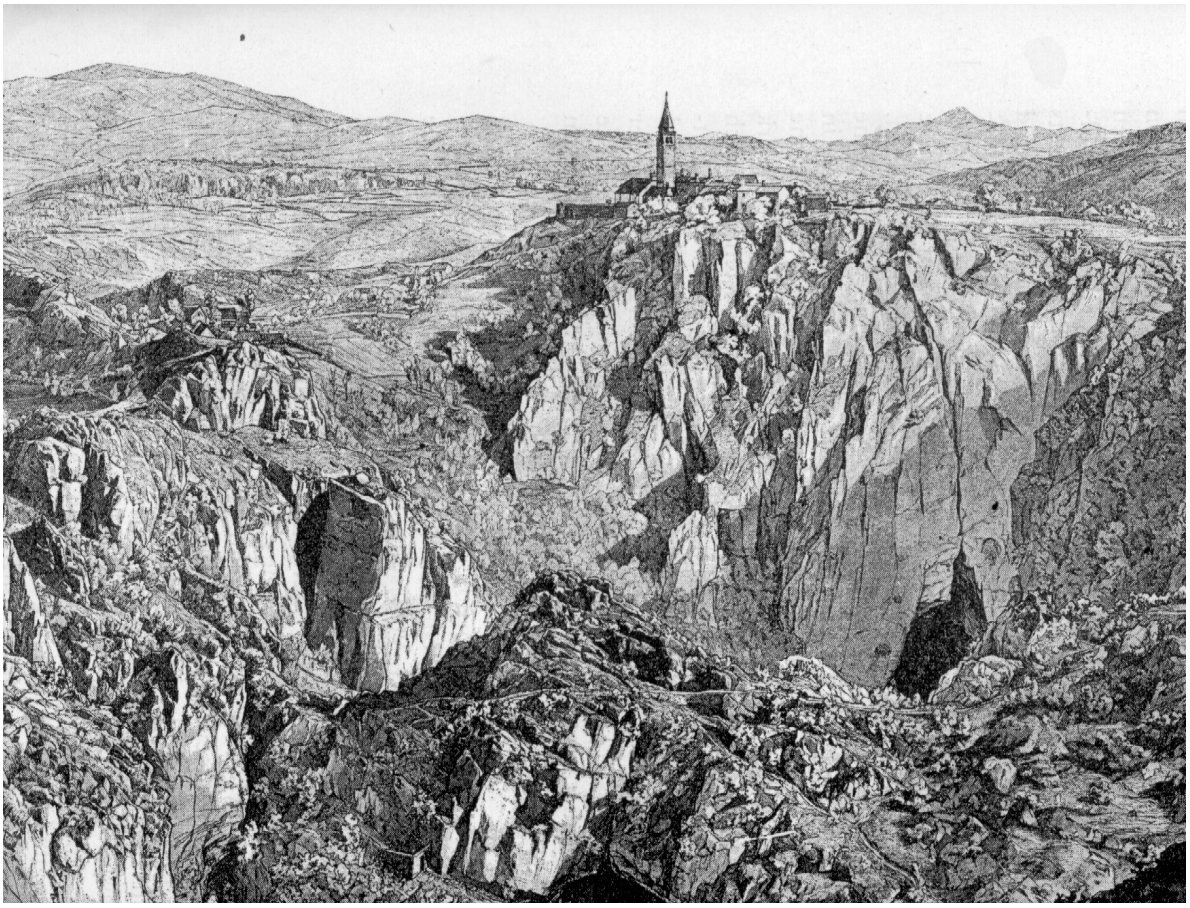
KARST RESEARCH INSTITUTE ZRC SAZU

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

20th INTERNATIONAL KARSTOLOGICAL SCHOOL
"Classical Karst"

KARST FORMS AND PROCESSES



GUIDE BOOK & ABSTRACTS

Postojna, 2012

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GENERAL INFORMATIONS:

Lunch:

- Lunches are not organized during the session days, but 90 minutes lunch breaks are in the schedule (see the places to eat given below).
- A field lunch will be organised for the excursion on Thursday and Friday. One non-alcoholic beverage is included in the price.

Excursions:

- register **for each excursion** at the registration desk,
- buss departure for field trips is from the parking place at the Bus station, see the map below,
- head lights are recommended, walking shoes and