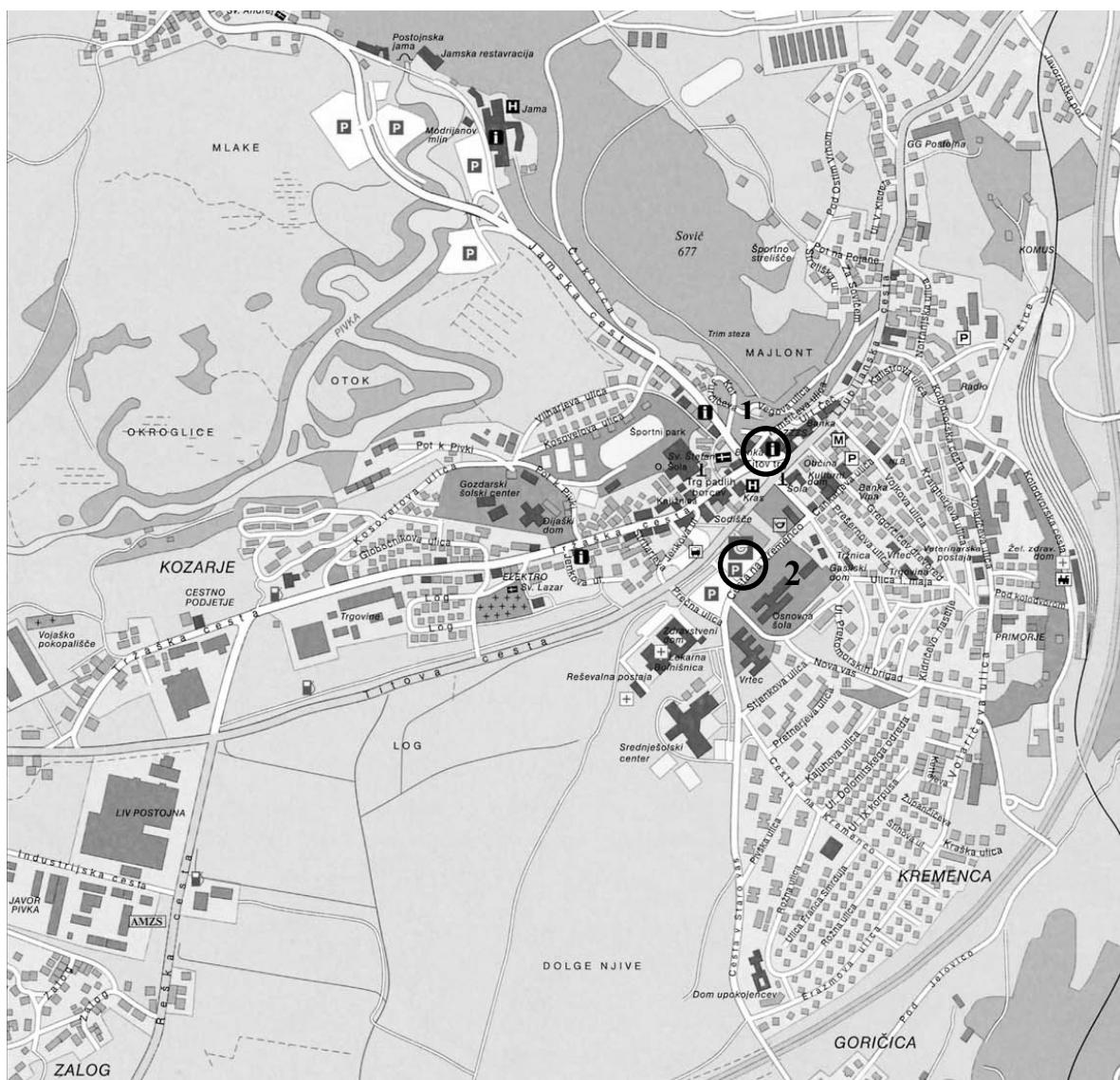
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MAP OF POSTOJNA



1 – Karst Research Institute ZRC SAZU, Titov trg 2

2 – Parking place for the bus excursions: In front of PTC Centre, Novi trg 6, Postojna

Additional information about Municipality of Postojna are on the
<http://www.postojna.si/>

NOTES AND HINTS FOR THE PARTICIPANTS

PRESENTATIONS

All presentations are at Karst Research Institute ZRC SAZU, Titov trg 2, Postojna.
Places for posters are marked by names of the authors.

EXCURSIONS

Don't forget to register your participation at registration desk!

- Seats on the buses are limited.

Departures for the excursions: PLEASE BE IN TIME !!!!!

- Meeting point for the bus excursions is at parking place in front of PTC Primorka (Business Centre Primorka), marked by No. 2 on the map of Postojna.
- Meeting point for the visit of Postojnska jama cave is at the tourist entrance to the cave at **15.45, train to the cave starts exactly at 16.00 !!!!**

Beverages and food

- Organizer will supply some beverages for the field-trips, take some additional if you need more.
- For the whole day excursions we organized lunches, which are paid by your own at restaurants (In Slovene Tolars!). If you not want to take organized lunch, take food by your own, because in the area of lunch stops there is no big shops.
- Please inform the organizers at registration desk weather you taking vegetarian or meat meal
- Prices for meal without drink:
- 23.6. (Matarsko podolje): Vegetarian or meat meal (pasta or gnocchii or “štruklji” with mushroom or venison goulash + apple strudel) = 1.000 SIT
- 24.6. (Classical karst): Vegetarian meal (“jota” + pancakes) = 1.100 SIT
Meat meal (“jota” + sausage + pancakes) = 1.200 SIT.
- Important, infected ticks (Lyme disease and Meningitis) are in the fieldtrip areas. USE REPELLANT! Do not forget to check yourself carefully for the presence of ticks after the excursions. Ticks are often found in tall grass also.



PROGRAMME

Monday, 21.6.2004

8.00-12.00	Registration of participants
8.30	Opening
8.35- 10.15	Lectures on Absolute dating methods: <i>P. Bosák: Cave sediments and their dating</i> <i>S.-E. Lauritzen: Uranium-series dating of cave deposits</i> <i>H. Hercman & G. Debaene: Uranium-series dating of dirty carbonates – is it possible?</i>
10.15– 10.30	Break
10.30 - 12.05	Lectures on Absolute dating methods: <i>N. Horvatinčić: ¹⁴C dating of carbonate deposits in the Dinaric Karst</i> <i>B. Blacwell: ESR Dating in Caves, Rock Shelters, and Karst Fissures</i> <i>P. Häuselmann & D.E. Granger: Dating caves with cosmogenic nuclides: methods, possibilities, and the Siebenhengste example</i> <i>R.A.L. Osborne: Dating Ancient Caves and Related Paleokarsts</i>
12.05 – 12.15	Discussion
12.15 –13.30	Break for lunch
13.30 – 20.00	Afternoon excursion: <i>Cave Divje Babe I.: Bus excursion with about 1 km walk to the cave, part of the walk is by steep secure path (in case of rain is slippery). No lights or special equipment required, just field shoes and an umbrella.</i>
20.30	Invited Reception by Karst Research Institute ZRC SAZU

Tuesday, 22.6.2004

8.30-10.30 Registration of participants

8.30-10.05 Lectures on relative and comparative dating methods:

P. Pruner: Principles of paleomagnetic and magnetostratigraphic methods applied to the cave sediment datings

I.D. Sasowsky: Paleomagnetic dating in caves of the Appelachien Orogen, North America

D. Genty: "Interest of speleothem carbon isotopes ^{13}C , ^{14}C for the study of present day carbon transfer and for the reconstruction of past environments in karst systems"

T. Nowicki & H. Hercman: Stable Isotopes (O , C) composition of speleothems is it paleoenvironmental records?

R.W. Harrison & M.P. Wright & D.J. Weary & R. Jacobson & M. Pavich & D.J. Wronkiewicz: Constraints on the geologic history of the Karst system in Southern Missouri, USA, provided by radiogenic, cosmogenic and phisical/chemical charasteristics of sinkhole fill

10.05 –10.20 Break

10.20- 11.45 Lectures on relative and comparative dating methods:

A. Mihevc: Dating of the cave sediments with a relative geomorphic dating method – case studies in Slovenia

I. Horáček: Biostratigraphic dating of cave sediments: scope of the approach, problems and shortcomings

J.P. Aguilar: & J. Michaux: The fossil-bearing fissure fillings (FFF) of Languedoc-Roussillon (France): A general overview

B. Sigé: Quercy cave Fillings and their blochronological succession since early Eocene to Quaternary times

O. Moldovan & E. Trinkaus & S. Milota & A. Bîlgăr & L. Sarcina & M. Gherase & S. Constantin: Old human bones associated with animal fossils in a Romanian cave

11.45 – 12.00 Discussion

12.00- 14.00 Break for lunch

14.00-15.15 Posters presentation (3 min/poster)

15.45-20.00 Afternoon excursion:

Postojnska jama cave: Tourist visit of the main parts with additional explanation on dating of cave sediments. No lights or special equipment required, just field shoes

Wednesday, 23.6.2004

8.30-20.0 Whole day excursion: *Dating of cave sediments*

Selected caves of Matarsko podolje: Visit to Račiška pečina cave, unroofed cave Ulica and Ulica pečina cave. Stop and lunch at Gradišče; afterwards visit of Jezerina blind valley and Pečina v Borštu cave. There will be about 4 km of walk before lunchtime and about 1 km in the afternoon. Lamp is needed for the caves, electric five LED lamp is recommended. No other equipment for caves is required, just field shoes and an umbrella in case of rain in the unroofed cave.

20.00 Invited Reception by Mayor of Postojna Municipality

Thursday, 24.6.2004

8.30-18.00/ Whole day excursion: *Significant spots of Classical karst*

From the springs of the Ljubljanica River to Škocjanske jame: The excursion visits Močilnik, one of the springs of the Ljubljanica River, visit to the ponors and springs at Planinsko polje, Rakov Škocjan and northern part of Cerkniško polje. After lunch visit to Škocjanske jame and large collapse doline of Risnik near Divača. Return to Postojna from 18.00 to 19.00. Bus travel and short walks, no more than 1 km at a time. No lights or special equipment required, just field shoes.

POSTERS

- H.F. González:** Historical review about datation cave in Cuba
- J. Kadlec & P. Pruner & M. Chadima & P. Schnabl & S. Šlechta & H. Hercman & D. Granger & M. Danisik:** Dating of cave deposits and reconstruction of karst morphology of the Nizke Tatry Mts. (Slovakia)
- N. Zupan Hajna:** Published data of cave sediment datings - a new knowledge about karst fills in Slovenia
- M. Surić & M. Juračić & N. Horvatinčić:** Comparison of 14C and U/Th TIMS dating of speleothems from submarine caves in the Adriatic Sea (Croatia)
- S.-E. Lauritzen & H. C. Linge & H. Hercman & J. Vit & J. & Glazek:** $^{230}\text{Th}/^{230}\text{U}$ dating of the Amaterska speleothem AM6, Moravski Kras, The Czech Republic
- P. Bosák & J. Móga & J. Kadlec & P. Pruner & M. Chadima:** The paleomagnetic study of the fine sediments of the Baradla cave (Hungary)
- P. Bosák & P. Pruner & A. Mihevc & N. Zupan Hajna & I. Horáček & J. Kadlec & O. Man & P. Schnabl:** Palaeomagnetic and palaeontological research in Račiška pečina Cave, SW Slovenia
- P. Pruner & P. Bosák & N. Zupan Hajna & A. Mihevc & O. Man & P. Schnabl:** Palaeomagnetic research of cave sediments in Križna jama, Planinska jama and Postojnska jama: preliminary results
- J.P. Aguilar & J.Y. Crochet & J.M. Mauch Lenardić & J. Michaux & A. Mihevc & B. Sige:** Fossil-bearing fissure fillings of Slovenia and Croatia
- L. Marjanac & K. Miculinić & S. Bergant & B. Lugović & D. Radić:** Sedimentology and stratigraphy of Vela Cave – Preliminary results (Island Korčula, Croatia)
- M. Vremir & Ridush & K. Alpar:** Late Pleistocene (Valdaian) vertebrate assemblages from the Emine-Bair-Khosar cave (Chatyrdag Plateau, Crimea)
- G. Szunyogh:** A Theoretical Approach to Establish the Duration of Denudation on Limestone Surface Without Soil Cover
- L. A. Dimuccio:** Development of parakarst features on lower liassic dolomites and calcareous-dolomites in the Lusitanian basin (Portugal)
- B. Zagoda:** Karstification along the thrust contact between dolomite and limestone at Idrijski log and Koševnik
- Benac:** Late quaternary sea-level change and cave formation in the Kvarner region (NE Adriatic sea)
- N. Bocić & Ž. Baćurin:** Morphological development of Ponor Jovac cave and surrounding relief (Croatia)
- L. Plan:** Analysis of Cave Distribution on the Hochschwab Massif (Styria, Austria)
- J. Hočevar & F. Šušteršič:** Relation between gravel size and sifon lenght in Postojnska jama
- A. Čop & D. Paar & D. Baskić & J. Bedek & J. Petričević & S. Boban:** Explorations in the region of Kita Gavarana, Velebit Mt., Croatia
- B. Vrbek & N. Buzjak:** Contribution to the knowledge about the content of heavy metals (Pb, Cu, Zn and Cd) in the cave sediments in the Risnjak national park, Croatia
- U. Stepišník & M. Geršl:** Longterm Monitoring of CO₂ in the Zbrasov Aragonite Cave (Czech Republic)
- R. Kaszala:** Further date of heavy metal content on the soil and the greenery of Aggtelek Karst
- J. Bruthans & R. Kadlecova & F. Buzek & J. Melková & O. Zeman & J. Himmel:** Transit time in different karst areas in the Czech Republic: tracer tests and isotopic methods
- H. Kazemi:** Application of videometry in recognition of Karst Features

EXCURSIONS

PALAEOLITHIC SITE DIVJE BABE I.

Monday, 21. 6. 2004

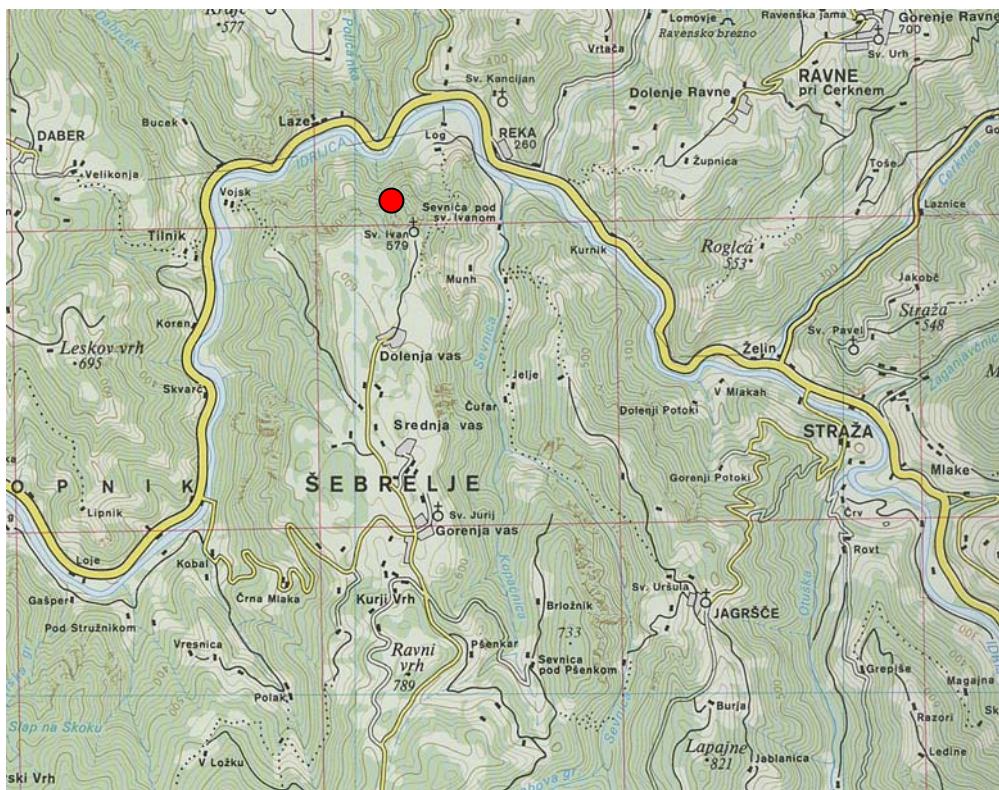


Fig. 1/1: Location of the cave Divje Babe I

Planinsko polje

It presents the most important water confluence in the river basin of Ljubljanica. Dolomite barrier along the Idrija fault zone, which crosses the polje, forces the karst waters to overflow from higher karstified limestone background to the surface and after crossing Planinsko polje toward NE where they can sink at elevation of about 450 m.

Idrija

The town of Idrija (population 7,000) developed in a basin on the edge of the Idrija Fault, which separates Slovenia's subalpine region from the Dinaric Karst. It is well known because of mercury mine and lace-making trade.

In 1490 a rich deposit of mercury ore was discovered. Mercury in Idrija comes in two forms: as cinnabar (mercury sulphide, HgS) rock inclusions, and as pure mercury. By burning cinnabar ore, the mercury miners of Idrija mined over 13% of the world production of this ore. They filled as many as 3,132,000 steel containers to be sold world-wide. Now, Idrija's famous mercury mine, which was the second largest mercury mine in the world, has closed

after 500 years. In spite of this, the people of Idrija are committed to preserving the miners' tradition and cultural heritage. In the 16th century, Paracelsus visited Idrija and introduced mercury in medicine. Joannes Antonius Scopoli served as medical doctor in Idrija from 1745 to 1769. (1761 is the year of the first lace and of the work by Scopoli: *De Hydrargyro Idriensi*.) Balthasar Hacquet, who also wrote the *Oryctographia Carniolica*, lived in Idrija from 1766 to 1773; at that time, Idrija was the second largest town in Carniola. For visitors the oldest part of the mine - Anthony's Shaft, which dates from the year 1500, and the underground chapel from the 18th century are opened. More about Idrija: <http://www.rzs-idrija.si>.

Divje babe I., introduction to a Palaeolithic site

Prepared by Ivan Turk

AI ZRC SAZU

It is a 45 m long, up to 15 m wide horizontal cave, 230 m above the Idrijca River at about 470m a.s.l.. The cave was formed in Triassic dolomite, under the edge of Šebreljska planota (low mountain plateau). Together with plateaus of Šentviška gora, Police and Ravne represents the remains of a larger plateau, which was dissected by tectonic processes and the valleys of Idrijca and its tributaries.

Divje Babe I are a Palaeolithic cave site with the greatest stratigraphic potential in Slovenia. Judged thickness of Pleistocene sediments is 50 m, out of which about 12 m were excavated reaching from the last Interglacial (OIS 5e) to the final part OIS 3, or approximately from 120 ka to 35 ka. Unfortunately there are numerous sedimentation and temporal gaps. Analysed and interpreted in detail are only upper 5 m of the sediments in the central part of the cave. The sediments in the entrance part of the cave were excavated in such a way that they do not allow an integral analysis and explanation.

The site belongs to the best chronometrically defined sites in Slovenia (80 dating of U/Th, ESR and ¹⁴C AMS).

Sediments were researched by geochemical methods and original procedures based on physico-chemical changes of the cave roof and sediments on the floor. In the floor sediments autogeneous aggregates, autochthonous dolomite congelifracts and etched mass of bone remains were studied on one hand and remains of corrosion ceiling and wall etchings (furrows) on the other hand. We took into account average size of all the clasts thus we successfully replaced the classical granulometry done in thin fractions of the sediment. By all the chosen parameters we reconstructed paleotemperature and paleohumidity in the cave environment on the base of certain presumptions at the same time. On the base of ceiling remains and wall etchings we also ascertained greater sedimentation gaps in such a way that we compared the sedimentological data with radiometric ones. The advantage of a sedimentological method compared to other methods is in allowing a continuous following of a single parameter; physico-chemical processes in the floor are continuous and the floor in the cave is constantly renovated depending on the velocity of sedimentation.

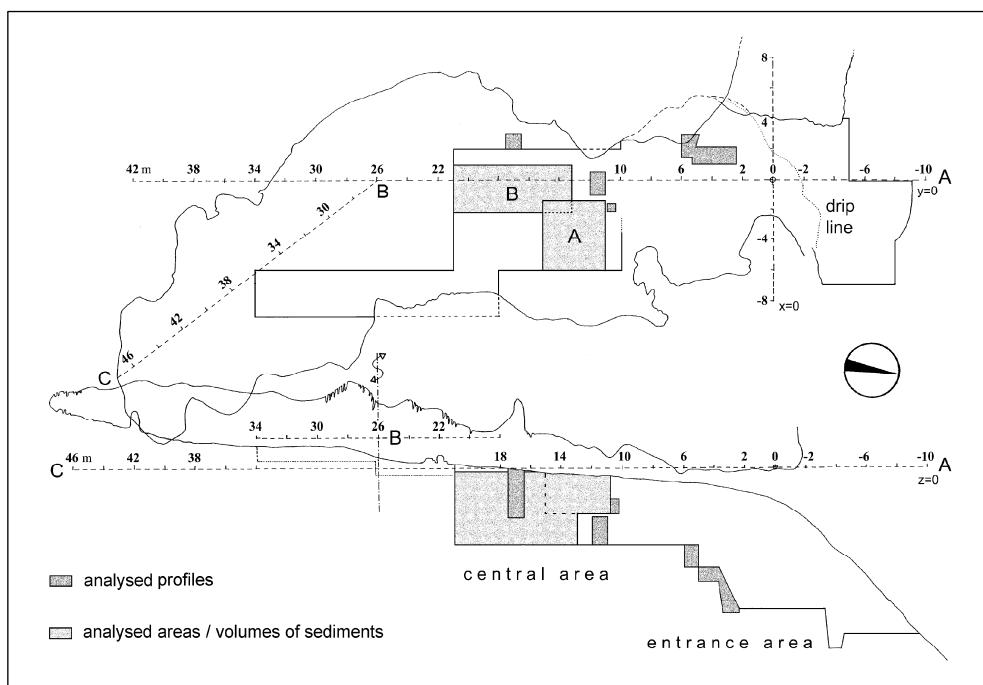
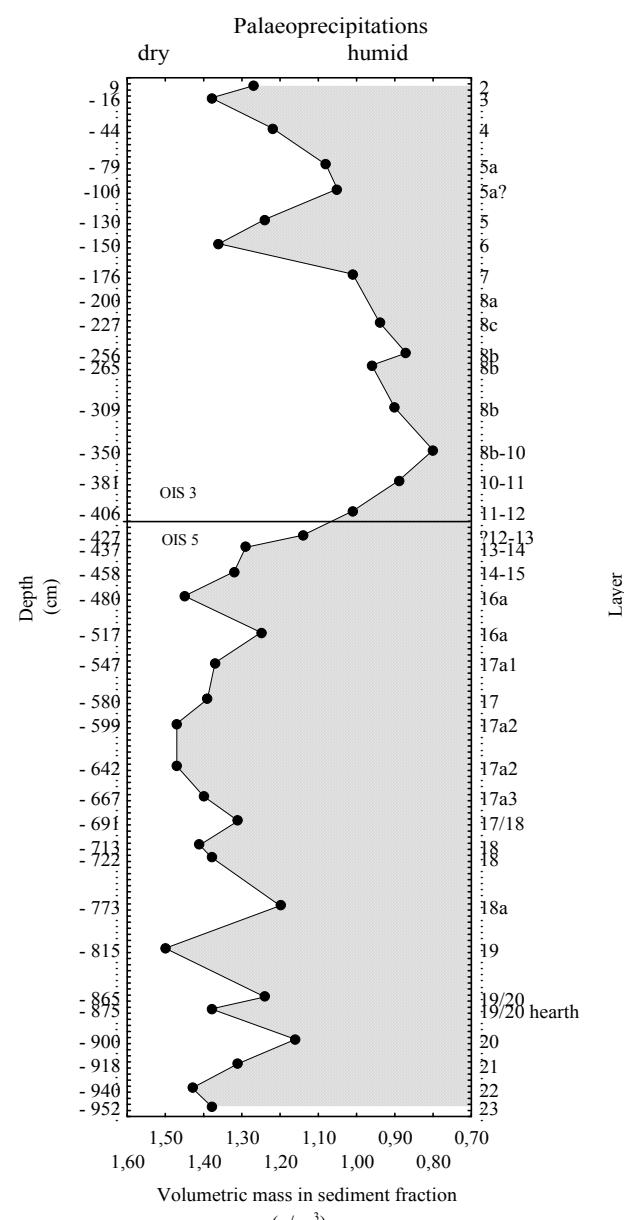


Fig. 1/2: Ground plan and profile of the cave Divje Babe. Excavated area (lines) and main sampled profiles and areas are marked (hatched).

Fig. 1/3: Distribution of the aggregates in the profile of the sediments in Divje Babe I which show the role of the humidity and precipitations during the sedimentation.

Divje Babe I is a rich **paleontological site**. Only in Divje Babe I we successfully distinguished pollen in the sediments and interpreted uncontinuous pollen profile. Chronostratigraphically is more important charcoal from numerous hearths. In 38 sedimentation levels we defined more than 3000 pieces of charcoal belonging to 11 tree and bush species. Among them is also wood of yew and juniper tree used by people for special purposes. The site boasts with relatively rich avifauna (18 species), micro fauna (22 species) and macro fauna (24 species). At least 10 animal species are extinct, among them some rare (leopard, wolverine, polar fox, birch mouse (*Sicista subtilis betulina*)). Stratified collection of cave



bear remains is the largest in Slovenia. Due to extreme fragmentation we could probably make in future stratigraphic-space connections among sediments by help of corresponding fragments. Stratigraphically-space distinction of each fragment is at least 1 m in horizontal line and 12 cm in vertical one. A speciality of the site are fossilized hairs and prints of cave bear fur, preserved in a great number.

In spite of all data and methods there still remain a lot on unknown and unclear facts in the chronology of the site compared to other Palaeolithic sites in Slovenia where chronology is, at least apparently, more or less explained and final. The only thing more or less exactly defined in the chronology of Divje Babe I is border between OIS 5 and OIS 4. There are practically no sediments of findings that could be attributed to OIS 4, as well as there is no belonging to OIS 2. Thus all the studied sediments belong to particular parts of OIS 5 (interglacial and upper glacial), to OIS 3 (middle glacial) and OIS 1 (postglacial or Holocene). Which are these parts remain unsolved. During OIS 5 the cave microclimate was stable, al the time moderately warm and dry with slight cooling. During OIS 3 the climate was unstable, in average cooler and more humid, alternating with very cool and moderately warm periods. The humidity was not the same all the time; the highest was in the beginning and in the middle, and the lowest at the end.

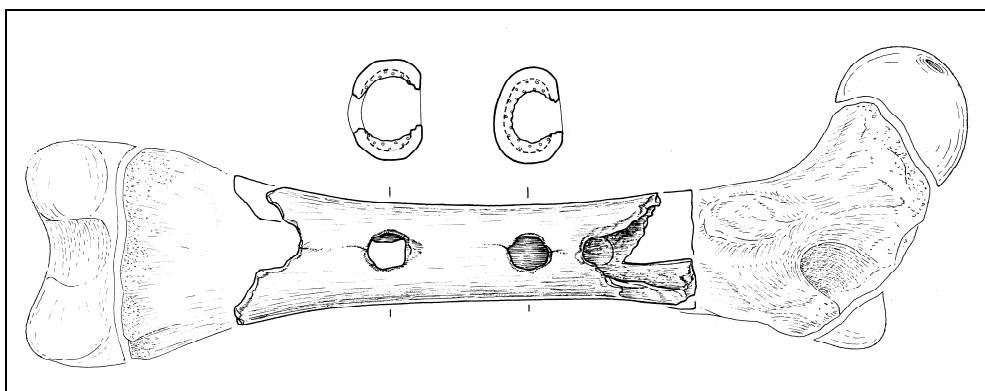


Fig. 1/4: The drawing of the flute. Flute is made of femur of cave bear cub and is probably the oldest flute known in the world.

Palaeolithic findings are controversial, not only due to supposing the oldest flute of Neanderthal origin but also due to some very old fragments of supposing bone nibs and general habitat of stone objects which should not be of Mousterian or Middle Palaeolithic. In short, Palaeolithic findings should be younger than proved by chronostratigraphical studies. This is hard to imagine as in the youngest layer we found Orignac bone nibs and also one, supposing made of horns and with cleft base and below it, up to 9 m in depth there were 14 levels with more or less poor Palaeolithic findings and with signs of very agitated climatic events.

An important property of Divje Babe I Palaeolithic are numerous hearths with very diversified wood charcoal and with some interesting fossil remains (fish scales and skin plates of lizards, fossilized wood) but there are only few remains of the usual hunting. Altogether there were 20 better or lesser preserved hearths discovered containing some hundreds of bone fragments of hunted animals.

The number of stone artefacts found around the hearths is low, altogether about 600. Almost all the artefacts are severely worn out and fragmented, presumably due to intensive use. The fragments could not be put together. A unique finding is an artefact, crumbled in the sediment and immediately after that cemented.

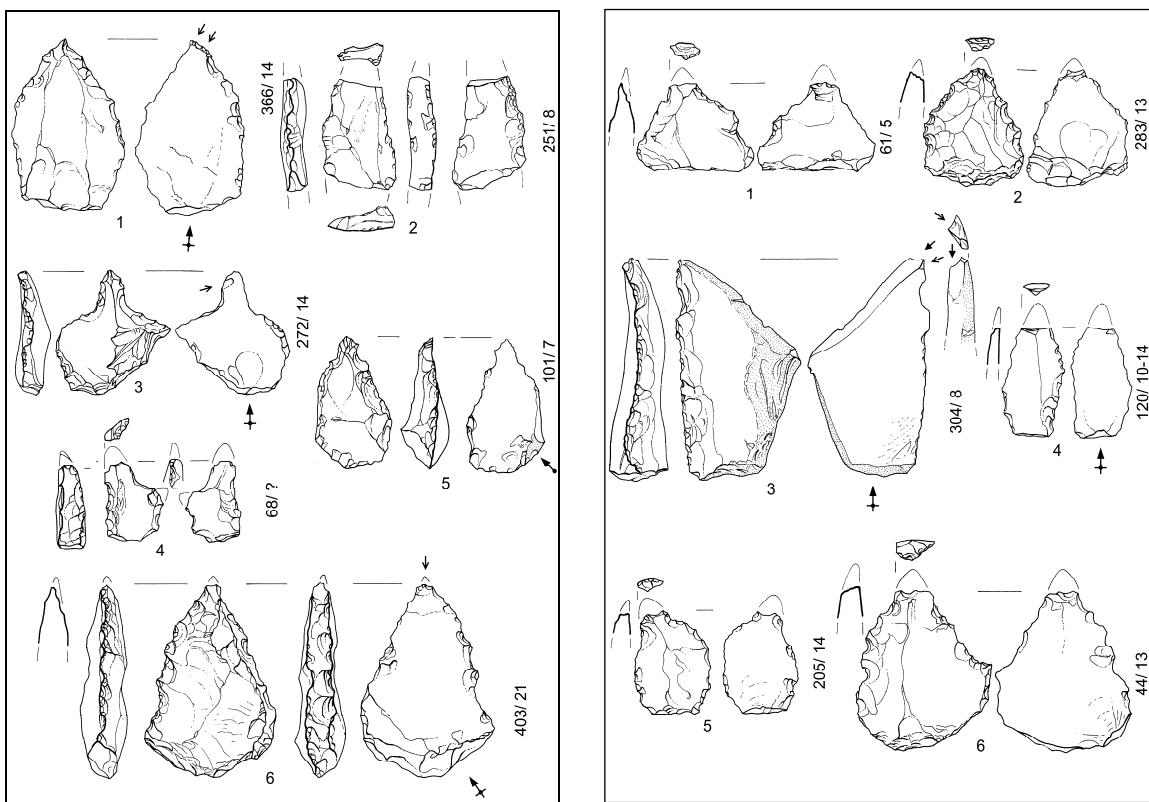


Fig. 1/5: The drawing of the typical stone tools found in the cave Divje Babe I. Points that are frequently broken off served as boring harder materials.

In Divje Babe I the excavations ended in 1999. Till now many articles and one book were published, a new book is in preparation.

References

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POSTOJNSKA JAMA

Tuesday, 22. 6. 2004

Introduction

The cave system is with 20 km of passages the longest in Slovenia. The cave has several natural entrances, each of them leading to the part of the system which was connected by cavers and divers in late 20th century. The caves are: Otoška jama, Postojnska jama, Magdalena jama, Črna jama and Pivka jama. Ground plan is on the Fig. 2/1.

Postojna cave is one of the oldest and largest tourist caves of the world. Important tourist development of the cave started in 1818, although cave was known for visitors in 13. century already. Between the years 1818 and 2000 27.000.000 people visited it, in 1990 only by 989.084 visitors. Later number decreased dramatically because of the wars in vicinity. The Postojna cave lies between the sink of Pivka River and entrances Pivka and Črna jama caves. The Pivka basin flysch surface in foreground is in a great contrast to surfaces of the lower plateau of Postojnski kras and high karst plateaus of Hrušica and Javorniki. The elevation of surface at the sinks of Pivka is 515 m, the elevation of Planina polje about 450 m a.s.l.

Cave lies on the northern side of the Pivka Basin in where Pivka River flows into it at 511 m above sea level. It is 20.570 m long. Above the river sinking in a sump there is one of the historical entrances, the others are scattered on the flat surface above the cave itself. From the last sump in Postojnska jama there is still more than 1500 m of unexplored underground course of the underground Pivka to the Planina cave where river re-emerges.

Geology

Postojnska jama was formed in the Upper Cretaceous limestone; all galleries are developed in the Postojna anticline in NW-SE direction; most of the channels are in the steeper south-western wing (Gospodarič 1976). The entrance to the Postojnska jama is formed near the contact between the Eocene flysch and Upper Cretaceous limestone (Buser et al. 1967). Most of the galleries are in the steeper south-western wing of Postojna anticline. The difference of altitude between higher and lower levels is about 18.5 m. Several large collapses above the old galleries formed large collapse dolines like Vodni dol, Jeršanave doline and Stara apnenica. The ceiling above the cave is up to 120 m. Intensive growth of sinter is due to high annual precipitation, about 1700 mm, and high mineralisation of percolating water.

More about geology in: Gospodarič (1962, 1965, 1976), Čar & Šebela (1998) and Šebela (1998a, b).

Cave sediments

In Postojna cave system Gospodarič (1976) describes here presents succession of cave sediments, from the oldest to the youngest: 1. coloured chert gravel, 2. rubble and white chert gravel, 3. sinter and red loam, 4. younger laminated loam and flysch sand, 5. sinter, 6. breakdown rocks and flood loam and sand, 7. sinter; with the contrast to Planinska jama, where after coloured chert gravel, old laminated loam was sedimented. It has to be stressed that after Gospodarič (1976) in Postojna cave system this old laminated loam is missing. That is very important to take into account when you dating cave sediments from Postojna cave. And the important think is also that the sedimentation in cave at the same time, but at different hydraulic conditions, may live different sediments in passages or even erode in one part and accumulate in other.

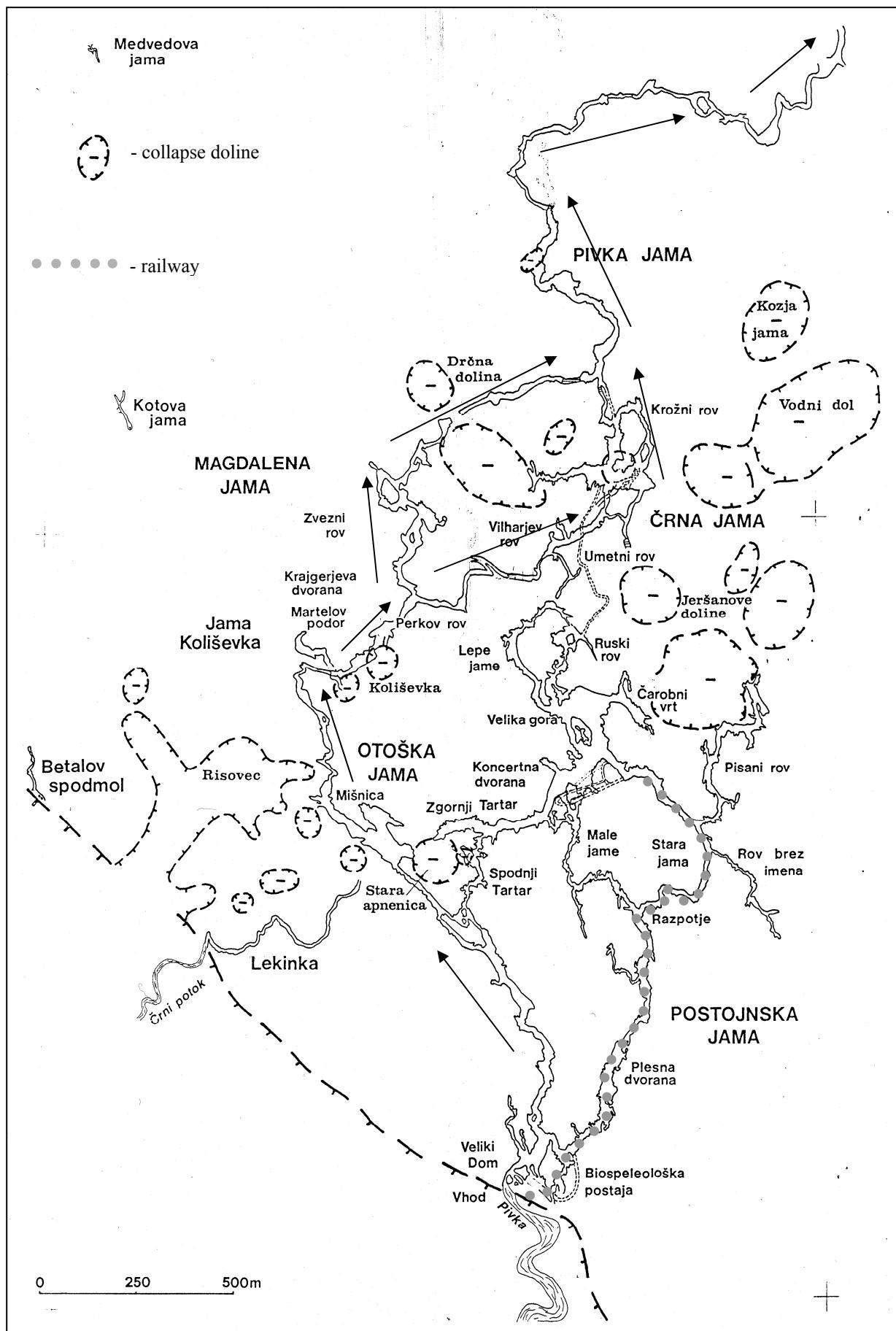


Fig.2/1: Ground plan of Postojnska jama cave system.

The mineral composition of studied cave fluvial sands and loam from Postojnska jama indicate that their origin lies in flysch rocks of Pivka basin (Zupan Hajna 1998). For example a sample of yellow loam from filled up passage in Umetni rov consists of: 86% of quartz, 5% of calcite, 4% of illite, 1% of plagioclase, chlorite, kaolinite, plagioclase and goethite. Mineral composition was defined by x-ray diffractometry; the quantity of present minerals is relative, calculated according to intensity of the main peak of each mineral.

Dating of fluvial sediments

Šebela & Sasowsky (1999) did the first paleomagnetic research of fluvial sediments from Postojnska jama. Paleomagnetic research of 4 samples from natural passage in Umetni (Artificial) tunnel between Postojnska jama and Črna jama showed reversed polarity and were at least 0,73-0,90 Ma old (Šebela & Sasowsky 1999). After the sedimentation of analysed fluvial sediments, passage filled by sediments was cut by younger fault in cross Dinaric direction (Gospodarič 1962, Sasowsky et al. 2003). Šebela and Sasowsky (1999) presumed that analysed reddish-brown sandy loams are older than coloured chert gravel. By the same authors were also analysed yellowish-brown fluvial sediments (authors presumed old laminated loam) from Male jame and Otoška jama and they were all normal polarity (younger than 0,73 Ma).

In 2003 Pruner et al. (2004) took samples for palaeomagnetic research from Umetni tunnel (same profile as Šebela and Sasowsky 1999), Spodnji Tartarus and Biospeleological Station. In Umetni tunnel almost whole 130 cm thick sequence of fine- to medium-grained sands, with clayey matrix and flat clasts of clays and distinct cross bedding overlain by clays and sands was sampled. At 21 cm from the top, plane of unconformity is clearly marked by surface enriched in Fe- and Mn-rich compounds. Results of analyses showed short normal polarised magnetozone at the top of clay below the stained surface, which can be preliminarily correlated with Jaramillo subchron (cca 0.99-1.07 Ma in reverse Matuyama chron). In Spodnji Tartarus 285 cm high profile composed of clays, reddish brown at base and ochreous in upper parts interlaminated by sands and silts, with local sandy intercalation in the lower part was sampled. At top entrenched cut is filled with brownish red clays. In whole profile two samples showed reverse polarisation within normal polarised background. Prevailing normal polarisation indicates preliminary interpretation within the Brunhes chron (< 780 ka).

Dating of speleothems

From Postojna cave different samples were analysed by ^{14}C , U/Th and ESR method by Gospodarič (1972, 1977), Franke & Geyh (1971), Ikeya et al. (1983), Zupan (1991) and Mihevc (2002).

The age of samples dated by ^{14}C method range from 7.5 Ka to 39.5 Ka (Franke & Geyh 1971, Gospodarič 1972, 1977). By ESR method the ages of samples are from 125 Ka to 530 Ka (Ikeya et al. 1983). Samples analysed by U/Th method were dated from about 12 Ka to more than 350 Ka (Zupan 1991, Mihevc 2002).

The oldest dated flowstone from Postojnska jama is the red nucleus of the stalactite from Pisani rov, being about 530.000 years old (ESR method). Red flowstone in the stalactite was precipitated during one of Mindel Interglacial and it was after also eroded. The next two rings of stalactite, between them is a layer of flood loam, were dated to Mindel-Riss Interglacial, with age about 270 Ka, and to Riss-Würm Interglacial, age about 75 Ka (Zupan 1991). The same type of stalactite next to it, have given the very similar data using ESR and U/Th dating method (Ikeya et al. 1983). From Podorna dvorana in Pisani rov another two samples were analysed by U/Th method (Zupan, 1991). According to resemblance of stalactite with red nucleus from the same channel, described above, infer that the stalactite

under the collapse block is younger than 75 Ka. The base of stalagmite, which continues to grow on the collapsed rocky block was established to about 20 Ka.

The age of samples dated by ^{14}C method in Postojnska jama range from 7.5 Ka to 39.5 Ka. Perhaps because just stratigraphically younger samples have been analysed by this method or there was already limit of the method under the question. It has to be emphasised that the results, obtained by ^{14}C are not reliable for the speleothems older than 37 Ka and a lot of time appeared that they are older by use of U/Th method at the same samples (Zupan 1991).

U/Th datation of the collapse processes on Velika gora

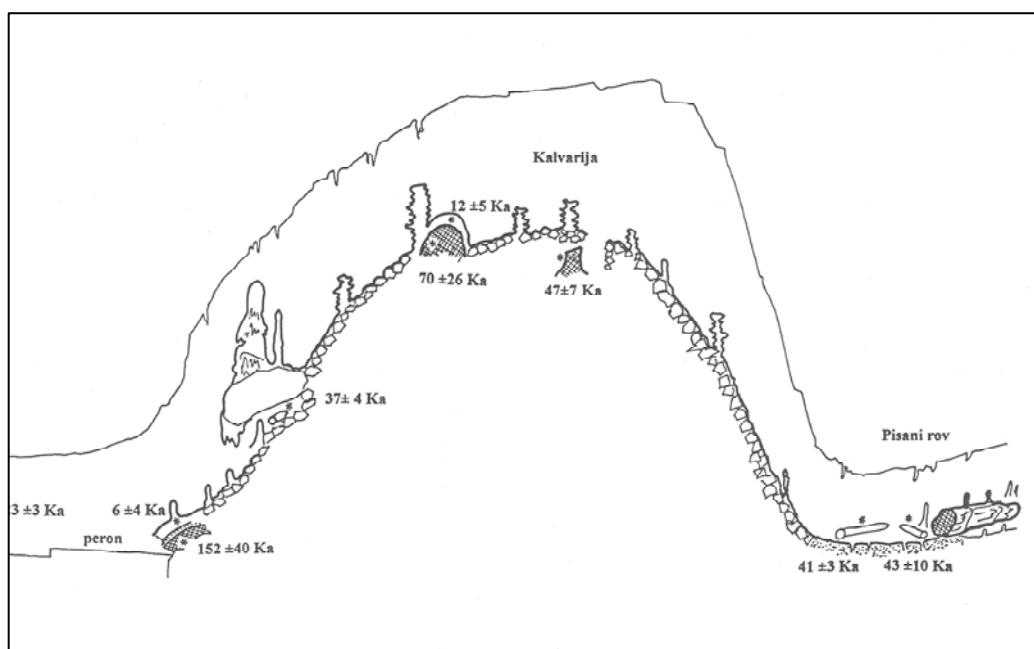


Fig.2/2: Schematic cross section through Kalvarija (Velika gora) collapse. Positions of samples and the age of the flowstone are marked on the sketch.

Kalvarija or Velika gora is the largest collapse chamber in Postojna cave. Collapsing is possible because of the favourable tectonisation of the limestone, but the sediments, rubble of different size and flowstone shows, that there were probably several phases of collapses and that at present the collapsing is in low intensity.

Samples of flowstone were taken and analysed in U series dating lab at dr. Stein-Erik Lauritzen, Department of Geology, University of Bergen by alfa counting.

Three periods of flowstone growth were recorded (Fig.2/2). The oldest flowstone was dated at the foot of collapse at the railway station. Flowstone was deposited above collapse boulders and some layers of flowstone that was polluted with sand and clay. The age is 152 ± 40 Ka. Possible of the same period is flowstone dome at the top of Kalvarija with age of 70 ± 26 Ka. From these two samples is difficult to reconstruct the environment in the cave.

Important growth of flowstone was recorded with five samples. Stalagmites were growing on the clay floor in Pisani rov (41 ± 3 Ka, 43 ± 10 Ka), on the collapsed boulders (37 ± 7 Ka) and on rubble (47 ± 7 Ka). They fall over due washing off the clays, were covered with big boulders or broken and covered with scree.

The youngest phase of flowstone deposition is recorded in samples of gray crystalline flowstone (12 +- 5 Ka and 6 +- 4 Ka), which forms a crust and stalagmites. This crust covers all collapse blocs, showing low intensity of collapsing in present conditions.

The sediments in Velika gora and dating of flowstone, even if the errors are large show some clear phases of collapsing in alternation with flowstone deposition. Apparently the collapsing is connected with colder climate, flowstone deposition with warmer.

Observations in the entrance parts of the cave show, that the freezing in Pleistocene was influencing only inner parts of the cave, where characteristic types of sediments and cryoturbation of them occurred. Collapsing in Kalvarija it therefore probably related to changed chemistry of percolating water. In cold periods water was not saturated, it was corroding only, making the fractured ceiling unstable. In warmer periods (Holocene and Wurm I/II, isotopic stage 3) there was deposition of the flowstone not only on the floor but also in fissures in ceiling, cementing them, and lowering the intensity of the collapsing.

Biospeleological station

Rov novih podpisov (Passage of New Signatures) is one of the old entrance passages formed by sinking stream Pivka. The passage is today out of hydrological function about 15 m above the level of the present river level. During the arrangement of the gallery two profiles of gravel-filled passage were exposed. One is in the tunnel for the railway; the other is exposed to visitors at the entrance to inner part of the passage.

There are two types of sediment in the passage. Grey, prevailingly flysch loam, sands and gravel, which are now buried under younger sediments. More recent sediments - reddish loam at the entrances, mixed up with debris, and in the interior heavily coated with sinter, which grow, according to datations, during warmer periods of quaternary.

Description of profile

Bottom of the profile forms sediment of flysch gravel and clay mixed with non-rounded limestone fragments. This is the remains of the oldest sediment deposited in the cave by the Pivka underground stream. Upper part of the sediment was eroded away.

On it was deposited after an important erosion phase about 2 m thick strata of rubble and breccias. It was formed through freezing and disintegration of the ceiling and walls in the entrance section of the cave. Pieces of flowstone outnumber pieces of limestone among the rubble. In places, the rubble is cemented into solid breccias. This stratum was probably formed at the beginning of the Würm glaciation.

Flowstone of porous sinter and dark coatings that follows shows warmer humid period. Towards the side of the passage the layers are much thinner and intercalated with clays.

Limestone rubble mixed with clay. Rocks of the layer show subcutaneous corrosion features. The origin of the rubble is the slope above the cave. The lower part of the stratum contains the bones of a cave bear. In similar strata in the other profile through the passage, sediments archaeologists have unearthed stone tools from the early Stone Age (Moustérien), so the stratum formed between 40,000 to 20,000 years before present and after in the last cold phase of the Würm glaciation.

Clayey layer. A stratum of clay up to 50 centimetres thick is washed into the cave from the surface.

The stalagmites and the flowstone, which covers the floor, is Holocene age. Most likely this stratum developed when the entrance to the cave was blocked and the passage was no longer exposed to intrusions of cold winter air and freezing.

The upper part of the profile showed only normal polarised magnetisation, which is in accordance to expected age of deposits (Pruner et al. 2004).

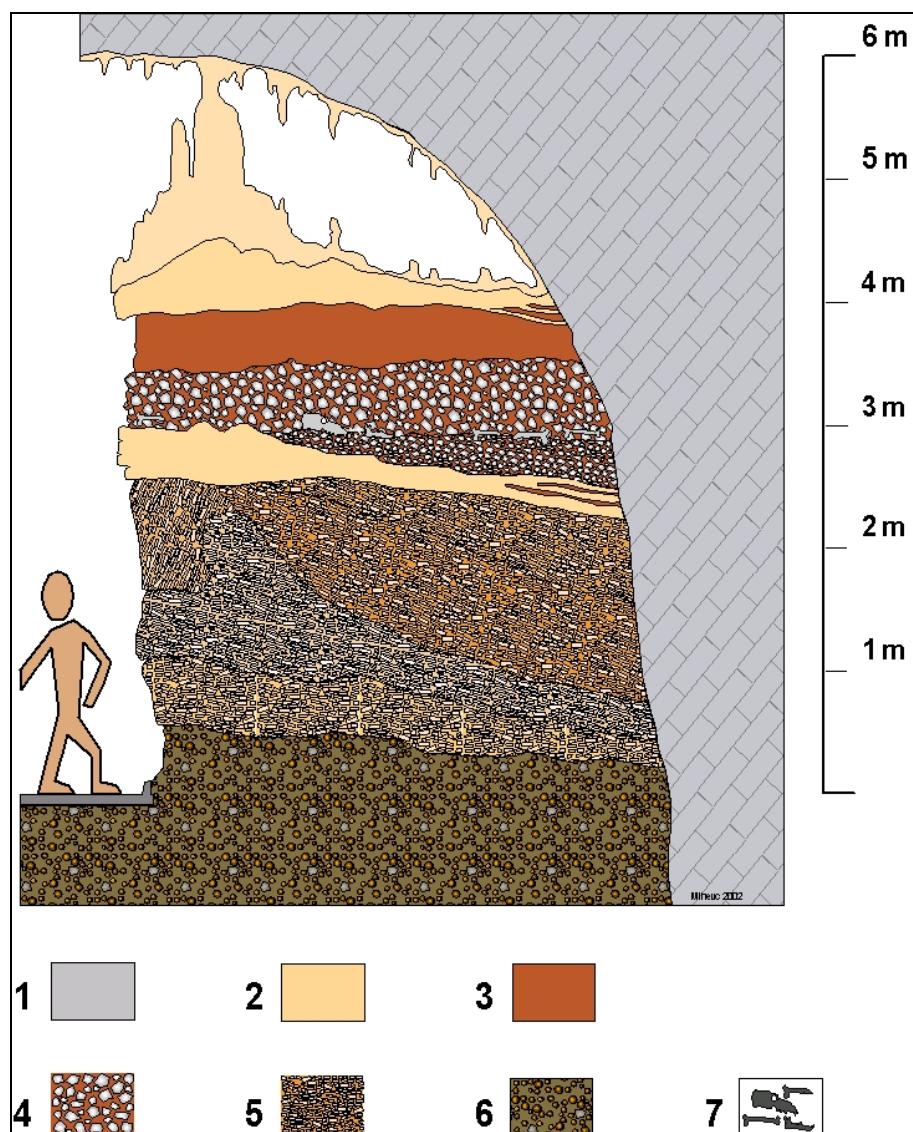


Fig.2/3: Schematic cross section of the sediment profile at the entrance part of the Rov novih podpisov passage. Legend: 1. limestone, 2. flowstone, 3. cave loam and clay, 4. limestone rubble mixed with clay, 5. rubble and breccias, mostly of broken flowstone, 6. flysch gravel and clay, 7. bones of a cave bear.

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Dating of cave sediments in caves of Matarsko podolje Wednesday, June 23, 6. 2004

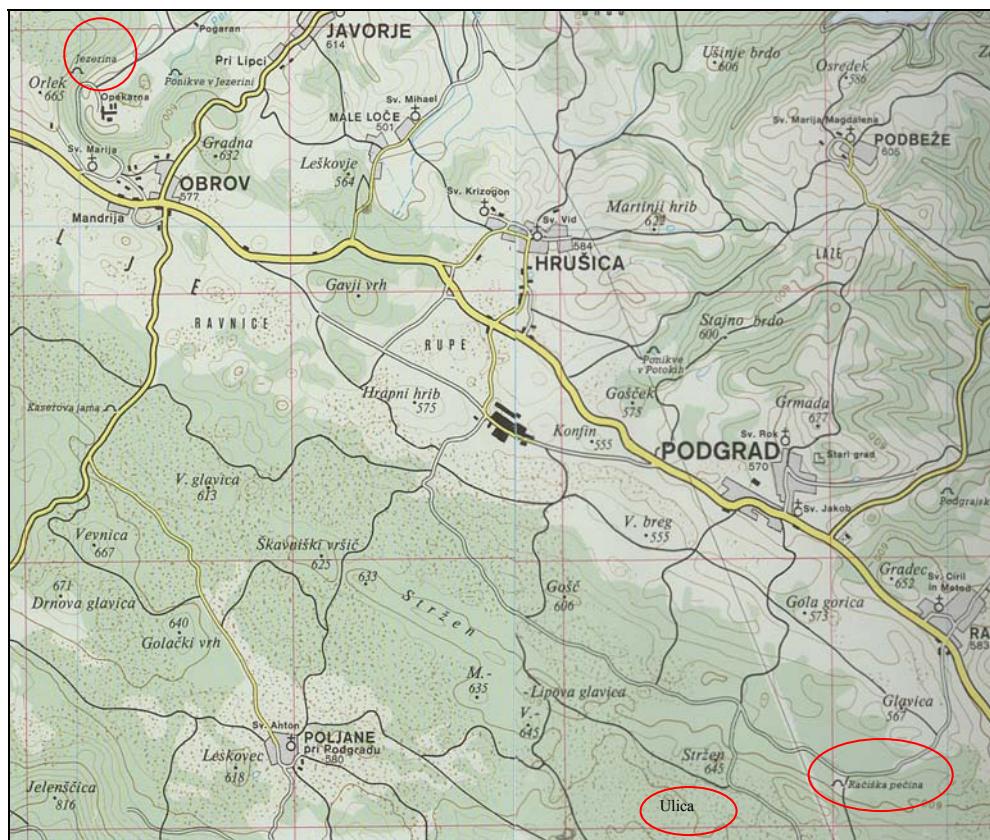


Fig.3/2: Location of caves of Račiška pećina, Ulica Pećina and Pećina v Borštu.

Matarsko podolje

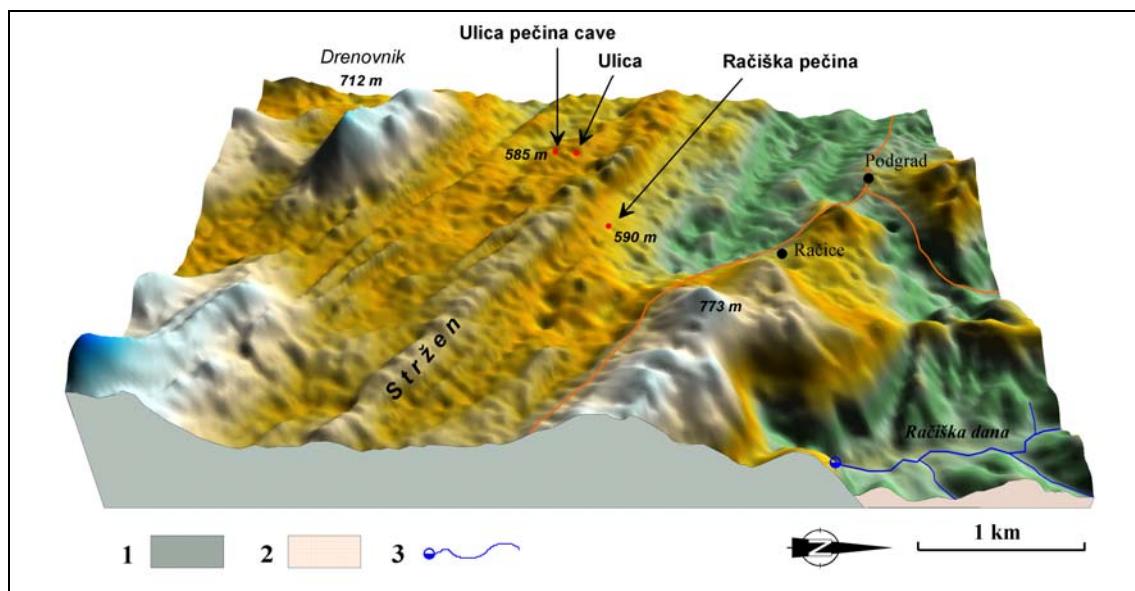


Fig.3/2: DEM of the upper part of the Matarsko podolje. The entrance to Račiška pećina and Ulica pećina are marked.

The Matarsko podolje is 20 km long and 2-5 km wide levelled karst surface south of Brkini hills. Surface probably developed as a base-levelled plain, later it was dissected by the dolines. It gently rises from about 490 m on NW to 650 m on SE side. The lowered surface continues towards SE but from the highest point near the blind valley Račiška dana blind valley it lowers on the distance of 2 km for 200 m towards SE to surface of Brgudsko podolje. This bend is most likely result of neotectonic movements.

Along the contact of a series of 17 brooks sinks. Most of the brooks developed blind valleys bottom widened by corrosion bottom. The bottoms of these valleys are situated between 490 to 510 m. As the valleys are incised in the border of the karst, uplifted towards SE, the blind valleys lying more to the south are deeper. The first, Brezovica blind valley is cut for 50 m only while the deepest is the last Račiška and Brdanska blind valleys. They are deepened into border limestone for 250 m and its bottom lies 120 m below the surface of the Matarsko podolje.

Possible sequence of the morphological events and dominant factors which were decisive for the formation of the actual relief forms were as follows:

1. The former shape along the contact with impermeable hills was levelled karst corrosion plain. The water flowing on it had modest gradient in karst and was capable of the planation of the surface only.
2. Tectonic uplift and lowering of the piezometric level enabled formation of deeper drainage and deepening of the blind valleys at the edge of Matarsko podolje. Alocthonous rivers no longer affected surface.
3. Surface has been lowered since for several hundred meters and is now cutting through many old caves. This has created unroofed caves or new entrances to caves. In some such features old sediments are preserved.

RAČIŠKA PEĆINA*

Račiška pećina Cave is situated in the SE part of the Matarsko podolje, SW Slovenia, near the Croatian border with entrance at 598 m a.s.l. Cave is developed in Lower Cretaceous thick-bedded limestone, breccias and dolomitised limestone. The cave represents relic of old cave system, which was opened by denudation to the recent surface. On the S side, the cave terminates with the collapse choke and sediment fill. The development of the cave is most likely connected to the sink of allochthonous streams from non-karst Eocene flysch area that occurs only 2.5 km to the N of the cave. Recent streams today sink at elevation of only about 500 m, i.e. 90 m lower than the cave altitude.

In the first half of 20th Century the cave was used as a military magazine by Italian and later by Yugoslav army. The floor was levelled and some large cuts were made through old massive flowstones.

Stable conditions of the cave passage, the cuts through sediments and in some political and military changes in the past made cave very good for the datation of the cave sediments and events connected with evolution of the cave and the whole area.

*Paleomagnetic and palaeontological research in the cave was done by: P. Bosák, P. Pruner, A. Mihevc, N. Zupan Hajna, I. Horáček, J. Kadlec, O. Man, P. Schnabl

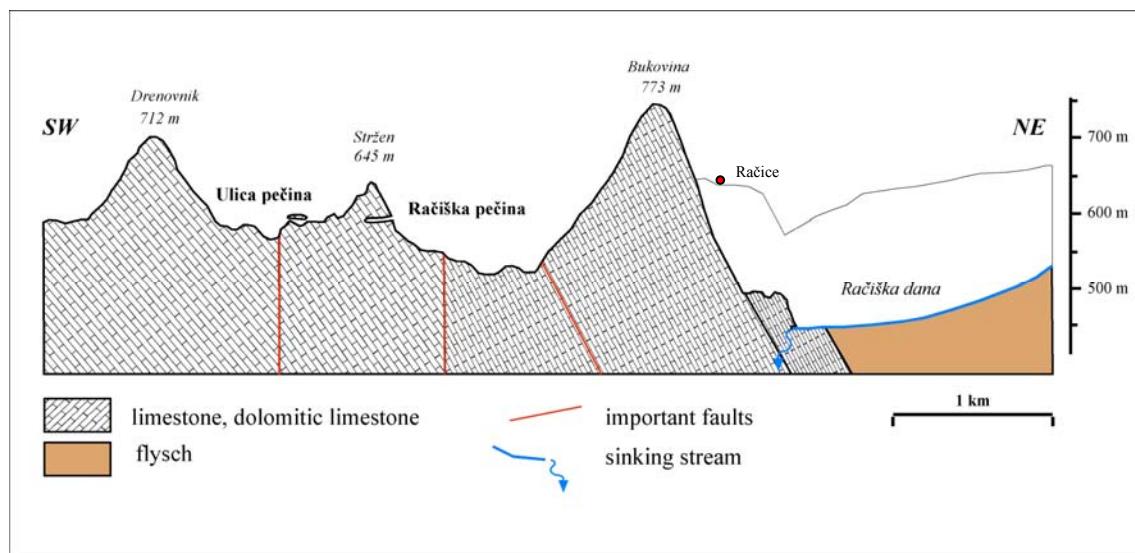


Fig 3/3: Cross section from noncarbonate flysch on NE and Matarsko podolje on SW.

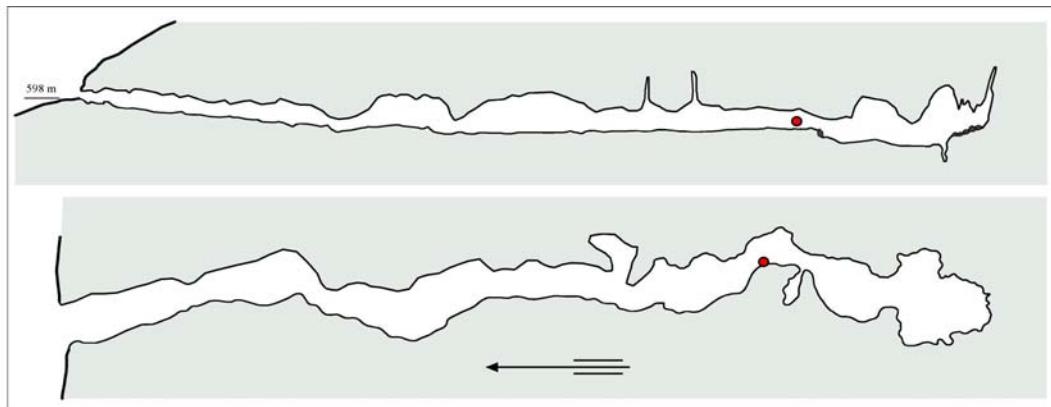


Fig 3/4: Plan and profile of the Račiška pećina cave. Situation before the cave was adapted for military use (Archive of the Karst research Institute ZRC SAZU).

Palaeomagnetic datations

The largest cut trough the banded flowstone is situated in the S part of the cave, about 200 m from present entrance. The cut trough the flowstone is more than 3 m high and about 20 m long.

The studied section is about 13 m long. The composite thickness of sampled profile reaches 552 cm; nevertheless the real uncovered thickness is only about 200 cm. The section is vertically composed of principal 3 parts. The lower part, 177 cm thick, is built of 3 sequences, representing the growth stages of huge vaulted stalagmite (sequences I to III). They consist of massive but porous speleothems with interbeds of red clays (1-2 cm) and two angular unconformities. At the top of sequences II and III broken rests of stalagmites are preserved. The second part (sequence IV; 375 cm) consists of subhorizontal laminated, mostly porous flowstones intercalated by flowstone with gourds, red clays and calcified silts. Collapsed roof blocks cover clays with finds of fauna (F). The top part is built of huge stalagmites, which were not studied.

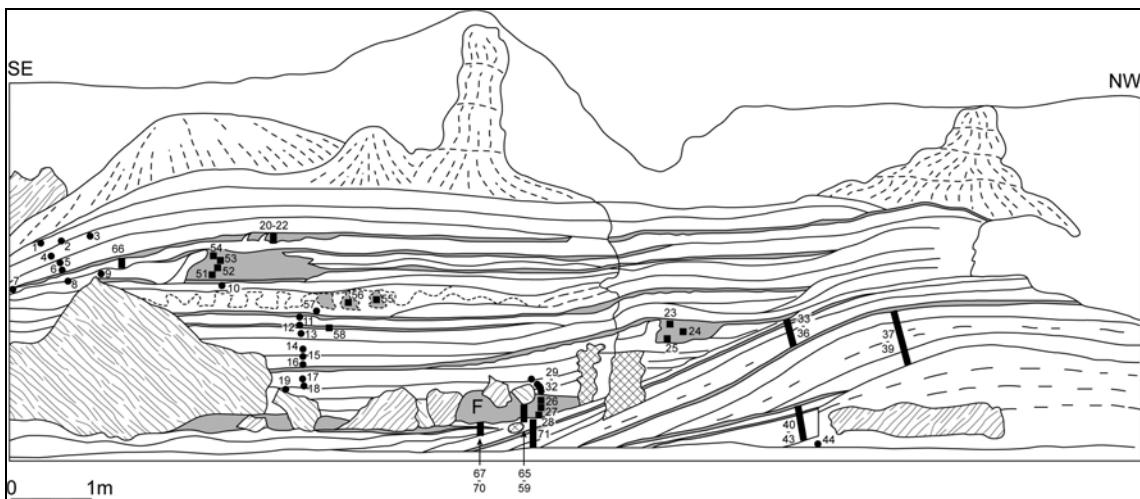


Figure 3/5: Sketch of profile in Račiška pečina Cave (digitised by J. Rajlichová). Legend: grey – clay; black squares – speleothem samples; black dots – clay samples; F – finds of fauna; shaded – collapsed blocks; cross shading – broken stalagmites

Palaeomagnetic and magnetostratigraphic investigation

Standard analytical procedures for detection of palaeomagnetic properties were used: thermal demagnetisation for 18 solid samples, and alternating-field demagnetisation for 111 samples both for solid (speleothem) and unconsolidated samples (clays). The obtained data have high-resolution character with distance of samples in centimetres. Most of the sequence IV shows normal polarised magnetisation. Inside clay layer with fauna (F) there is boundary with reverse polarised magnetozone, which prevails up to the profile bottom. Three normal polarised zones were detected within the reverse polarized one.

The profile consists of two parts. The lower one represents lower part of huge stalagmite form. Red clays intercalate the overlying flowstone formation. The character of speleothems, internal textures and structures and high porosity can indicate very rapid growth in warm and humid climate. High porosity, on other hand, can also indicate post depositional corrosion of speleothems. Clay intercalations represent results of floods bringing allochthonous load. Alternation of normal and reverse polarised magnetozones and palaeontological content enable to fix well our data with the GPTS (Cande and Kent 1995). The boundary of normal and reverse polarised magnetozone within the layer with fauna (F) can be identified with bottom of Olduvai subchron (1.77 to 1.95 Ma), as the character of fauna excludes Quaternary age. Short normal chron just below detected Olduvai bottom is compared with Reunion subchron (2.14-2.15 Ma). The lower part of profile can be compared with dominantly normal polarised Gauss chron (from 2.581 Ma). According to arrangement of individual normal and reverse polarised subchrons, studied profile terminates at about 3.2 Ma. The geometry of obtained palaeomagnetic subchrons is changed by numerous breaks in deposition especially within the lower part of the profile (sequences I to III). Obtained picture can estimate the duration of individual breaks up to 150-250 ka. This fact can also explain 36° difference in declination values in upper and lower parts indicating paleorotations of the respective tectonic block (Pruner et al. 2003). Collapsed roof blocks in the clay with fauna indicate some tectonic unrest at about 1.9 Ma.

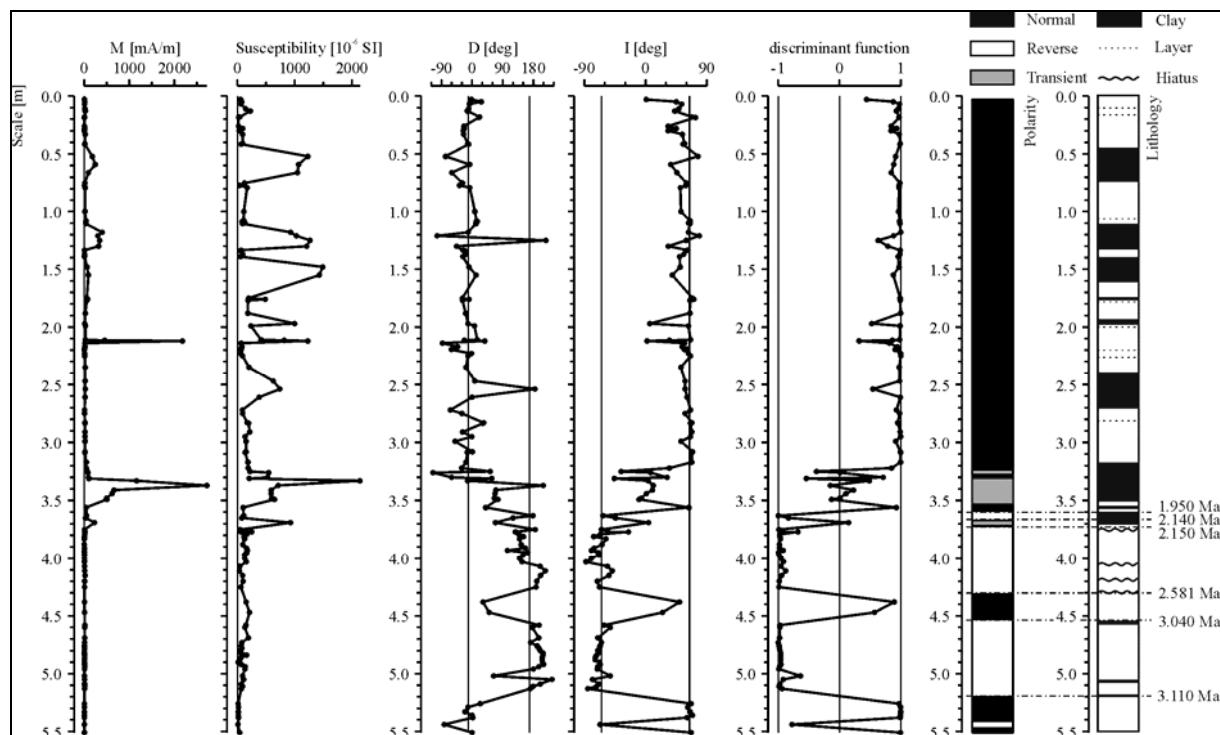


Figure 3/6: Basic magnetic and palaeomagnetic properties and simplified lithological log with principal clay interbeds and position of principal hiatuses, ages in Ma (drawing composed by O. Man)

Palaeontological analysis.

Samples of clays from principal clay accumulation were washed (samples Nos. 20-22, 54-51, 23-25 a 26-28-65-59). Fossil remains were found in clay layer at the base of sequence IV covered by collapsed blocks from roof. Rodents and rests of probably fresh-water crabs were found. Rodent (vole) rests represented poorly determinable assemblage of fragments of rooted teeth (molars). Rodent teeth treated by diluted acid were studied by scanning microscope to identify the internal structure of the tooth. The character of mammal assemblage, especially rooted form and internal texture of teeth, and determined *Borsodia* (Lagurini) – *B. cf. hungarica*, *Mimomys pitymyoides* groups and *Apodemus* (*Sylvaemus*) cf. *sylvaticus* indicate Pliocene age of fauna, i.e. biozone MN17 (Villányian, cca 1.8 to 2.4 Ma).

Cave bear footprints, ¹⁴C and cultural datation of cave sediments

When surface lowering opened recent entrance cave became a den of a extinct *Ursus spelaeus* (Mihevc 2003). Cave bear bones can be found in all parts of the cave. There are cave bear claw marks on rock or flowstone and footprints in clay preserved in a cave. They were discovered while we were sampling sediments. Traces of cave bear are preserved in three parts of the cave only. They are older than 10 ka.

Prehistoric people were using used cave too. In a profile we found a thin layer of charcoal, most likely a remnant of a fireplace. The charcoal that belongs to *pinus* was dated with ¹⁴C method. The radiocarbon age is 9174 ± 40 BP. Fireplace is covered with 20 cm thick sequence of laminated porous flowstone, which is today no longer depositing.

In the main passage pieces of pottery with thick walls was found. It can be Neolithic age, probably no older than 5500 BC, but most likely younger.

On the walls there are also modest signatures of visitors from the end of 18.th century and first half of 19. th century. There is a change in style and size of signatures that appeared after 1920, when the area was occupied by Italians. They were made by cavers of caving

societies from Fiume and Trieste. Signatures of Italian soldiers working in the cave also appear in that time. Style and alphabet too changed gain after WW II. Signatures of this time belong to soldiers from Balcan peninsula serving their military service.

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THE UNROOFED CAVE ULICA AND ULICA PEĆINA CAVE

Ulica pećina is 125 m long, 10 – 15 m wide cave with two entrances. Cave is developed in Lower Cretaceous thick-bedded limestone. Dip of strata is 45° towards NE. The cave represents relict of old cave system, which was opened by denudation to the recent surface.

The bottom of the cave is composed of clastic sediments, clays, rocks and gravel. There are evidences of fast sliding of sediment into the lowest part of the passage as a result of periglacial processes in the cave. The ceiling is horizontal, levelled to same height, most likely the result of paragenetic evolution when still in phreatic conditions. The thickness of roof above the cave is about 10 m.

On the S side, the cave opens on the slope of the hill, while on the N side cave was continues in unroofed cave Ulica.

The unroofed cave Ulica is 250 m long series of elongated depressions. The unroofed cave is about 10 m deep and 20 – 30 m wide. The walls of the unroofed cave are mostly steep, the floor of it are composed of sediments, on one spot with massive flowstone.

Continuation of the unroofed cave is not clear, possibly is towards NW, where are some large boulders, the remnants of collapsed cave ceiling.

The unroofed cave Ulica and Ulica pećina cave are possibly remains of the same cave system as Račiška pećina. The passages of Račiška pećina are in elevation between 598 – 589 m. The 1200 m distant Ulica pećina cave has its paragenetic ceiling in elevation 585 – 589 m, while sediments at the bottom of the passage are between 585 – 562 m. In similar height, 580 – 585 m, is also the floor of the unroofed cave Ulica.

Even if the caves are not of the same system, they were most likely developed at the same time, and were probably connected with the sinking rivers from the flysch. Datations of the sediments in Račiška pećina with two methods show certain age of the sediment, 2,3 Ma namely. But this is the age of the cave sediment, not the age of the caves itself.

After the presumed lowering of the surface with denudation rate of about 50 m/Ma with this age there was about 100 m of the rock above the caves removed since de deposition of the dated sediments.

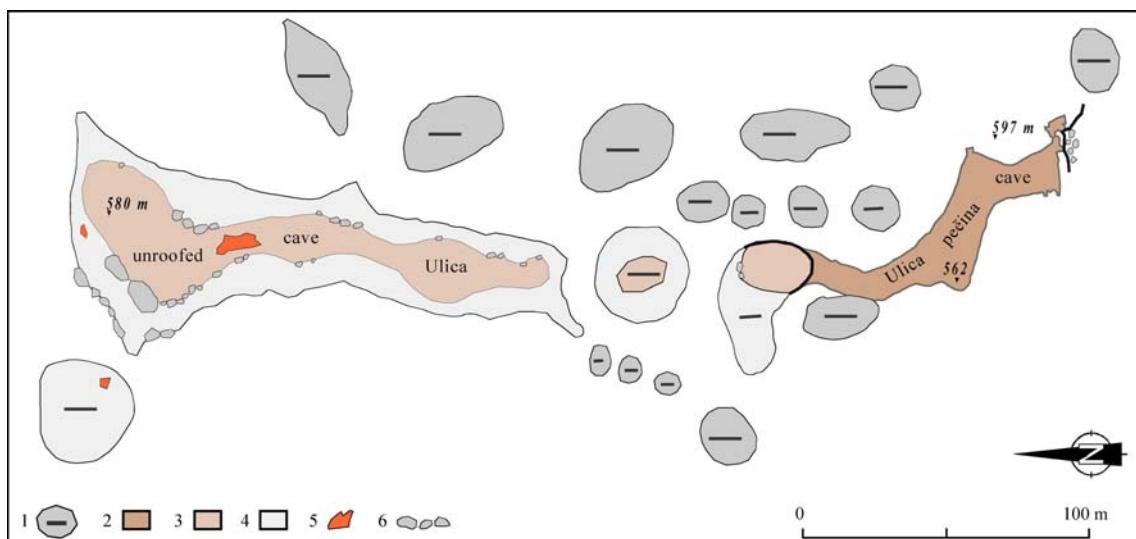


Figure 3/7: Plan of the Ulica pečina cave and unroofed cave Ulica.

Legend: 1. doline, 2. cave passage, 3. floor of the unroofed cave, 4. slopes of the unroofed cave, 5. speleothems, 6. larger rocks.

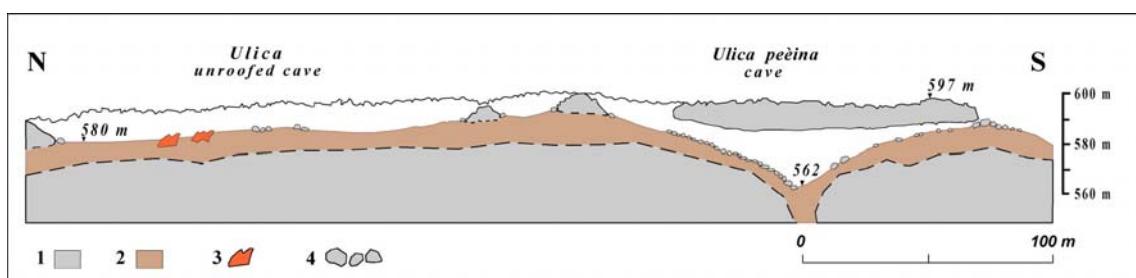


Figure 3/8: Profile of the Ulica pečina cave and unroofed cave Ulica.

Legend: 1. doline, 2. cave sediment, 3. speleothems, 4. larger rocks.

JEZERINA BLIND VALLEY AND CAVES WITHIN

The blind valley was formed at the contact between Cretaceous and Palaeocene limestone and flysch (Mihevc 1994). Two rivulets, which flow in from Brkini, sink in 120 m deep cave at the edge of the valley bottom.

In the beds of both streams several swallow-holes may occur, their activity depends on the water level. Ponikve v Jezerini, cave is located at the valley bottom. It is also a temporary swallow-hole of one of the rivulets and its lower parts are flooded several times a year.

The valley's bottom is covered by the sediments, in altitude of 500 - 510 m. Into this older sediment younger, up to 20 m deep alluvial sinkholes and riverbed of the brooks are cut.

Two important caves are located at the edge of the valley. The Mitjeva cave is situated at the level of the deposited valley floor; in it there are the same fluvial sediments as in the valley floor itself. Pečina v Borštu, however, is situated around 70 m above the floor of the blind valley.

14 datations were made on stalagmites and cement of the scree material using $^{234}\text{Th}/^{230}\text{U}$ method to determine the end of the deposition of fluvial sediments in cave and the stabilisation of the collapsed material in caves and scree the slope of the blind valley.

DATATIONS IN MITJEVA JAMA CAVE

Entrance to Mitjeva jama is in the quarry at the side of the blind valley bottom. Entrance is at 512 m a.s.l., but the passages of the cave are at approximately 500 m a.s.l., that is in the same elevation as the bottom of the blind valley. In them the same sort of sediments can be observed.

Samples were taken from two places from the cave. Location JEZ-A is a chamber with a talus cone of boulders and scree. This material slide in a chamber from other inaccessible part of the cave. The material shows with the angle, orientation of particles and structures that it was sliding in the past, but today the slope is not moving any more and there are several tall stalagmites growing on them.

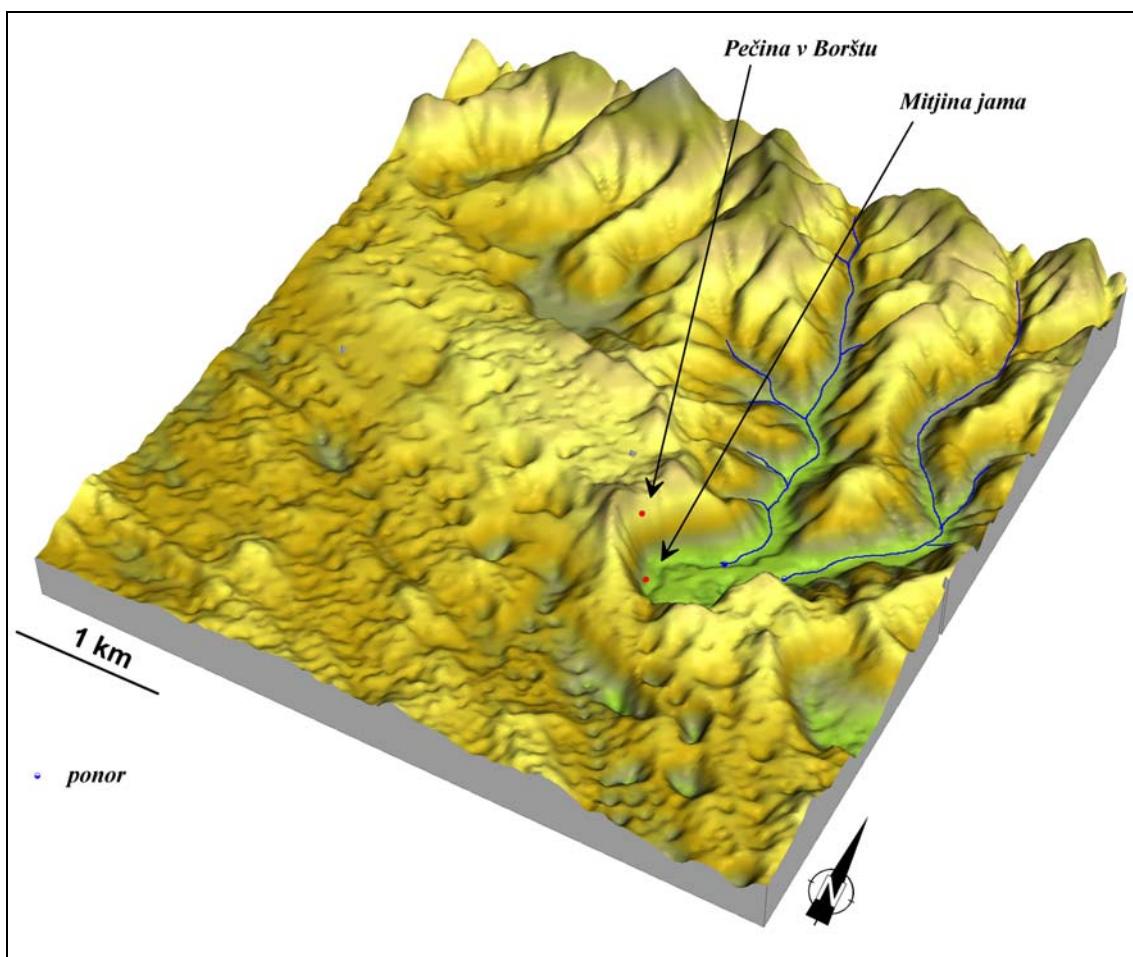


Figure 3/9: DEM of the Jezerina blind valley with the position of the caves an ponors.

Dating of the flowstone

Two, 124 cm and 151 cm tall stalagmites from that location were analysed. Stalagmites were cut to two halves, exposing well laminated internal structure. Sub samples were taken and were dated. The age at the base of the first stalagmite was $16,3 \pm 2$ Ka and the second stalagmite at 28 cm above the base (the sample of the base was contaminated) gave age of $12,2 \pm 2,4$ Ka.

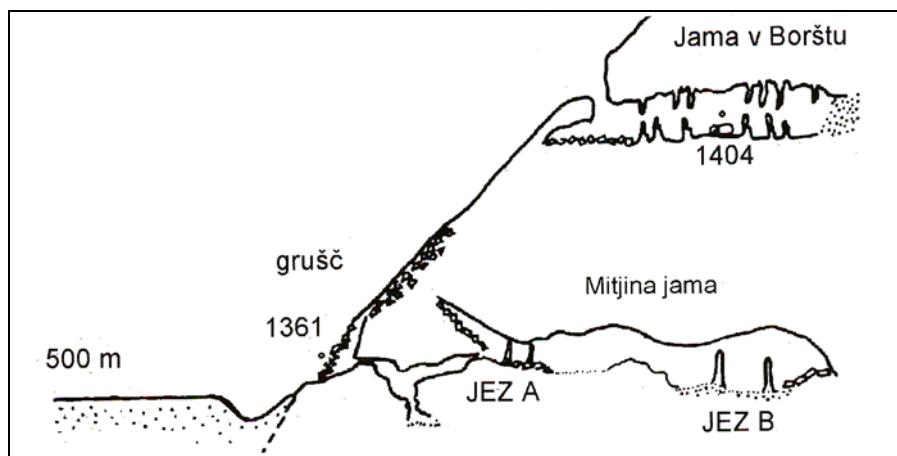


Figure 3/10: Schematic cross section of the edge of the Jezerine blind valley with caves and sampling points of the flowstone. Five stalagmites and a cement of the slope breccias were taken and 15 $^{234}\text{Th}/^{230}\text{U}$ datations were on the sub samples.

In both stalagmites growth laminae were counted and compared. But this gave no result for two reasons: there are too many hiatuses and changes in deposition rate in each stalagmite and they show great differences in arrangement of them.

In the 124 cm long stalagmite 3855 pairs of laminae, from 0.3 – 0.08 mm thick and also 26 darker, translucent thicker segments with no lamination were detected. If we presume, that laminated part of the stalagmite grew for 3855 years, than in only 26 layers the main, 12.500 years long period of the stalagmite growth is expressed. The lamination of the second stalagmite was completely different.

Location JEZ-B is in lower part of the cave, where tall stalagmites grow on the fluvial sediments. Two stalagmites were sampled here. At the base part of them hiatuses with sand and clay dirty layers were observed in them. Some of the samples were polluted with detritic ^{230}Th . Datations were made on the sub samples showing, that age of 12.6 ± 1 ka at the base of the 126,5 cm tall stalagmite and age of 12.4 ± 1 ka at the base of 85 cm tall stalagmite.

On the W slope of the blind valley there is large cemented scree. It is cemented in some places with several cm thick flowstone. Sample if it was dated to 6.3 ± 1 Ka.

From the results of datations we can conclude, that stalagmites began to grow on collapsed boulders and scree in Mitjina jama about 16 Ka ago. The talus cone in Mitjina cave is made of rock that slid in from elsewhere, meaning that the collapsing and sliding of the scree was still from then. The cessation of the movement of the scree cone can be the consequence of a warmer climate and cessation of freezing in this cave. The same effect, talus cone stabilisation, would be rendered by heavier flowstone deposition in the ceiling fractures cementing them or flowstone stabilising the collapsed material.

The same event, changing to warmer climate and gradual stop of flooding and depositing the fluvial sediments made the growth of stalagmites possible in lower part of the cave. Because of flooding this occurred slightly later, at about 12,5 ka.

PEČINA V BORŠTU

Pečina v Borštu cave lies on the western slope of Jezerina, at an altitude of 566 m. It is formed in well stratified Turonian limestones (K_2^2), limestone dips steeply towards the NE.

The cave is approx. 250 m long and is oriented in a N-S direction following a fissured zone. Limestone beds dip towards the NE.

The passage walls in the cave are extensively covered with flowstone; individual features of the cave passages indicate their formation in phreatic conditions. At specific places within the cave there are remains of alluvial deposits, mostly sand, which indicate a phase of intensive cave filling in the past. In some places the shape of the flowstone indicates that it was deposited on top of the clastic sediments, which were later removed.

At the end of the cave cavers removed large amount of sandy sediment. Sand contains predominantly quartz, with an insignificant quantity of a mineral from the illite/muscovite group and other clays. The mineral composition suggests that the sand is derived from the flysch rocks of Brkini, where water flows into the Jezerina blind valley. No calcite was found in the sediments from the passage.

The cave is of phreatic origin; however initial phreatic features are only visible in a small chamber beside the eastern wall of the chamber in front of the passageway, where flowstone is not so abundant. Elsewhere almost all of the passage walls are coated with a thin layer of reddish brown flowstone, while the entire cave contains much flowstone.

There is no flowing water in the cave, only percolating water that accumulates in pools after rainfall. The temperature in the entrance area fluctuates with the exterior temperature.

In places where the rock is not covered by flowstone, it shows signs of weathering. The surface of the wall has initial weathering and in some sections "boxwork" a few millimetres deep has formed. In some places "boxwork" is visible through the thin layer of flowstone that covers the walls. Condensation corrosion occurs (Zupan Hajna 2003) when cold air enters the cave. An abundance of condensed water drops was observed during winter.

In the middle part of the cave a broken stalagmite with alteration of white and reddish calcite layers was dated. White calcite from middle part of the stalagmite was dated to 211 +20 –17 Ka. It shows the rather high age of the flowstone in the cave (Mihevc 2001).

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FROM THE SPRINGS OF THE LJUBLJANICA RIVER TO ŠKOCJANSKE JAME
Thursday, 24.6.2004

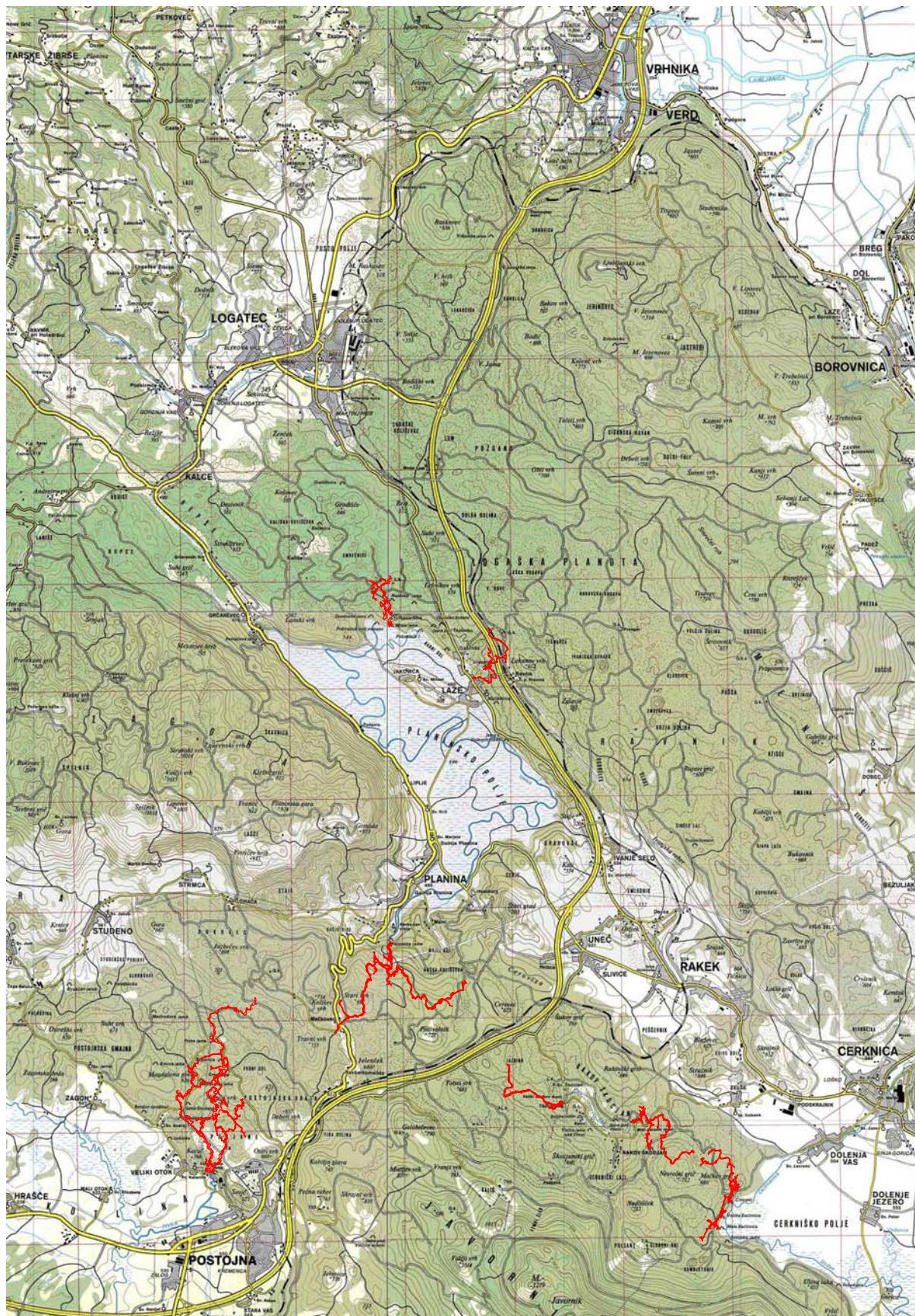


Fig. 4/1: Route of the excursion in the Ljubljanica River basin.

Ljubljanica river system

Ljubljanica River collects the water from SW part of Dinaric karst in Slovenia and belongs as right Sava affluent to Danube part of Black Sea water basin. The real watershed is placed somewhere in the underground, and the waters from karst plateau are flowing to all sides.

The Ljubljanica water basin is about 1100-1200 km². 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.

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 is no surface rivers. Triassic dolomite is important, allowing some surface flow, forming bottoms of some karst poljes or forming hydrologic barriers.

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: Trbušovica, 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 River at springs is 38,6 m³.

Logatec karst polje

The Logatec polje developed on the contact of dolomite and limestone between 470 and 480m a.s.l. A number of small streams flow onto in, the largest being the Logaščica, which collects run-off from a dolomite area of 19km². The mean flow is 0.3m³/s. Short lasting floods occur at the swallow-holes on the Logaško polje when the flow exceeds 30m³/s.

Planina polje

Planina polje is overflow polje, of rectangular shape, 6 km long, 2 km wide, with two narrow pocket valleys on SW part, 50 m deep, with 16 km² flat surface at height of 450 m. Its wider surrounding is built by Upper Triassic dolomite, Jurassic and Cretaceous limestone. The development of closed karst depression is result of accelerated corrosion, controlled by a geological structures.

It presents the most important water confluence in the river basin of Ljubljanica. Tectonically crushed and almost impermeable dolomite barrier along the Idrija wrench fault zone, which crosses the polje, forces the karst waters to overflow from higher karstified limestone background to the surface and after crossing Planinsko polje toward NE they can sink into the underground again. The principal Unica springs, with mean annual discharge 24 m³/s (min. 0,3 m³/s, max. 100 m³/s) are situated in the southern polje's part in Cretaceous limestone, where the confluence of waters from Cerknica, Javorniki Mt. and Pivka is located. Main spring is 6656 m long Planinska jama cave.

The principal Unica swallow-holes are disposed at northern edge, where mostly medium and high waters are sinking. At low waters the whole Unica is disappearing in swallow-holes at eastern polje's border. The water is sinking directly from Unica bed through the polje's bottom across more than 150 swallow-holes and impassable fissure. Only at

Dolenje Loke and in Škofji lom, up to 160m long ponor caves are known, but there are several horizontal caves in vicinity of the polje, where water oscillations can be observed. Larger caves behind the ponors are over 4987 m long Najdena jama cave and Logarček.

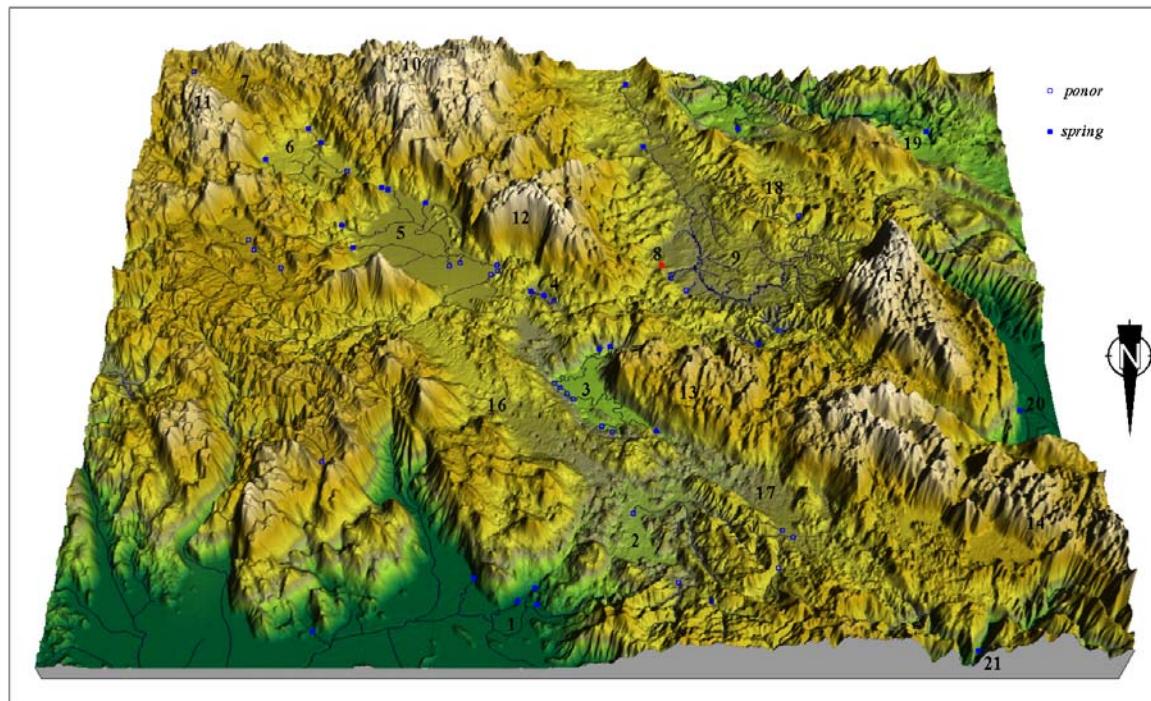


Fig 4/2: Legend: 1. Ljubljanica springs at Vrhnika, 2. Logatec polje, 3. Planina polje, 4. Rakov Škocjan, 5. Cerknica polje, 6. Loško polje, 7. Babno polje, 8. Postojna, 9. Pivka basin and polje. High karst plateaus: 10. Snežnik, 11. Racna gora, 12. Javorniki, 13. Hrušica, 14. Trnovski gozd, 15. Nanos. Karst levelled surfaces: 16 Logaški ravnik, 17. Hotenjski ravnik, 18. Slavenski ravnik; 19. Škocjanske jame cave, ponor of Reka river, 20. Vipava spring, 21. Divje jezero spring at Idrija.

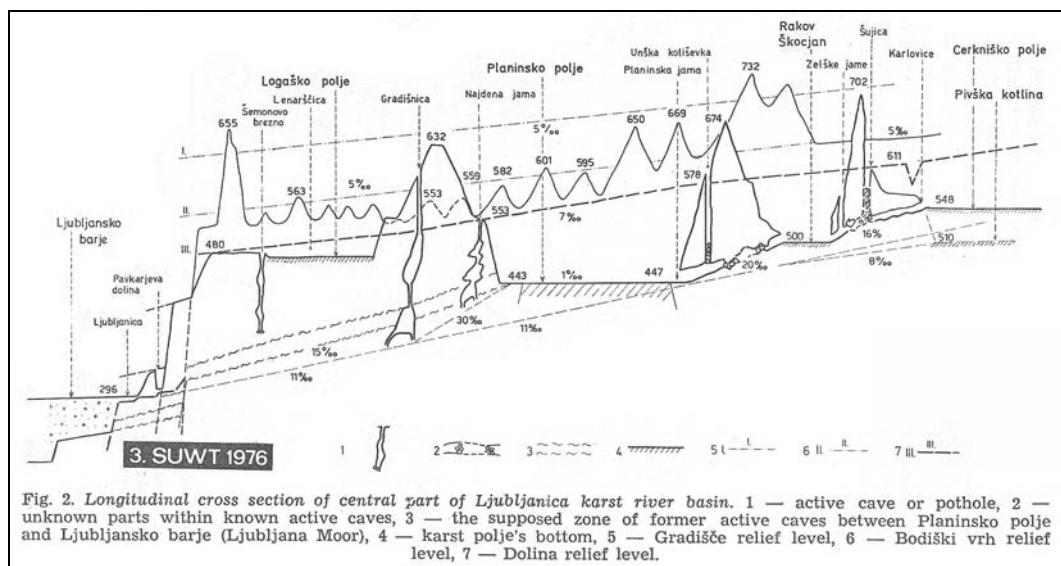


Fig 4/3: Longitudinal cross section of Ljubljanica karst river basin (Gospodarič & Habič 1976).

Planinsko polje is flooded several times in a year. The minimum inflow to the polje amounts to $1,5 \text{ m}^3/\text{s}$; mean $23 \text{ m}^3/\text{s}$, maximal was estimated to $100-120 \text{ m}^3/\text{s}$, the total ponor capacity being about $60 \text{ m}^3/\text{s}$. At floods, lasting 1-2 months, the water increases up to 10 m and up to 40 millions of m^3 of water inundate the polje.

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 connections of the Rak with water from Cerkniško polje and with the Unica springs at Planinsko polje were proved by water tracing.

Before 1st World war 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.

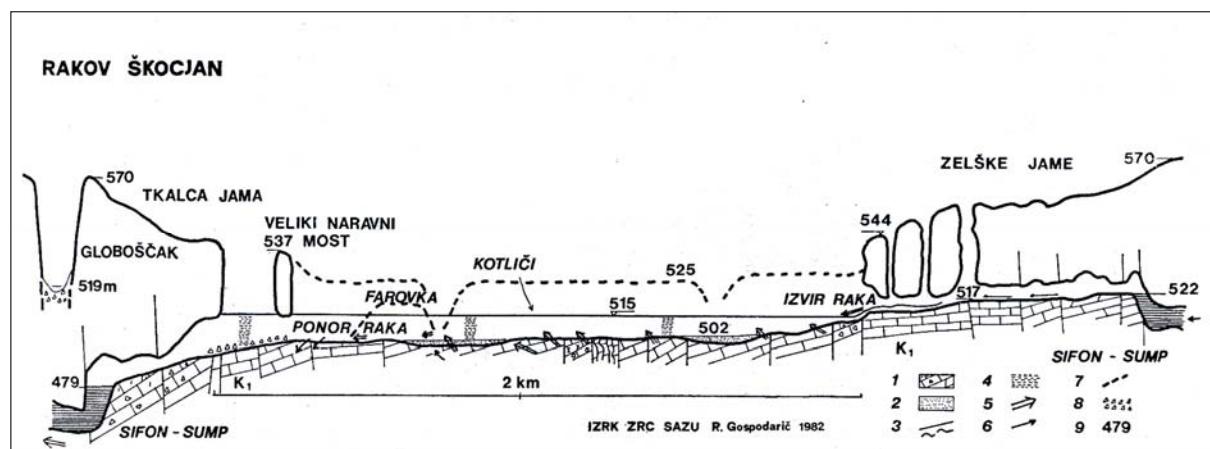


Fig.4/4: Cross-section along Rakov Škocjan karst depression between spring at Zelške jame and sink in Tkalca jama. Legend: 1 – rocky bottom, 2 – alluvia, 3- fault zone, 4 – flood in 1982, 5 – karst spring, 6 – water flow directions, 7 – terraces, 8 – boulder rocks, 9 – altitude (Gospodarič et al. 1983)

Cerknica polje

Cerknica polje is the biggest 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 Triasic 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 hydro melioration of polje has 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 bottom are filled with alluvia. Alluvium at altitude of 550 m is distinctive in all the ponor caves, its thickness is possibly the same as a thickness of alluvia in Jamski zaliv, 8 - 15 m respectively.

Pivka basin

The bottom of the Pivka basin, an area of about 70 km^2 , is of Eocene flysch rock. A river network has formed on the floor of the basin; the water flows into the boundary limestone rock going to different river basins (Habič 1982, 1989).

Karstified limestone surrounds the valley from all sides; at the contact on higher levels there is flysch. Along the 59km long lithologic contact of flysch and limestone, 17 larger and a number of small rivers sink, transforming only 2.3 km^2 of karst.

The Pivka, with a mean flow of 6 m^3 , is the largest sinking river in the basin. Most of its water flows from karst sources on the southern part of the basin, at the foot of the Javorniki, where a karst polje formed on limestone. For a large part of the year, the Pivka is dry; when waters are high, it floods the floor of the field.

The main inflow into the Pivka from flysch rock is the Nanoščica, which flows from W.; it collects water in the western part of the flysch basin.

The Pivka sinks into the 20km long Postojna Caves at about 511m a.s.l.. The caves have several levels, the main level being 520 to 530 m a.s.l. The lowest parts of the caves are located at the outflow sump at 477 m a.s.l., while sources on the edge of the Planina polje are at 453m a.s.l. (Gospodarič 1976).

Kras

Kras is a low carbonate plateau between Divača, Sežana and Trieste. The name itself has a pre-Indo-European origin from word karra, which means rock – stone. The ancient word for “stone” gave the origin to the ancient name for the region (Carusadus, Carsus) and this word changed according to different languages into Kras (Slovene), Karst (German) and Carso (Italian) (Kranjc 1997). From this toponym the international term – karst – for such type of landscape is derived. The name and some other terms from the area like dolina, polje, ponor have entered to international scientific terminology from here.

Kras is a limestone plateau, lying above the Trieste bay at 200 - 500 m a.s.l., the northernmost part of the Adriatic Sea. The climate is Mediterranean in general: hot and dry summer, cold winter with most of precipitation and NE wind "burja" (bora = borealis). Because of different land use, pasturing, in past centuries, the Karst was bare, with rocky and grassy surface. Last decades the bushes and trees are overgrow the landscape.

Kras plateau is stretching in "Dinaric" direction (NW - SE); it is 40 km long and up to 13 km wide, covering about 440 km², sloping towards NW. The karstification of mostly Cretaceous limestone started after its uplift in Oligocene. There is about 300 m of vadose zone accessible and there are caves formed in all elevations from the surface to the sea level and below. The central part of Kras is built by well permeable Cretaceous limestone and partly less permeable dolomite, which may play a role of a relative isolator. Cretaceous rocks pass into well permeable Paleocene limestone, and very low permeable Eocene Flysch that acts as an important impermeable dam surrounding the carbonate massif.

Average yearly precipitation on Kras varies from 1400 to 1650 mm, and average yearly evapotranspiration from 700 to 750 mm (Kolbezen & Pristov 1998). There are no surface streams on the Kras area, but some rivers are sinking edge of it, largest of them is Reka.

Divaški kras

Karst surface above Škocjanske jame, Divaški kras is a SE part of the Kras plateau between the sinks of Reka river and the village of Divača. It is built mostly by Cretaceous and Paleogene limestone. The surface is leveled in elevations between 420 and 450 m a.s.l, inclined slightly towards NW. The karst features here are exceptional; there are sinks of Reka river, 15 large collapse dolines and hundreds of dolines.

In the Divača kras there are known 64 caves with the total passages length of 18,500 m. The largest caves of the area are Škocjanske jame, 5800 m long and 250 m deep cave. They were formed by the sinking river Reka that after sinking flows towards Kačna jama, Labodnica and then to springs of Timavo.

The largest collapse doline in the area is the Radvanj double collapse doline (volume 9 million m³). It is followed by the 122 m Sekelak, the volume of which is 8.5 million m³ and Lisični dol (6.2 million m³). Then there are: Globočak (4.6 million m³), Bukovnik (1.5 million m³), Risnik (1.5 million m³) and others. As rooms as big are not usual in the Karst, we must assume, that collapse dolines this large could develop only with simultaneous rock removal. If this were not the case, the room would fill up with caved-in rock and only collapse dolines much smaller than the primary cave would appear on the surface.

Kačna jama is the longest cave system of Reka river in the continuation of Škocjanske Jame. The entrance lies west from Divača 435 m a.s.l. The total length amounts to 12.500 m. In the lower level the actual underground flow of Reka is met at 195 m respectively.

Unroofed caves are an important part of the surface morphology of Divaški kras where 2.900 m of the unroofed caves was mapped (Mihevc 2001). They are caves exposed to the surface due to the surface denudation lowering which re-shapes them into the surface relief forms. In such features flowstone, allochthonous sediments and morphology are testifying their cave origin. Several unroofed caves were studied and sediments were analyzed (Mihevc & Zupan 1996, Bosak P. et al. 1998); clastic sediments are dated to 1,6 - 1,8 Ma or/and 3,8 to 5 Ma.

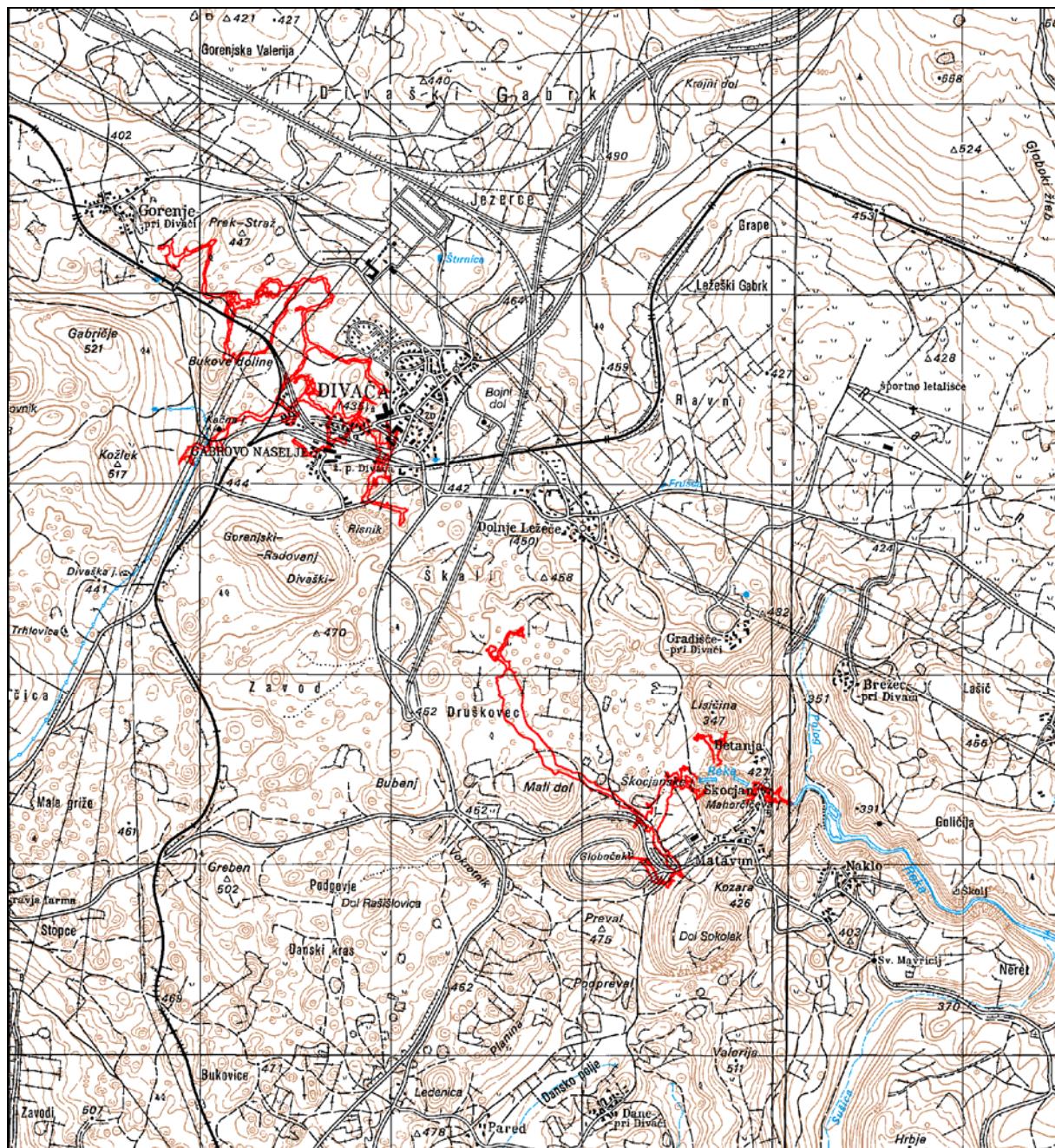


Fig.: Divača Karst with Škocjanske jame caves and Kačna jama cave (Drawing by Hajna 2002).

Reka river - Timavo

The Reka river is the main sinking river of the Kras. It gathers the water from the area of more than 350 km². Around 60 % of it is with surface drainage network on Eocene flysch. In the period 1961-1990 the minimal measured discharge of the Reka river was 0.18 m³/s and the mean discharge 8.26 m³/s. In the time of extremely high waters its discharge can reach up to more than 300 m³/s. At such conditions the water is dammed in the underground and over 100 m high floods occur in Škocjanske and other caves.

After underground flow the Reka and rainwater from the Kras and inflows from the rivers Soča, Vipava and Raša reappear at springs as Timavo about 35 NW from Škocjanske jame. Three main springs with mean discharge 30.2 m³/s are on the coast are connected by a network of passages that reach a depth of about 80 m below the sea level (Civita 1995).

Škocjanske jame

The Škocjanske jame caves are 5,8 km long. The Reka river, mean annual discharge 8,26 m³/s enters the cave at an altitude of 317 m; in the Martelova dvorana room, it is 214 m above sea level (i.e. 103 m lower). The Reka can all sink before it enters the cave. Floods usually reach up to 30 m. The largest known flood in the previous century raised the water table level for 132 m.

Morphology and development of Škocjanske jame cave are described according to Mihevc (2001). Caves are developed in a contact area of cretaceous thick-bedded rudistic limestone and Palaeocene thin-bedded dark limestone (Gospodarič 1983, Habič et. al. 1983).

Škocjanske caves are composed of phreatic tunnels, and gravitational or paragenetic reshaped galleries. The proto-channels developed in phreatic conditions, formed along tectonised bedding-planes. The water flow demanded a high degree of phreatic rising and falling between individual bedding-planes which, in the area of the chambers Svetinova dvorana and Müllerjeva dvorana, is approximately 175 m. Large quantities of water could flow through all these tunnels, but meanwhile, rubble was transported through water table caves above them. Such a cave is unroofed cave in Lipove doline at an altitude of around 450 m. A long period followed when the piezometric water table was 340-300 m above sea level and the gradient was in a SW direction. The Reka formed new or adopt old passages by paragenesis and bypassing. The large galleries Mahorčičeva and Mariničeva jama, Tominčeva jama, Schmidlova dvorana in Tiha jama were formed.

In the further development of Škocjanske caves, potent entrenchment prevailed. Cutting occurred in inner parts of the cave, in Hankejev channel for about 80 m, much less about 10 m, in the eastern, entrance part of the cave.

First paths in the cave area were made in 1823, but construction of paths for exploration and for the visitors started in 1884. Cave exploration and construction of the pathways were done by cavers of DÖAV from Trieste. The most important explorer was Anton Hanke. In 1891 they reached the final sump in the cave.

The largest chambers are Martelova dvorana, with a volume of 2,100,000 m³, and Šumeča jama (870,000 m³). Some of big chambers collapsed forming the big collapse dolines like Velika and Mala dolina.

Because of their extraordinary significance for the world's natural heritage, in 1986 the Škocjanske jame were included in UNESCO's World Heritage List. The Republic of Slovenia pledged to ensure the protection of the Škocjanske jame area and therefore adopted the Škocjanske jame Regional Park Act.

Risnik collapse doline

Collapse dolines are, by definition, relief forms which occur when ceilings above underground caves collapse. Slovenian expert literature understands collapse dolines as those with exceptional dimensions, and steep or vertical walls. Smaller collapse forms are frequently left aside because of lack of signs of collapse processes.

Risnik is about 80 m deep collapse dolina situated south of Divača village on levelled karst surface. Its edges are on elevation about 440 m, and bottom at 366 m a.s.l. Most of the doline has vertical walls in upper parts and boulders and scree in lower part of doline.

About 50 m N an E of the doline there are galleries of Kačna jama where Reka flows at 190 m a.s.l. There are no signs of connection between the doline and the gallery, so we have to suppose, that the Risnik was formed above unknown passages of Kačna jama.

Only 50 m W of Risnik is dolina much larger, 800 long and 450 m wide double dolina Radvanj. Volume of both depressions is about 9.000.000 m³.

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ABSTRACTS

FOSSIL-BEARING FISSURE FILLINGS OF SLOVENIA AND CROATIA

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Within the French-Slovenian Proteus research program n° 97011, several fossil-bearing fillings of cavities initially formed as different caves have been discovered (1997 and 1999 field trips). Some of them have also been found in Croatia. The aim of the project was to find new localities in the area and with biochronological dating of the localities date the evolution of the karst, specially the large unroofed caves.

In Slovenia, two quarries that of Črni Kal in the SW, and that of Velika Pirešica in the central part of the country have been particularly productive. Two other isolated sites have also been discovered, in the road cut near Sežana and the other at Snežna Jama, a high altitude cave.

In the case of the sites recognised in Croatia, the work was done in Istra peninsula in cooperation with the late Maja Paunović from the Zagreb Institute of Quaternary Paleontology and Geology.

In 2003 two new localities were found Dol Bestažovca near Sežana in Slovenia and locality Modrič on the cost of the Adriatic Sea in Croatia. In both cases these are unroofed caves filled with sediments, being now exposed to the surface because of the lowering of the karst surface.

Here are presented some photographs of the sites, some of them have disappeared since, and faunal lists of small mammals are given. The faunas have all a Pleistocene age.

THE FOSSIL-BEARING FISSURE FILLINGS (FFF) OF LANGUEDOC-ROUSSILLON (FRANCE): A GENERAL OVERVIEW

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The area known as Languedoc – Roussillon in southern France is well known since more than one century and a half for its numerous ($N > 150$) fillings of fissures and cavities of the karst opened in the limestone massifs, which yield numerous remains of mammals. The time interval documented by these faunas goes from Late Eocene to uppermost Pleistocene; the highest number of localities is observed for the Miocene period. The collected fossils are

mainly bones and teeth of small mammals, among which rodents are prominent. Teeth represent the best-preserved material and are thus used for diverse paleontological studies.

The biochronological dating of the localities is based first on the overall composition of faunas and second on the recognition in these faunas of evolutionary stages of a few lineages they share. These stages are defined on the basis of morphological and metrical criteria of the lineage representatives. Then, this local biochronology is correlated with the biochronological European Mammalian Zonation (MN zones). Calibration with the international chronostratigraphic scale is also attempted based on a few correlations between marine and continental deposits, a few radiometric dates and some paleomagnetic data obtained on sections in which rodents have been collected.

It is necessary to point that the chronological homogeneity of any sample taken from a FFF is tested simultaneously with its paleontological analysis. Among the many Miocene fissure fillings which yield fossils, only one - Baixas 202 - has been demonstrated to be chronologically heterogeneous: the filling results of several successive phases, which are separated by no more than a 500 000 year long interval (upper value).

Owing to the high number of analysed deposits and their rich and diversified faunas, the history of the regional mammalian settlement can be reconstructed. Major shifts are interpreted as climatically and / or paleogeographically forced. In some cases, FFF can be used to date tectonic events, as it is the case for the limestone massif of Baixas near the town of Perpignan. An attempt to used dated FFF is actually under way in order to understand why some time intervals are characterised by many fillings and some other void (up to now) of any filling. A relation may exist with geodynamic evolution and surface formation: in the area of Montpellier, the Thau basin is an active field laboratory.

ESR DATING IN CAVES, ROCK SHELTERS, AND KARST FISSURES

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In cave systems, rock shelters (abris), and karst fissures, ESR (electron spin resonance) dating can be used to establish chronometric (absolute) ages for tooth enamel, molluscs, and some speleothem and spring travertine deposits. The ESR signal depends on the total radiation dose received by the material to be dated, and the dose rate supplied by the environment, including the material being dated it self.

Tooth enamel can be used to date the clastic sedimentary deposits which enclose them. The ESR limits for tooth enamel depend on the U concentrations in the teeth, but tend to range from about 8 ka to about 4-5 Ma. Determining the internal dose rate is critical to accurate dating, because teeth absorb U post-depositionally. Reworking in karst systems can also introduce inaccuracy, but can often be modelled to give geologically reasonable ages nonetheless.

Molluscs found in abri deposits can provide absolute ages from about 5 to 500 ka in age. Each species, however, needs to be tested for signal stability. Determining the internal dose rate and reworking are less serious problems for mollusc dating.

Although aragonite and calcite from speleothem and travertines have several signals that can potentially be used for dating, trace impurities often interfere with the signal detection, thereby reducing accuracy. The internal dose rate determination is not problematic.

Problems associated with changing sedimentary water concentrations in karst systems can make calculating the external dose rate more complex, but do not substantially reduce

dating precision or accuracy. In caves, the cosmic dose rate contribution is usually minimal, but in rock shelters, it may need to be modelled.

Generally, ESR in tooth enamel is the most frequently used ESR chronometer in karst systems. Other potential chronometric materials include burnt flint, burnt hearth sands, and phytoliths, but still require development and testing.

MORPHOLOGICAL DEVELOPMENT OF PONOR JOVAC CAVE AND SURROUNDING RELIEF (CROATIA)

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The middle part of the Slunj karst plateau is built of permeable, karstified upper Cretaceous limestone. The Miocene sandstones and marls lie over them in transgressive contact in the form of denudation remains. This area is impermeable and have characteristics of fluviodenudational relief. In morphological sense, the blind valley of Đedinovac periodical stream is remarkable. The Đedinovac stream sinks underground in the contact zone of the Miocene and Cretaceous and continue its flow through the main channel of the Ponor Jovac cave. The Ponor Jovac cave is over 600 m long and has the function of permanent percolating and periodical sinkhole cave. The area built of limestone is well karstified and without a surface fluvial network. But in continuation of the Đedinovac stream blind valley a dry valley exist which is a morphological trace of the former surface flow of the Đedinovac stream.

DATING OF CAVE SEDIMENTS

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Cave sediments (deposits, fills) represent important source of information on evolution of karst and caves. The whole karst functions as giant trap preserving evidence, which has been removed from the surface by erosional and denudation processes. The principal problems, which can be facing when studying karst sediments are polycyclic and polygenetic nature of most of karsts and the dynamics of depositional processes. From this point of view, cave sediments represent relatively special kinds of geologic materials. On one side, the karst environment favours the preservation of evidence and on the other hand its destruction. Reactivation of processes degrades the record often mixing karst fills of different ages (collapses, redeposition, reworking, slumping, ...). The typical feature is also in diachronity in age of cave fills, highly variable depositional rates, disturbances in superposition (e.g., sandwich structures) and wide variety of fills (from eolian to marine or volcanic in origin). There are two principal cave fill facies: entrance and interior. They differ substantially in paleontological content, response to outer conditions (especially climatic) and in stratification. Interior cave facies can be often found in paleokarst, while entrance facies is normally lost. Interior cave facies is generally poor in fossil remains, more most of them can be endemic. Cave fills are allochthonous (brought from outside) and autochthonous (formed within the cave). There are numerous methods how to date the age of cave sediments, which offer

numerical-age, calibrated-age, relative-age and correlated-age data. The application of individual method depends on their time spans, i.e. the older is the object of our study, the more limited are the methods of dating available. Until now, we have been applying only limited number of dating methods; the most frequent are: radiocarbon, U-series, thermoluminescence, cosmogenic isotopes, ESR, dendrochronology, some of isotopic methods, aminoacid racemization, collagen method, and especially stratigraphic, archeological data, paleomagnetism and stable isotopes.

THE PALEOMAGNETIC STUDY OF THE FINE SEDIMENTS OF THE BARADLA CAVE (HUNGARY)

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In connection with the study supported by the Hungarian Scientific Research Foundation (OTKA), during 2001-2, in the interest to reconstruct the Quaternary development of the Gömör-Torna karst, we conducted the research of the surface and sub-surface sediments of the karst region. The sample collection was organised in order to understand the paleomagnetic and magneostatigraphic relations of the sediments of the Baradla cave. The main aim of the research in procedure is the marking of magneostatigraphic borders in the chosen sections of the cave and the collection of data for further correlations.

During our visits in the cave we studied the suitability of sediments for laboratorial usage, the thickness of sections, their geological circumstances, as well as the morphological position of the sediments. We found 8 places in the cave which can come into account for the present or for later research purposes. The sample collection was directed by Pavel Bosák, the director of the Geological Institute of the Czech Scientific Academy, while further two geologists (Jaroslav Kadlec and Martin Chadima) also took part in the project. Choosing 5 out of the 8 preliminarily marked sections altogether 96 samples were taken (88 from loose sediment, while 8 from the dripstone crust closed between the sediments). Out of the 5 sample collecting sections one was placed in the main branch (Nádor utca in the Aggtelek part), two in the upper level (Münnich-táró, Meseország), while the remaining two in the side branches (Rákosi-ág, Arany-utca).

In the chosen sections we collected the samples 10 cm from each other, and placed them into small, plastic boxes in such a way, that we secured their original position to the magnetic North. The paleomagnetic research was conducted in Prague at the Geological Institute of the Czech Scientific Academy in 2002. The samples of flowstone were subjected to the U-series method (U-Th laboratory, the Geomorphological Institute of the Polish Scientific Academy in Warsaw). According to the data collected at the place of sample collections we drew the strata of the 5 sections.

Our results: In all places the fine-grained cave sediments showed normal magnetism. The flowstone bench and the upper part of the stalagmite of the section of the Münnich-táró showed a reversed magnetism. The lower section of the flowstone bench of reversed magnetism according to the U-series method is 114-115 ka. The section of reversed polarization can be drawn parallel with the "Blake event", which was written down in the Chinese loess region by Zhu et al. (1994) and is dated between 117,1 (+1,2 ka) to 111,8 ka (+- 1 ka).

PALAEOMAGNETIC AND PALAEOONTOLOGICAL RESEARCH IN RAČIŠKA PEĆINA
CAVE, SW SLOVENIA

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Račiška pećina Cave (SE part of the Matarsko podolje, SW Slovenia) at about 590 m a.s.l. consists of simple southwards dipping gallery, which is mostly over 10 wide and 5–10 m high and 304 m long. It was formed in paragenetic or epiphreatic conditions. The studied section was about 13 m long with composite thickness of sampled profile of 552 cm. The lower part (177 cm) is built of 3 sequences, individual growth stages of huge vaulted stalagmites (sequences I to III). They consist of massive but porous speleothems with interbeds of red clays and two angular unconformities. At the top of sequences II and III broken rests of stalagmites are preserved. The second part (sequence IV; 375 cm) consists of subhorizontal laminated, mostly porous flowstones, sometimes with gours, red clays and calcitised silts. Collapsed roof blocks cover clays with finds of fauna (F). The top part is built of huge stalagmites, which were not studied. Standard analytical procedure for detection of palaeomagnetic properties was used: thermal demagnetisation for 18 samples, and alternating-field demagnetisation for 111 samples. The obtained data have high-resolution character with distance of samples in centimetres. Samples of clays from principal clay accumulation were washed. Fossil remains were found in clay layer at the base of sequence IV covered by collapsed blocks from roof. Rodents and rests of probably fresh-water crabs were found. Rodent (vole) rests represented poorly determinable assemblage of fragments of rooted teeth (molars). The character of mammal assemblage, especially rooted form and internal texture of teeth excludes Quaternary age. Determined *Borsodia* (*Lagurini*) – *B. cf. hungarica*, *Mimomys pitymyoides* groups and *Apodemus* (*Sylvaemus*) *cf. sylvaticus* indicate Pliocene biozone MN17 (Villányian, cca 1.8 to 2.4 Ma). The character of speleothems, especially high porosity, can indicate rapid growth in warm and humid climate and syn- and postdepositional corrosion of speleothems. Clay intercalations represent result of floods with allochthonous load. Alternation of normal and reverse polarised magnetozones and palaeontological content enable to fix well our data with the GPTS. The bottom of Olduvai subchron (1.77 to 1.95 Ma) was detected within clay with fauna. Short normal chron just below detected Olduvai bottom is compared with Reunion subchron (2.14-2.15 Ma). The lower part of profile can be compared with dominantly normal polarised Gauss chron (from 2.581 Ma). According to arrangement of individual subchrons, studied profile terminates at about 3.2 Ma. The geometry of subchrons in profile is changed by numerous breaks in deposition especially within sequences I to III. Obtained picture can estimate the duration of individual breaks up to 150-250 ka. This fact can also explain 36° difference in declination values in upper and lower parts indicating paleorotations of the respective tectonic block. Collapsed roof blocks in the clay with fauna indicate some tectonic unrest at about 1.9 Ma.

TRANSIT TIME IN DIFFERENT KARST AREAS IN THE CZECH REPUBLIC: TRACER TESTS AND ISOTOPIC METHODS

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New data on mean residence time were obtained in various karst areas in the Czech Republic. Several environmental tracers were used (tritium, ^{18}O , CFC, SF₆). Selected springs were sampled for ^{18}O between years 2001 - 2003. To assess the transit time of water in unsaturated zone, three distinct drip waters were sampled on ^{18}O in the Ochoz Cave, Moravian Karst. The mean residence time of the prevailing spring component is between 7 to 10 years on most of karst springs except of Bohemian Karst, where it could reach up to 40 years. Malá Chuchle and Čerlinka 2 show the longest residence time (up to 200 years). It could be surprising, that karst environments which differ a lot in degree of exokarst development and geological settings show similar residence times.

The CFCs and SF₆ were used for first time in the Czech Republic as a tool for dating young groundwater. Both methods are applicable in many other areas in the Czech Republic. These two tracers could replace tritium, which potential is nearly finished. The ^{18}O yield considerably underestimated residence time compare to other methods. The comparison of residence time obtained from environmental tracers and tracer tests on 5 springs shows necessity for using both methods for proper describing the whole spectrum of residence times in various parts of karst environment. The long residence time does not mean, that karst conduits with rapid water movement are not present and vice versa. The results of this study can be used for estimation of future trends in nitrates contents on karst springs in the Czech Republic.

EXPLORATIONS IN THE REGION OF KITA GAVRANUSA, VELEBIT MT., CROATIA

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The region of Kita Gavranusa is located in the middle part of the Velebit massif. The specificity of this region is large number of vertical caves on relatively small area, explored to the maximal depth of 400m. During the exploration, some meteorological parameters were measured and biological samples were collected. The ice was found deep in caves and a sample of ice from - 400m was collected for analysis. The exploration was organised by Speleological Section of Mountaineering club Velebit from Zagreb, Croatia, in spring and summer 2003.

DEVELOPMENT OF PARAKARST FEATURES ON LOWER LIASSIC DOLOMITES AND CALCAREOUS-DOLOMITES IN THE LUSITANIAN BASIN (PORTUGAL)

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Most of the meso-cenozoic carbonates rocks that structure the Lusitanian Basin (in the western country-side of Portugal), present karst and parakarst features that started to show up in the sinemurian/lotaringian dolomites and calcareous-dolomites, and finished in the quaternary charges of coal sediments. In the dolomites, the superficial features are represented by few large dolines, karren and some polygenic structural depressions, all buried from earlier detrital autochthonous and allochthonous sediments. The subsurface shows very small intra-strata natural caves related to the presence of fine marl layers. The aquifer is very heterogeneous and, according to the structural features, sometimes it doesn't exist. In lower Liassic dolomites and calcareous-dolomites, the superficial and subsurface carbonate features seem to be attenuated in its expression, in comparison with those of the, so called, *Classical Karst*. For this reason, according to the Anelli's classification (1954), we might be in the presence of a typical range of parakarst features. Their geologic evolution can probably be associated with five important phases, already recognized in other different sectors of the meso-cenozoic Lusitanian Basin:

- 1) In the Jurassic (Dogger, Malm) a complex phase formed dolines and karren;
- 2) In the lower Cretaceous, the whole area was buried by continental sediments;
- 3) In the upper Cretaceous and in the Tertiary, important erosive processes occurred in tropical and sub-tropical climates, that led to the exhumation of paleolandforms, formed new parakarst features and provoked the heaping of red sands in the dolines and karren;
- 4) In the Pliocene the occurrence of a transgressive phase allowed detrital deposits to bury some parakarst features;
- 5) In the Quaternary, sea-level changes provoked new erosive processes and formed new subsurface parakarst features.

"INTEREST OF SPELEOTHEM CARBON ISOTOPES ^{13}C , ^{14}C FOR THE STUDY OF PRESENT DAY CARBON TRANSFER AND FOR THE RECONSTRUCTION OF PAST ENVIRONMENTS IN KARST SYSTEMS"

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The most appropriate way of dating speleothems is undoubtedly the uranium-series methods, especially TIMS or ICPMS U/Th. However, in some specific cases, the quantity of calcite needed for such analyses is too large; this occurs when calcite layers (clean calcite suitable for dating) are too thin (i.e. less than 0.5cm for a stalagmite) or when we need to constrain accurately a specific event such the duration of a hiatus or a laminae sequence. In such cases, the use of ^{14}C for dating might be a good alternative provide the error on the dead carbon proportion (dcp : the carbon which comes mostly from the limestone dissolution) and its variability is well constrained. We have used, a few years ago (Vogel, 1983; Genty et al., 1997-2001), the ^{14}C on modern stalagmites in order to estimate the dead carbon proportion and, thanks to the atmospheric nuclear bomb tests which gave their imprints in the stalagmite ^{14}C activity, we were able to calculate the dcp prior these tests. Results have shown that most

of the carbon that constitutes the speleothem calcite we studied comes from the soil CO₂ (i.e. 80-90%) and that it did not changed significantly during the Holocene. This results has at least tree major consequenses :

- 1) stalagmite dating using ¹⁴C is possible, at least where the dcp of the studied site is well known. This was demonstrated by the good agreement with U/Th results after dcp correction and correction for the initial ¹⁴C activity (calibration);

- 2) any changes in the climate and/or vegetation cover will change the soil CO₂ δ¹³C and, consequently, the speleothem δ¹³C. This explains why, in some sites, the calcite δ¹³C signal responds much better to climate change than the calcite δ¹⁸O one : this is the case of the Villars cave stalagmites (SW-France) where the last deglaciation and also the Dansgaard-Oeschger events of the last glacial period are specifically well marked on the δ¹³C signal (Genty et al., 2002, 2003);

- 3) it is possible to reconstruct past atmospheric ¹⁴C activity up to 50 kyr using speleothems with some assumptions of the dcp variability (Beck et al., 2001, Vogel and Kronfeld., 1997). This is also a way to give an age to palaeomagnetic activity changes.

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DATATION OF CAVE IN CUBA

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In Cuba, in spite of being an eminently karstic country, with a rich but modest history of karstological investigations, the subject of cave dating have been somewhat left behind in respect to others themes of karstological investigations. However, some progress have been made in regards to investigations of the paleogeographic conditions, based mainly on the

correlation of the cave levels and the defined levels of the glacioeustatics movements that have affected the territory in the Quaternary period, and also the analyses of sediment cuts and their correlations. Most of the analysis that have been done have been related to the bones of natives and some cases on the remains of fossil, and to a lesser extent in relation to cave sediments, based upon ^{14}C tests, X-ray diffractions patterns and by the Collagen method, etc. In relation to the dating done by means of isotopic techniques in speleothems, few have been made in order to evaluate the paleoclimatic conditions. In the present work, a thematic historical approach have been adopted in the development of this investigations, making use of a meticulous material search (which were dispersed, and many cases unpublished), with the purpose of contributing to the knowledge of the evolution of the karstological and speleological studies in Cuba.

**CONSTRAINTS ON THE GEOLOGIC HISTORY OF THE KARST SYSTEM IN
SOUTHERN MISSOURI, U.S.A. PROVIDED BY RADIOGENIC, COSMOGENIC AND
PHYSICAL/CHEMICAL CHARACTERISTICS OF SINKHOLE FILL**

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The Ozark Plateaus region of southern Missouri is underlain by dominantly carbonate Paleozoic marine platform rocks. The region has been sub-aerially exposed since the Late Paleozoic and is characterized by extensive karst, which is extremely complex and its geologic history is poorly understood. To better understand the geologic history of this regional karst system, we examined the stratigraphic record preserved in the fill of a large sinkhole near the largest spring in the region. Samples of fill from natural exposures and drill core were analyzed using thermoluminescence (TL) and ^{10}Be cosmogenic techniques, and the physical/chemical characteristics of the fill material were determined by visual inspection, X-ray analyses, and grain-size measurements. Drill-hole data indicate that the sinkhole fill is approximately 36.3 m thick and rests on at least 15.6 m of cave fill. The sinkhole fill is divisible into 6 zones, based on textural, structural, and color variations. The upper zone consisted of loess and reworked loess and is about 1 to 2 m thick. Placed in a regional context, this loess is Late Wisconsinan in age; TL analyses indicate that the reworked loess is from 4.3 to 7.6 ka in age. Underlying this is a reddish-brown clay zone, as much as 6.2 m thick; a 3rd zone (~ 4.6 m) consisting of pale-brown silty clay; and a 4th zone (~ 6.7 m) of light-gray silty clay. Samples of the 4th zone analyzed for fossil pollen were barren. However, subrounded pebbles of black and red chert were recovered from this zone, none of which exist in the local stratigraphic section. Our interpretation is that these ‘exotic’ pebbles are representative of relic Pennsylvanian rocks that once covered the area. The 5th and 6th zones (~ 10.1 & ~7.3 m) consist of pink and deep-red silty clay, respectively; their boundary is gradational and both zones contain mm-scale laminations and localized cross bedding. Analysis of ^{10}Be concentrations suggest that the entire fill was derived from local residuum during the Middle to Late Pleistocene. X-ray diffraction analyses of clays throughout the sinkhole fill indicate that they consist of sub-equal amounts of kaolinite and illite, consistent with terrestrial weathering. Our conclusion is that much of the shallow karst system in the Ozarks has developed during the Quaternary.

DATING CAVES WITH COSMOGENIC NUCLIDES: METHODS, POSSIBILITIES, AND THE SIEBENHENGSTE EXAMPLE

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Cosmic rays constantly bombard the Earth and thus produce a variety of nuclides at and near Earth's surface. The cosmogenic nuclides ^{10}Be and ^{26}Al in quartz are of particular interest, because together they can be used to date sediment burial. The production rates of these nuclides vary with latitude and altitude (and other factors) and are difficult to determine exactly. However, the ratio of ^{10}Be : ^{26}Al always remains approximately 1:6, and so at Earth's surface these two nuclides are present at a known ratio. If sediment containing quartz is washed into a cave, then radioactive decay lowers the concentrations of both ^{10}Be and ^{26}Al . Because ^{26}Al decays more quickly than ^{10}Be , measurement of the $^{26}\text{Al}/^{10}\text{Be}$ ratio indicates the time since the sediment was washed underground.

To make the measurement possible and meaningful, it is important to remember the following: First, the sediment must be irradiated sufficiently prior to burial. Then, upon being washed into a cave, it must be buried deeper than 20-30 m from the surface so that production ceases. Last (and importantly), great care should be taken to know the stratigraphic position of the sediment and its relationship with the cave and other sediments, particularly since sand is highly mobile. This method allows dating of sediments in the age range of 0.1 to 5 Ma under the best circumstances.

Burial dating is only applicable to sediments. However, if a link between the sediment and the cave morphology can be established, the age of the cave itself may be determined. In ideal cases, we can thus constrain valley lowering rates. In addition, if the provenance of the sediment is known, averaged erosion rates of the source area can be estimated.

The oldest cave phases of the Siebenhengste system were dated using cosmogenic nuclides. Eighteen cave samples, plus one sample calibrated by U/Th and one sample from the surface were taken. The results show that the method works well. The oldest sediment is 4.4 Ma and thus proves that the Siebenhengste were karsted in the Pliocene. Within these old passages, however, much younger sands were found, indicating that, unless there are additional constraints, these ages should be interpreted as minimum ages.

URANIUM-SERIES DATING OF DIRTY CARBONATES – IS IT POSSIBLE?

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Uranium-Series method base on Uranium and Thorium separation at the time of clean secondary calcite deposition. But Uranium and Thorium isotopes are commonly incorporated by adsorption, or present as a constituent of the crystal lattice of many materials (clay minerals, ferro-hydroxides, etc). Such materials are likely to be incorporated in Quaternary carbonates. These carbonates are called dirty carbonates. Unlike clean carbonates, dirty carbonates contain ^{230}Th which is not related to the *in situ* decay of ^{234}U . Uranium-series dating of such carbonates involves the application of a correction method to deal with these non-authigenic isotopes.

For many years now, correction methods (Kaufman and Broecker, 1965; Schwarcz and Latham, 1989; Bischoff and Fitzpatrick, 1991) with their respective assumptions have been employed without a profound understanding of some basic chemical information (e.g. U and Th behaviour during acid treatment). Some investigations have been held previously (e.g. Bischoff and Fitzpatrick, 1991) but mainly focused on a method involving the total dissolution of the sample (TSD method). Unfortunately, the TSD method is not applicable with homogeneous samples such as calcite cementation, lacustrine marls etc.

Isotopic fractionation of Thorium has been found when Successive Leaching method is used (Debeane, 2004). The method, based on the leachate alone method (Schwarcz and Latham, 1989), called Full Leaching method (FL method) has been developed. Sometime, mitigate results are obtained for some samples and a question arised: do isotopes behave similarly during the acid treatment involving different kinds of acids? With a view to provide the answer to this question a set of experiments were carried out using prepared mixtures of calcite and clay minerals standards (illite, kaolinite and montmorillonite).

Some of the most surprising results are that (1) the level of contamination is strongly dependent upon the mineralogical composition of the detritus (the highest contamination occurs for mixtures with montmorillonite and the lowest contamination for mixtures with kaolinite). (2) The Bo method is completely unreliable because of the uranium contamination. (3) With 10% of clay content the kaolinite mixtures present an activity ratio $^{230}\text{Th}/^{232}\text{Th} > 20$. Such a ratio is generally an indicator of still pure sample. Then, a $^{230}\text{Th}/^{232}\text{Th}$ isotopic ratio higher than 20 is not a valuable proof for calcite purity and should not be used as a criterion for applying a correction method. (4) Depending on the nature of the detritus, the corrected ages obtained with isochrones method are different but always younger than the real age of the clean calcite. Finally (5), analyses have proved that the isochrones method should not be interpreted in terms of a two-component model (calcite – detritus) but in terms of a tri-component model (calcite – detritus adsorbed species (U and Th) – U and Th in the mineral lattice). This model explains the discrepancies of the isochrones ages obtained in this study.

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RELATIONSHIP BETWEEN PEBBLE DIMENSIONS AND SYPHON LENGTHS IN POSTOJNSKA JAMA, SLOVENIA

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In purely phreatic conditions “syphon” (drowned passage) lengths depend upon the relationships between the positions of inception horizons, fracture locations and the general flow direction along the local hydraulic gradient. If the underground river carries a substantial particulate load, it will gradually fill the lower parts of the tier with sediments. In such cases

paragenetic (antigravitational) erosion will tend to eliminate down-loops, eventually bringing about tunnel-like, epiphreatic passages. The dynamics of channel adaptation thus depends heavily upon the erosional capability of the water. In Postojnska jama, a negative correlation between pebble dimensions and syphon lengths, relating to the distance from the cave entrance (ponor), is immediately apparent to the naked eye. The present study sets out to express the qualitative visible relationships in quantitative terms. Sediment samples were collected along the cave streamway, but not within the syphons themselves, and pebble dimensions and syphon lengths were both first related to the distance from the cave entrance. Based partly on published data and partly on our own pebble size measurements, the following relationships were obtained: *pebble diameter [mm] = -0.00688 × distance from the entrance [m] + 21.7610* and *syphon length [m] = 0.1655 × distance from the entrance [m] – 389.8444*. By combining the two equations the complementary *distance from the entrance* components were eliminated, providing a direct relationship between *syphon length* and *pebble dimensions*. It thus transpires that *syphon length [m] = -24.05902 × pebble diameter [mm] + 133.7037*. In all cases, correlation values are quite high. Among several possibilities that vary only in detail, two broader explanatory hypotheses can be suggested. Hypothesis 1: Syphons become shorter due to the abrasive power of the entrained stream load. Provided that the sediment flux through the cave is constant, any decrease of pebble diameters would lead to greater loads of suspended sediment. Therefore, any correlation between syphon lengths and distance from the entrance would be positive. Hypothesis 2: Syphons become shorter due to erosion related to the impacts of saltating load against drowned conduit ceilings. As both the dimensions and kinetic energy of the pebbles decrease, their abrasive power is also reduced. In this case, correlation between syphon length and distance from the entrance would be negative. Conclusion: The second hypothesis is more reliable, and syphons are gradually eliminated due to erosion by saltating sediment particles.

BIOSTRATIGRAPHIC DATING OF CAVE SEDIMENTS: SCOPE OF THE APPROACH, PROBLEMS AND SHORTCOMINGS

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In contrast to instrumental methods, the biostratigraphic dating is quite cheap as a rule and often also more universal, more versatile and sometimes even more reliable. All these qualities, in particular the reliability of a biostratigraphic datum, are very sensitive to respecting several prerequisites to the biostratigraphic method. Their major components were discovered more than 200 years ago, in time when biostratigraphy opened a gate to the dating of geological past. C.Lyell expressed the major prerequisites exactly in form of the basic principles of historical geology (superposition, index fossils, faciility, actualism), the further prerequisites concern the way of their applications at a current act of the dating effort, of course.

An act of the biostratigraphic dating proceeds in several steps: (a) extraction and identification of fossil remains and gathering all supplementary information on the record to be dated (lithologic context, taphonomy etc.), (b) correlation of the respective information and the diagnostic characters of particular units of a biostratigraphic system operating with the respective group of fossils (i.e. LAD and FAD of particular index fossils, community structure etc.), and (c) consensual analysis of the biostratigraphic information reconsidered in respect to actual magnitude of the biostratigraphic signal of the record under study and its possible meaning, and (d) final estimation of possible maximum and possible minimum age

of the fossil and its integration into the lithostratigraphic context of the site and dating of the respective deposit, fossilisation or karstification events.

Each of these steps includes different methodological and conceptual requisities and, at the same time, it may bias the proper dating effort in quite a serious way. Reliability of a datum depends not only on richness and quality of the actual fossil record and /or its taxonomic treatment but at the same time on qualities of the biostratigraphic system, reality of its units and applicability of its criteria as well as on the reliability of the lithostratigraphic mapping of the site and techniques of sampling and extracting fossils. The present contribution discusses some details of the requisities and provides several case examples (some cave deposits of the Late Cenozoic age mostly from Central Europe).

¹⁴C DATING OF CARBONATE DEPOSITS IN THE DINARIC KARST

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¹⁴C dating of carbonate deposits in form of speleothems in caves, tufa in river water or lake sediments is based on the fact that a large part of their carbon is of biogenic and/or atmospheric origin. Three factors affect the accuracy and reliability of the ¹⁴C age of carbonate samples: 1) the initial ¹⁴C activity (Ao) of the carbonate defined as the ¹⁴C activity of carbonate sediments at the moment of precipitation, 2) the degree of contamination with allochthonous calcareous deposits and 3) the effect of carbon isotope exchange during the aging of the deposits.

The results of ¹⁴C dating, of tufa, speleothem and lake sediment samples collected at the Dinaric Karst area of Croatia and Slovenia will be presented. The ranges of ¹⁴C ages recorded by Holocene speleothems (~12 000 yr) is wider by several thousand years than that of Holocene tufa samples (~6000 yr). The $\delta^{13}\text{C}$ values for tufa samples range from -12‰ to -6‰ and for speleothem samples from -12‰ to +3‰ in the Dinaric Karst, indicating that influence of soil carbon and/or vegetation impact is more significant for tufa than for speleothem formation. The $\delta^{18}\text{O}$ for tufa samples range from -11‰ to -6‰ and for speleothem from -8‰ to -4‰. The difference here is a consequence of the different stable isotope composition and temperature of waters from which the calcite precipitates.

Isotope analyses, including $\delta^{13}\text{C}$, $\delta^{18}\text{O}$ and ¹⁴C age values, of tufa, lake sediments and speleothems in the Dinaric Karst confirm that these deposits record environmental and climatic information. While speleothem is a good indicator of global climate and palaeoclimate changes, tufa is a more sensitive indicator of palaeoenvironmental changes.

DATING OF CAVE DEPOSITS AND RECONSTRUCTION OF KARST MORPHOLOGY OF THE NIZKE TATRY MTS (SLOVAKIA)

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Large cave systems were created by subsurface streams in Triassic carbonate sediments forming the N slopes of the Nizke Tatry Mts. Up to eleven horizontal cave levels occur at different altitudes in the Demanovská, Janská and Mošnická karst valleys. The caves were filled with allochthonous sediments transported by streams from an area formed by granite in dependence on deepening of the karst valleys. The fluvial cave sediments are intercalated with, or capped by, flowstone layers in the sedimentary sections. Based on the obtained paleomagnetic polarity data, measured both in clastic and chemogenic cave deposits, we are able to distinguish sediments deposited during the Brunhes (<780 ka), Matuyama (780–2,581 ka) and Gauss (2,581–3,580 ka) chronos. The stratigraphic interpretation is partly verified by U-series datings of speleothems (Th/U, U/Pb methods). Except for the horizontal cave levels located in the mentioned karst valleys, additional cave systems were formed at extremely high altitudes in the Nizke Tatry Mts. Based on predominantly reverse paleomagnetic orientations we suppose the deposition of fluvial sediments in these caves during the Gilbert Chron (>3,580 ka). The magnetostratigraphic interpretation concerning the age of sediments deposited in the extremely high elevations is verified by cosmogenic isotope datings of quartz pebbles transported by ancient streams into the caves.

Development of cave levels and subsequent deposition of fluvial cave sediments should be related with mountain uplift. Therefore, thermal and uplift history of the Nizke Tatry Mts. was reconstructed based on fission-track analyses in apatite from granites formed the crystalline core of the mountain. Based on the thermal history model two distinctive periods of carbonate exposure connected with karstification were distinguished in the latest Mesozoic and during the late Cenozoic, respectively). The proposed magnetostratigraphic interpretation allows us to estimate the rate of vertical erosion (incision rate) in karst valleys of the Nízke Tatry Mts. during their Cenozoic development: 0.05 m/ka in the time period of 2,581–1,950 ka, 0.06 m/ka in the period of 1,950–1,070 ka, 0.32 m/ka in the period of 1,070–780 ka and 0.04 m/ka in the period between 780 ka and the present.

FURHER DATES OF HEAVY METAL CONTENT ON THE SOIL AND VEGETATION OF AGGTELEK KARSTS (HUNGARY)

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During the previous investigation of the Aggtelek karsts we published physical and chemical parameters of the soils and the microelement content of the greenery. The presentation now gives further information about the soil (eg. EDTA soluble heavy metal content), and the greenery (more species, more elements). The poster presents the relationship between the heavy metal content of the karstic soil, and the sprout of plants.

APPLICATION OF VIDEOOMETRY IN RECOGNIZATION OF KARST FEATURES.

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Because of some reasons, discharge of water wells will be reduce normally 7 to 10 years after drilling. The reasons, which influence on reducing water wells discharge, could be as: Aquifer groundwater drawdown, screen obstruction by sedimentation of minerals, sedimentation of minerals in the Karstic caves and caverns and between the voids of gravel - packing.

Videometry could be used in recognition of the se factors. Videometry also shows the Karstic features in water wells, which drilled in Karstic areas. By this new method you can see the joints, fractures, caverns, caves and the other karstic features.

Recharges and discharges zones in the wells, also could be recognize by this method. It is possible to design the injection mantle in dam's foundations by videometry. This paper shows some of videometry samples, which used on drilled karstic water wells in Iran.

URANIUM-SERIES DATING OF CAVE DEPOSITS

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Uranium-series dating is probably the single most important geochronological method used on cave deposits. The method is based on daughter ingrowth of members in the ^{238}U and ^{235}U decay series, of which the $^{230}\text{Th}/^{234}\text{U}$ system is the most widely used. U- series dating can be applied to most secondary minerals which form a closed-system phase. First of all, this applies to carbonate and sulphate speleothems and diagenetic concretions. However, radon-daughters (e.g. ^{210}Pb) may be used as ventilation tracers and dating of very young deposits. The principles of each method and applied examples will be presented.

$^{230}\text{TH}/^{230}\text{U}$ DATING OF THE AMATERSKA SPELEOTHEM AM6, MORAVSKI KRAS, THE CZECH REPUBLIC

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In 1995, several speleothems were collected for chronological purposes in the Amaterska cave system of the Moravský Kras in the Czech Republic. Some of the samples were already broken, like the 3 m long AM6 sample, a complete broomstick stalagmite that have seemingly grown continuously up through the whole Holocene. The sample, which was broken in many smaller pieces, was reassembled, cast in plaster blocks and cut into longitudinal wafers for analysis. The sample proved to be of good quality, with few vugs and

holes, and it displays well-developed opaque and dense laminae of 1-2 mm period. Alpha particle dating of the base, middle and top section suggests that the sample represents a continuous growth record during the last 9.14 ka over a stratigraphic length of 2650 mm. This corresponds to an average growth rate of 0.29 mm/year, or approximately 3 years per millimetre. The specimen then offer annual or even seasonal resolution to proxies that can be tied to the stratigraphy. The sample contain 0.2 – 0.5 ppm uranium. We have commenced a detailed TIMS dating program, aiming at dating every 50 mm of the sample.

SEDIMENTOLOGY AND STRATIGRAPHY OF VELA CAVE - PRELIMINARY RESULTS (ISLAND KORČULA, CROATIA)

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Location and geological setting: Vela Cave (Vela spila in original) is located in the hinterland of Vela Luka town, 130 m a.s.l. This single-chambered cave of Vela Spila today represents only the remnant of once a large system. It has been developed within a fault zone in upper Cretaceous limestones, which are thin to thick bedded and gently dip (20-25°) northwards.

Sedimentology: First detailed sediment logging has been conducted in 2002, on two earlier excavated archaeological sections. Section-1 is 5.5m high and 2m wide and Section-2 is 4m high and 6m wide. Samples were taken for grain-size analysis, petrographical and chemical analyses. Deposits are in general very poorly sorted and are represented by alternating clayey sands or gravels and open-work rock debris layers with more or less infiltrated silt or sand. At several levels there are accumulations of cobble-size rock debris. Fossil bone debris occasionally represents over 30% of bulk sample. Several layers are composed only of bones and rock debris and very little infiltrated clayey silt or sand. Carbonate content is very low in fine-grained layers, commonly 5 - 20%, rarely 30-50%, while modal analyses showed domination of amphibole-pyroxene-epidote-quartz mineral association. In Section-1 there is a volcanic ash layer, 2-10 cm thick, composed of 95% altered volcanic glass shards. Preliminary insight of the Vela Cave sediment sequences indicates on very complex depositional history.

Fossil fauna: Preliminary analysis of vertebrate fossil content through sections shows changes in human economy and hunting strategies. Transition between periods are very good defined, providing biostratigraphic zones that correspond with stratigraphy and radiocarbon dating.

Stratigraphy: During earlier archaeological investigation of Vela Cave, samples of bones and charcoal have been taken for radiocarbon dating. C14 dating enabled division of four cultural periods Epigravettian, Early Mesolithic, Late Mesolithic and Neolithic which correspond to Late Pleistocene and Holocene. One of the archaeological layers in Section-1 yielded calibrated age of 13.500-11.900 BC (VERA-2346). Immediately above this layer there is the volcanic ash layer. It was defined by the X-ray diffraction analysis of global sample, chemical analyses and microsonde. The quantitative analyses of chemical composition (microsonde) performed on vulcanoclastic particles separated from the global sample showed undoubtable compatibility with pyroclastic products dispersed over Mediterranean by explosive eruption of Napolitan Yellow Tuff (NYT) in Campi Flegrei

14.000 years ago. The ANYT@ layer of Vela Cave was determined in this region for the first time. Thus, it represents an excellent regional chronostratigraphic marker and could probably be traced in other locations.

DATING OF THE CAVE SEDIMENTS WITH A RELATIVE GEOMORPHIC DATING METHOD – CASE STUDIES IN SLOVENIA

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Geomorphic dating methods are based on comparison between surface features of known age, processes of known intensity or specific past processes of known duration and cave sediments. This method gives only a rough estimation of the age or only the succession of events.

The method is used as a first approximation of the sediment age or when the sediment cannot be dated with other methods. It can be used independently or in combination with other methods, for instance for normal or reversal time estimation for paleomagnetic dating. Several cave sediments and caves were dated by this method in Slovenia. Here we present three case studies where the method was used.

On the Kras plateau several unroofed caves that were filled with sediments were studied. In the unroofed cave near Povir several metres thick sequence of fluvial sediments, deposited in underground was exposed. Layers of well-rounded gravels and sands were interrupted by layers of flowstone on which stalagmites are grown. On the walls of the unroofed cave scallops and eroded flowstone are preserved.

We estimate the age of the fill of the cave using the denudation rate of the surface, which is according to several authors between 20 -60 m/Ma. We presumed, that there was about 100 m of the rock removed from above the cave since it was filled. The age of the sediment is therefore between 1.5 – 5 Ma. Later the paleomagnetic dating of the similar sediments in vicinity confirmed the estimated age.

In the Alps remnants of horizontal caves can be found. In two of such caves fluvial allochthonous sediments were found. In Snežna jama, on the Raduha mountain (2062 m) more than 10 m thick sequence of laminated clays, sands and well-rounded pebbles to 3 cm in diameter are preserved. Pebbles are made of the upper Oligocene andesite tuffs. Thick flowstone, probably deposited after the fluvial sediments, was dated by paleomagnetic method to be 1.8 – 3.6 M or 3.0 – 5 M years old.

In similar altitude, 1500 and 1600 m a.s.l in Potočka zijalka among the autochthonous cryoclastic gravels, well-rounded allochthonous pebbles of the Miocene limestone and marl can be found.

Sinking rivers formed both caves. Allochthonous sediments in them were deposited before the main tectonic uplift of the Alps that caused downcutting of the surface river valleys for about 900 m and the disintegration of the old contact karst relief. The uplift started after deposition of pebbles of Miocene rocks and before the deposition of the flowstone.

There are hundreds of sinking streams in Slovenia. Most deposited thick sequences of fluvial sediments in blind valleys and caves. As today the streams are eroding the sediments it is obvious that the sedimentation took place during specific climatic conditions, when the production and transport of gravels was larger than today. Such conditions were met during the last glaciation.

In Matarsko podolje contact karst area in Mitjeva jama stalagmites grown on the fluvial sediments and frost-shattered gravels were dated. They start to grow at about 15 - 12

ka before present and they show traces of floods in their lower part. Thus we can asses the end of fluvial sedimentation, cryogenic processes and the beginning of flowstone deposition. The same type of sedimentation change occurred in other caves in the area and can be used as a good morphologic age estimation signal.

OLD HUMAN BONES ASSOCIATED WITH ANIMAL FOSSILS IN A ROMANIAN CAVE

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Several pieces of human skulls of three individuals were discovered in a Romanian cave. Located near the Danube, the cave contains an important deposit of animal bones, especially *Ursus spelaeus*, very well preserved because the natural entrance into the cave collapsed a long time ago. The human bones were dated at 34.000-36.000 BP, as the oldest directly dated modern human remains in Europe. Moreover, the individuals - a man, a woman and an adolescent - show a mixture of modern, archaic and possibly Neandertal features not described until now on humans of similar age, providing new insights for the emergence and the evolution of early modern humans in this part of the world.

STABLE ISOTOPE (O, C) COMPOSITION OF SPELEOTHEMS – IS IT PALAEOENVIRONMENTAL RECORDS?

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Carbon isotopic composition changes in speleothems calcite are usually interpreted as results of palaeovegetation activity changes. Oxygen isotopes composition reflects palaeoclimatic, mainly thermal, conditions. Two basic questions arise: the first is if speleothems can be used as a palaeothermometer and the second if carbon isotopic composition is a function of vegetation intensity.

The results of stable isotope (O and C) analyses of several Holocene stalagmites from Tatra Mts. and Low Tatra Mts. caves are presented. The stalagmites were dated by the U-series method using alfa spectrometry and TIMS techniques.

The comparison of results for the samples from different areas shows only minor variation in Oxygen composition within a range of 1‰ and a striking similarity in their records. Palaeoclimatic events of Younger Dryas and 8.2 ka event are recorded.

The significant differences of Oxygen composition (ca. 1.5 ‰) in the samples from stalagmites of equal age collected in Czarna Cave (Tatra Mts.) show a problem with using of Oxygen record as a direct palaeotemperature indicator because of local water circulation path changes.

Much stronger variation of $\delta^{13}\text{C}$ is recorded because it reflects changes in local vegetation activity rather than global climatic changes. Possible reasons of $\delta^{13}\text{C}$ variation are changes in biogenic CO_2 content or/and slow CaCO_3 deposition and isotope exchange between cave atmosphere CO_2 and solution CO_2 . It is possible to use $\delta^{13}\text{C}$ record as a palaeovegetational indicator basing on the strong sensitivity of carbon isotopic ratios to

vegetation activity at the surface above the cave. Generally, lighter carbon indicates periods of intensive vegetation and higher carbon dioxide production in the soil.

DATING ANCIENT CAVES AND RELATED PALAEOKARSTS

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There are few cases of open caves that have been reliably dated to ages greater than 65 Ma. This does not mean that such caves are extremely rare, although they may be uncommon, rather it is difficult to reliably establish that a cave, or palaeokarst related to a cave, is this old. Relative dating methods such as: - regional stratigraphic, lithostratigraphic, biostratigraphic, relative, climatic, relative isotopic, morphostratigraphic, and regional geomorphic are very useful for dating ancient caves and palaeokarsts. These methods suffer however from significant difficulties and their results lack the impact of a crisp numerical date. While many of the methods used to date younger caves will not work over the required age range, some isotopic methods and palaeomagnetic methods have been applied with varying degrees of success. While finding something to date and having it dated is difficult enough, producing the date is rarely the end of the story. The difficult issue is not the date or relative correlation itself, but what the date or correlation *means*. Demonstrating that caves are ancient seems to rapidly become beset with the old adage that “extraordinary claims require extraordinary proof”. The presence of a well-dated or correlated sediment (or anything else capable of being dated) in a cave does not necessarily (or ever to some critics) mean that the cave is that old or older. Perhaps the dated material was stored somewhere in the surrounding environment and deposited much more recently in the cave. A lava flow in a cave must be demonstrated conclusively to be a flow, not a dyke or a pile of weathered boulders washed into the cave. It must be conclusively shown that dated minerals were precipitated in the cave and not transported from elsewhere. Meeting this burden of proof is a major challenge, but it can be done. There seems little doubt that in the future more ancient caves, or ancient sections of caves, will be identified and that as a result our perception of the age of caves in general will change.

ANALYSIS OF CAVE DISTRIBUTION ON THE HOCHSCHWAB MASSIF (STYRIA, AUSTRIA)

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The Hochschwab is one of the major karst massifs of the Northern Calcareous Alps (NCA), situated in the north of the Austrian province of Styria and provides freshwater for the city of Vienna. Detailed (1:5000) karstmorphological mapping of 44 km² of its plateau brought the discovery of 770 new caves. Together with formerly recorded caves and possible caves detected on aerial photographs a total of 1284, mainly vertical objects are integrated into a GIS. In combination with additional digital datasets, statistical analyses are performed considering the spatial distribution of cave density as well as the dependence on altitude and lithology.

The investigated caves are mainly pits and vertical canyons which developed in the vadose zone. Phreatic cave levels associated with former valley floors, which are common in the NCA, do not exist in the Hochschwab. A few caves of phreatic origin developed above aquitard geological units. The average cave density in the investigation area is 24 objects/km². In glacially strongly overprinted areas it increases to more than 400 caves per km². Remarkable facts of the dependence on lithology are that the limestone of the Dachstein Formation does not show an increased cave density. In contrast, the diverse facies of the limestones of the Wetterstein Formation exhibit major differences.

PRINCIPLES OF PALAEOMAGNETIC AND MAGNETOSTRATIGRAPHIC METHODS APPLIED TO THE CAVE SEDIMENT DATING

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Paleomagnetism is the study of the magnetic properties of rocks. It is one of the disciplines in geophysics, having uses in diverse fields such as geomagnetism, tectonics, sedimentology, volcanology, paleontology and paleogeography. One of the underpinnings of paleomagnetic endeavors is the relationship between the magnetic properties of rocks and the Earth's magnetic field. When a rock forms it usually acquires the magnetization parallel to the ambient magnetic field referred to as primary magnetization. This can give information about the direction and intensity of the magnetic field in which the rock was formed. The magnetization first measured in the laboratory is called natural remanent magnetization (NRM). The mechanism by which NRM is required depends upon the mode of formation and subsequent history of the rocks as well as the characteristics of the magnetic minerals they contain. To distinguish the primary and secondary magnetization, paleomagnetism apply various demagnetization procedures to the NRM. The two most commonly used techniques are alternating field (AF) demagnetization and thermal demagnetization (TD). In palaeomagnetic studies the direction of magnetization of a rock sample is specified by declination and inclination. Therefore, the palaeomagnetic directions may record of tectonic rotation for the region, as well as paleosecular variation. Rocks whose magnetizations are in the same sense as the present field are termed normal (N), whilst in the opposite sense are reversed (R).

Palaeomagnetic studies of cave deposits can serve as helpful tool to interpret the age of cave sediments as well as to understand the evolution of karst. The aim of such studies is to determine the principal magnetic polarity directions both in clastic and chemogenic deposits, to compare them with geomagnetic polarity timescales (GPTS), and to prepare data for the stratigraphic correlations of studied sections. Palaeomagnetic studies conducted in caves are concentrated with determining the age of the sediments based on magnetic polarity (magnetostratigraphy) and/or paleosecular variations, and on palaeoenvironmental applications of mass-specific magnetic susceptibility. Relative ages could then be obtained by applying the well-known principles of stratigraphy, and this approach is referred to as magnetostratigraphy. One or more absolute ages usually also required to compare a magnetostratigraphic section to a magnetic anomaly sequence. In caves, palaeomagnetic studies have been applied principally to fine-grained deposits (fine-grained sands, silts, clays) and some speleothems.

Dating of cave sediments by the application of palaeomagnetic method – magnetostratigraphy – represents a highly difficult and sometimes risky task, as the method is

comparative in its principles and does not provide numerical outputs. The magnetostratigraphic method for dating clastic cave sediments and speleothems has been limited by the complex conditions underground and it is often necessary to combine it with other methods offering supplementary numerical-, relative- or correlate-ages. The application of complete palaeomagnetic analysis, both of TD and AF, only to pilot samples and shortened selected field/step approach to other samples did not offer sufficient data set for interpretation. It is necessary to apply a complete demagnetization process to obtain reliable data. The magnetostratigraphic studies from the Classical Karst (Slovenia), Slovakia, Italy and Czech Republic indicate, that without the help of other dating methods, especially biostratigraphy and/or numerical dating, any correlation of obtained results cannot be explicit. Magnetostratigraphic results indicate also some important interpretations of speleogenetical processes and correlation of cave levels with river terraces.

PALAEOMAGNETIC RESEARCH OF CAVE SEDIMENTS IN KRIŽNA JAMA, PLANINSKA JAMA AND POSTOJNSKA JAMA: PRELIMINARY RESULTS

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In 2003, sampling of cave fill from several caves in the Classical Karst for palaeomagnetic analysis was performed. Standard palaeomagnetic analyses were used (thermal and alternating field demagnetisation, magnetic susceptibility measurements, etc.).

Classical *Ursus spelaeus* site in Medvedi rov in Križna jama was studied. Profile consists of alternation of clays and silts with speleothem layers underlain by laminated ochreous clay (170 cm). Short reverse polarised magnetozone was found in basal laminated clays below principal speleothem layers and bone-bearing beds. Prevailing normal polarisation of profile indicate position within the Brunhes chron (< 780 ka).

Rudolfov rov in Planinska jama contains profile (225 cm) of ochreous silty clays interlaminated by silts and fine-sandy silts and sands, locally with cross bedding, in lower part with ferruginous laminae. Lamination is of turbiditic type with erosional bases of sandy laminae. Deposition is expected in calm environment of cave lake from suspension. No reverse polarisation was found. It seems that profiles can be dated within normal polarised Brunhes chron (< 780 ka).

Spodnji Tartarus in Postojnska jama contains profile (285 cm) composed of clays, reddish brown at base and ochreous in upper parts interlaminated by sands and silts, with local sandy intercalation in the lower part. At top entrenched cut is filled with brownish red clays. Deposition is expected in calm environment of cave lake or on dammed flood-plain from suspension repeating after deep erosion. Two samples showed reverse polarisation within normal polarised background. Prevailing normal polarisation indicates preliminary interpretation within the Brunhes chron (< 780 ka).

In corridor from new entrance to Biospeleološka postaja in Postojnska jama about 2 m high profile was uncovered: partly calcite-cemented coarse-grained debris at base (95 cm) covered by gravel (4 cm) and sequence of clays and loams (brown and reddish brown) with horizon with limestone clasts and blocks (106-60 cm from the profile base). Two layers of flowstone with clay interbed terminated the profile. The profile showed only normal polarised magnetisation, which is in accordance to expected age of deposits.

Umetni tunnel in Postojnska jama represents the artificial connection to Črna jama. Tunnel cuts several palaeokarst passages filled with material derived from Eocene flysch of the Pivka Basin. Sequence (130 cm) of fine- to medium-grained sands, sometimes with clayey matrix and flat clasts of clays and distinct cross bedding overlain by clays and sands. At 21 cm from the top, plane of unconformity is clearly marked by surface enriched in Fe- and Mn-rich compounds. Sediments are disturbed by slinkenslides. Our data showed short normal polarised magnetozone at the top of clay below the stained surface, which can be preliminarily correlated with Jaramillo subchron (cca 0.99-1.07 Ma; reverse Matuyama chron).

PALEOMAGNETIC DATING IN CAVES OF THE APPALACHIAN OROGEN, NORTH AMERICA

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The Appalachian Mountains, including an eastern foldbelt and a western plateau region, make up a linear belt about 1600 km long and 250 km wide in eastern North America. Many caves are known, and are developed in carbonate rocks of Cambrian through Carboniferous age. In the late 1960's Victor Schmidt (University of Pittsburgh, Pennsylvania) began to investigate paleomagnetic dating of clastic sediments in the caves of West Virginia. He later expanded his work to the Mammoth Cave region of Kentucky, where he used this method to calculate an incision rate for the base level stream (Green River). In the 30 years following, paleomagnetic dating of cave sediments has been used by a number of geologists to increase knowledge of cave development and landscape evolution in the region. Similar techniques have also been applied with great success throughout the world. The method is desirable because it 1) is relatively inexpensive, 2) does not disturb speleothems, 3) does not require extensive laboratory work, and 4) addresses timescales (0 to 4+ Ma) that include speleogenesis. Difficulties with the method can be 1) minimum and relative, not absolute dates, 2) paleohydrologic complexities, 3) lack of suitable sediments, and 4) stratigraphic incompleteness.

We have collected hundreds of samples, and have almost always had good results. Measurement is usually made with a superconducting rock magnetometer housed in a shielded room. Even samples that are extremely weakly magnetic can be used this way. Although we usually sample from laminated silt and clay layers, we have also had success collecting from cross-bedded sands, and from small clay pockets in between gravel/cobbles.

In Butler Cave, Virginia, an active cave stream flows through extensive indurated gravels that were thought to represent modern fluvial activity. Sampling showed that these deposits were magnetically reversed, indicating that sedimentation in the cave is episodic (possibly climate controlled), or that hydrologic reactivation had occurred. In Organ Cave, West Virginia, finely laminated clays were found in a small, high-level, phreatic cross passage that bears no hydrologic relation to the present day cave. The reverse clays are found on top of normal clays, providing a minimum age of 980 ka for the cave, and illustrating fluctuations in surface drainage (sinkhole input) above the cave. In the Obey River Gorge, Tennessee, sampling in several caves was used to determine a maximum incision rate of 0.04 m/ka. Recent sampling in the same area by other researchers using cosmogenic isotope methods has reduced this estimate to 0.03 m/ka.

THE QUERCY CAVE FILLINGS OF SW FRANCE; THEIR FOSSIL DATED SUCCESSION SINCE EARLY EOCENE TO QUATERNARY TIMES

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In the NE part of the Aquitaine basin (SW France), the Quercy region extends as a wide carbonate platform between a continental Tertiary subsiding basin on the SW side and the old basement on the NE side. The platform is composed of thick horizontal marine Jurassic limestones. This area evolved to become a continental environment during the Cretaceous, this process being achieved by Senonian times. Intense alteration, erosion and karstification occurred during the Maastrichtian and Paleocene. The karst elaboration continued throughout the Paleogene, resulting in a typical landscape with underground systems of linked pits and galleries. Depending on the evolving water table, the karst voids were successively either filled with various materials, or more or less emptied by intense erosion which also enlarged the underground systems. This resulted in a long polyphased karst filling process. Due to local conditions, a significant proportion of previous fillings were preserved.

The karst filling materials are varied in nature. The major components are brown to red clay minerals, variably associated with phosphates, sands, gravels, limestone clasts, and including various surface alteration materials. Associated with these are numerous fossil remains of continental organisms, most representing land vertebrates of various kinds and size (amphibians, reptiles, birds, mammals).

As soon as the rich phosphate mineral contents of the Quercy fillings were discovered (close to 1870), intensive quarrying began and lasted until the beginning of the 20th century. Many hollows were emptied for fertilizer production. This also resulted in the exhumation of abundant fossil material. Unfortunately most if not all of these fossil collections were mixed together and so the question of their geological age remained artificially obscured.

Modern field studies in the Quercy paleokarst began in the 1960s. These concentrated on the remaining fillings: exploration in the quarried caves, observation of local conditions, and then specialized studies of the fossil material recollected *in situ*. Natural groups represented were studied. Although now reduced, this process still continues in the field and in the laboratories.

Studies soon showed that the Quercy clay fillings, carefully considered one by one, are well characterized in age by their homogeneous fossil assemblages. Some rodent and ungulate lineages with high rates of evolution allow faunas to be distinguished through time with high resolution. Information from different groups help cross-check dating results. A recent method produces theoretical numerical ages, by considering size increase in several lineages simultaneously.

Currently the Quercy paleokarstic fossil remains provide evidence of faunas since the early Eocene (3 faunas, the oldest relating to MP 8+9 of the European mammal scale, the others of MP 10), the middle Eocene (7 faunas representing MP 13, 14 and 16), late Eocene (all of 5 MP, each represented by several faunas), early Oligocene (all of 5 MP well represented, one of them by 16 distinct faunas), late Oligocene (only represented for two of 5 MP) and early Miocene (MN3 zone represented with one fauna). More than 130 different Quercy localities with Tertiary fossils, most of which are well dated, are now known. The Plio-Quaternary period was active in the Quercy with intense uplift then karstic renewal and fillings. This mostly occurs in relation to previous systems, and superficially removes their Tertiary fillings. Vertebrate fossils are also associated with this latest karstic phase.

The overall available fossil data from Quercy has valuable bearing on the biochronological record for Early Tertiary continental deposits in Europe, which can be considered of world class, possibly the best at the present time.

A THEORETICAL APPROACH TO ESTABLISH THE DURATION OF DENUDATION ON LIMESTONE SURFACE WITHOUT SOIL COVER

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The lecture deals with the question how the duration of karstic denudation on open, sloping limestone surface without soil cover and plane at the outset depends on the dip angle of the area, the yearly amount of precipitation, the intensity of the rains, and on prevailing wind direction and speed. The answer is given by the solution of a differential equation system describing the sinking speed of the rock surface. It turns out that the speed of denudation does not increase in proportion to the intensity of precipitation and can never exceed a maximal value; long, quiet rains result in yearly greater denudation than short, abundant downpours; with increasing speed of wind the speed of dissolution increases also, but above a certain wind speed dissolution does not become faster. The lecture exemplifies with numerical calculations and diagrams how these factors affect the expectable duration of denudation.

COMPARISON OF ^{14}C AND U/TH MC-ICPMS DATING OF SPELEOTHEMS FROM SUBMARINE CAVES IN THE ADRIATIC SEA (CROATIA)

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In order to reconstruct relative sea-level changes on the Eastern Adriatic Coast, 16 samples of speleothems were taken from 7 submerged speleological objects in depths of 1 to 41 m. Dating of last surface layer of speleothem, as a typical subaerial feature, should provide the time when speleothem was still under the vadose condition i.e. above sea level, whereas the age of the initial part of marine overgrowth that covers the submarine speleothems should indicate the time of establishment of marine conditions. The combined data should help to reconstruct the sea level changes.

Nine speleothems were dated by the conventional ^{14}C method and ages of nine speleothems were measured by U/Th MC-ICPMS method (two of them were measured by both methods).

Results of both methods indicate relatively big time gap between cessation of speleothem growth (83 ky - 17 ky BP) and commencement of marine overgrowth (12 - 2.4 ky BP). This discrepancy could be a consequence of both, environmental settings (changing of vadose conditions to freatic, and then to marine ones), and employed dating methods. Prevalence of stalactites over stalagmites (which offer better insight into growth layers) in investigated submarine objects was the first problem encountered already in the sampling phase. Moreover, different geological, and especially former and present hydrogeological settings of some submarine objects could adversely influence the pattern of coastal submersion. The results will be discussed taking into account unknown initial activities and different factors that can influence on ^{14}C and $^{230}\text{Th}/^{234}\text{U}$ age, respectively. Possible sources of contamination of submerged speleothems will be considered: a) presence of detrital material in speleothems originating from the period of speleothem deposition, b) subsequent

contamination caused by boring organisms from the marine overgrowth from the period within marine environment.

Due to a small amount of carbonate samples for U/Th MC-ICPMS method (100-300 mg per analysis) dating by this method provided much better age resolution of single speleothem layer than conventional ^{14}C method (requiring ca. 30 g per analysis). In the same time, U/Th method is much more sensitive to the initial contamination by detritial material.

However, each of this methods has its advantages and disadvantages, and possible solution can be expected by employing ^{14}C AMS method, which encompasses advantages of both methods used up today on Croatian submerged speleothems.

**CONTRIBUTION TO THE KNOWLEDGE ABOUT THE CONTENT OF HEAVY
METALS (Pb, Cu, Zn and Cd) IN THE CAVE SEDIMENTS IN THE RISNJAK
NATIONAL PARK, CROATIA**

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In this paper chemical analyses of the silt from the pits and caves are presented. Investigations include standard chemical soil analyses and some heavy metals (Pb, Cu, Zn and Cd) analyses. Samples were taken at six places of the Risnjak National Park in Gorski Kotar area (western Croatia). Approximately 1 kg of silt was put into a plastic bag, marked and firmly closed before the treatment. Average depth for taking samples was 1-15 cm. Chemical analyses and mechanical content analyses were carried out in the Soil-physiological laboratory of the Forest Research Institute (Jastrebarsko, Croatia). Humus content %, total nitrogen content %, pH in H₂O and M-KCl, CaCO₃ %, P₂O₅ and K₂O content, mechanical soil composition and some heavy metals content (Pb, Cu, Zn and Cd) were determined (Table 1 and 2). Heavy metals were determined by atomic absorption spectrophotometer "Perkin Elmer 300 S". Standard solutions were prepared according to working instructions (Analytical methods). The obtained results are specific for the pits and caves of the Risnjak National Park and its dominant conditions. Theoretically speaking an intact initial phase of the soil should exist because it is protected from some pedogenetic factors that influence its development as well as from the factors that influence pollution. Silt in this system is very poor and also poor in humus. Samples No. 1, 2, 3 and 5 are poor with nitrogen but samples No. 4 and 6 are well provided with nitrogen. All samples are very poorly provided with phosphorus and potassium except from the sample in Kaličak pit. Acidity ranges from 7.5 to 8.0 (pH in M-KCl), and it is more carbonate (up to 83.6 %; Table 1).

There is no doubt that samples found in speleological objects of the Risnjak National Park have the lowest content of Lead, Copper and Zinc but that is not the case with Cadmium. The Cadmium content in sediments from four speleological objects lies over the boundary (2 mgkg⁻¹), which means the some pits and caves are heavily polluted with cadmium. Therefore the research must be continued.

LATE PLEISTOCENE (VALDAIAN) VERTEBRATE ASSEMBLAGES FROM THE EMINE-BAIR-KHOSAR CAVE (CHATYRDAG PLATEAU, CRIMEA)

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The most recent (2002 and 2003) palaeontological and speleological investigations carried out on the caves of the Chatyrdag karst-plateau (Crimea peninsula), revealed a very interesting case of so-called “mega-trap” cave. At present moment, ten bone-caves (most of accumulations Late Pleistocene and Holocene in age) were investigated on this high-plateau (985-1527 m a.s.l.): Mramornaya, Emine Bair Khosar, Emine Bair Koba, Krapivinij, Cherepa, Binbash Koba, Angar Koba, AK4, K18 and Vielova. There is information about bone accumulations also in the Suuk Koba (Holodnaya) cave, and the impressive Bisdonka pothole, which accumulate a large amount of snow and ice even in late summer. The most relevant and well-documented site is represented by the Emine Bair Khosar cave, the subject of this study.

The plateau: Chatyrdag (*crushed mountain* in tatarian) is located 30 km S from Simferopol, in the middle part of the main mountain range, being the second highest massif in Crimea (Ecliziburun Peak – 1527 m). The plateau (yayla) has a strongly karstified flat-top relief and includes two levels named the Upper (1350-1450 m a. s. l.) and Lower (985-1100 m a. s. l.) Plateau, respectively (the total extension is less than 20 km²). From geological perspective, a flysh-type marine sequence, represented by the *Tavricheskaya* series (upper Triassic-lower Jurassic) is unconformably overlapped by a very thick, up to 1000 m, carbonatic series consisting of Oxfordian conglomerates and massive Tithonian limestones (deep of strata 25-45° NW). The limestone plateaus and cliffs are extensively developed between the elevations of 700 and 1527 m, and especially in the last ten years, more than 150 (latest information indicate over 180) potholes (over 90%)

The cave: Emine Bair Khosar (*Bair Emine's pit* in tatarian) cave is still the most interesting palaeontological site in the Lower Chatyrdag plateau. With a total length of 1460 m and a depth of –125 m is one of the largest cavities in the area. The collapse-pit entrance is located on the northern edge of the plateau (990 m a. s. l.), but all known passages are oriented not towards the closest erosional base level, but inside the mountain massif. This peculiar configuration is related to the hydrothermal origin of the cave.

From morphological point of view, huge phreatic voids are developed on two main levels: the upper one is composed by large chambers and passages which progressively descend to –50 m, while the lower level, interconnected by pits, is sub-horizontal and develops at the depth of –125 m. The first stage of development is probable linked with an approximately 2-2,5 MY old hydrothermal activity (mineralogical and morphological evidences), which is responsible for the main phreatic- morphological features. A subsequent stage of vadous evolution can be recognized, followed by a second, cold-phreatic stage, which is well expressed by superposed under-pressure phreatic morphological elements, especially on the flowstones and other speleothems belonging to the early vadous stage. Finally a fourth, the latest vadous stage is now developing. The question of such phreatic caves situated in isolation on the edge of the karst plateau (including Mramornaya cave), can be answered as hypothesis by The first speleological and palaeontological investigations on this cave were carried out in the 1960th (Dublyansky & Lomaev, 1980). That time some two hundred bones were collected from a small chamber near the main access passage (artificially reopened in the last decade). This material belongs mainly to carnivores (*Canis lupus*, *Vulpes corsac*, *Ursus spelaeus*, *Panthera leo spelaea*, *Lynx lynx*) and some herbivores (*Equus* sp., *Cervus elaphus*) and lagomorphs (*Lepus* sp.). The authors considered that this bone accumulation was

formed not far from the former entrance (subsequently closed by breakdown), following a long inhabitation by large carnivores. This observation is very important, because this site and possibly the bone material are no more available for study.

The next palaeontological studies were started in 1999 (Vremir, 2000) and especially 2002 and 2003 (Vremir & Ridush, 2002; Ridush & Vremir, 2003, Vremir, Kovacs & Ridush, 2003), when few other sites were investigated inside this cave. The most important bone accumulations (sites Bb and Bc) provided more than 5000 bones. From different stratigraphical units, at least 35 vertebrate species (mainly mammals, but birds and reptiles are also present) are recorded so far (the taxonomic identification is in progress). The most important results come from the Bc site (Skull chamber) which preserves partial carcasses and whole skeletons, accumulated very close one to another in several stages. Every stratigraphical unit presents particularities from palaeontological, and taphonomical point of view. The vertebrate assemblages, the preservation and spatial distribution of the bone material, the stratigraphic (micromineralogic) and microambiebntal data suggest a very peculiar taphofacies as well as very complex sedimentFrom chronostratigraphic point of view, based on the faunal assemblages (absolute dating is not available yet), the bone accumulations from Bb and Bc sites belong to the Valdaian cold stage, most probable Middle to Late Valdaian.

Palaeoenvironmental indicators (including pollen) shows the presence of steppes (mountain steppe + shrubs and bushes on the plateau, as well as silvo-steppe on valleys, and probably wide sprade desert-steppe on the plains), extensive pine-woodlands on the Northern mountain slopes as well as more wet areas on stream-valleys. The presence of elks could also indicate marshy areas in the vicinity of the mountains, most probable the Don paleodelta and addiacent wet areas. A more precise reconstruction and succession of local faunas and floras based on the indicators entrapped in the cave sediments (parallel to the isotopic analysis), will give answers regarding the climatic and palaeoenvironmental changes during the last cold stage and the early Holocene in the Crimean mountains.

KARSTIFICATION ALONG THE THRUST CONTACT BETWEEN DOLOMITE AND LIMESTONE AT IDRIJSKI LOG AND KOŠEVNIK

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I will represent karstification along thrust contact between dolomite and limestone in Idrijski Log and Koševnik. Dominant structural element in the studied area is thrust contact between Norian- Rheatian dolomite and Lower and Upper Cretaceous limestone in the basement. The contact is cut by several younger fault systems mainly in NW-SE and NE-SW direction. Thrust contact between dolomite and limestone indices contact karst. Cretaceous limestones are deeply karstified with many dolines, shafts and sinkholes. In dolomite karst morphology is much less expressed, because of the impermeable cataclastic zone near thrust plane. In case that such cataclastic zone is cut by younger faults, it became transmissive enough for vertical water outflow (Čar, 1974) and karstification of the base. The dolines in dolomite are believed to be reproduced from limestone's base. More remote from the thrust contact the reproduced karst features in dolomite become less impossible, as the dolomite becomes too thick

PUBLISHED DATA OF CAVE SEDIMENT DATINGS - A NEW KNOWLEDGE ABOUT KARST FILLS IN SLOVENIA

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In SW Slovenia, in the area of Classical Karst the last evidence of marine sedimentation exists since the Eocene when flysch sediments were deposited. After that there are no younger marine sediments present. All younger sediments are surface soils or cave sediments with almost no flora and fauna remains and their age was an object of long time speculations.

In late 80ies a good chronostratigraphy of cave sediments in Slovenia was made by Gospodarič (1987); he bases on his previous work (Gospodarič 1972, 1974, 1976, 1981, 1984, 1985, 1986) and on works of Ikeya et al. (1982), Brodar (1952, 1956, 1966, 1970), Osore (1968), Rakovec (1975) and Šercelj (1962, 1965). But a data of speleothems dated by U/Th method in the last decade by Ford et al. (1989), Zupan (1991), Mihevc (2001, 2002) it was indicated that a lot of speleothems in different caves in Slovenia is much older than the last glaciation. Specially a new view on sedimentation in the caves was opened by palaeomagnetic research of karst sediments on the surface and in the caves. By this method clastic sediments and speleothems were analysed by Bosak et al. 1998, Bosak et al. 1999, Šebela & Sasowsky 1999, Bosak et al. 2000, Bosak et al. 2002, Bosak et al. 2004a, Bosak et al. 2004b, Pruner et al. 2004. Results indicate that sedimentations in now unroofed caves and in still active caves may started million years ago.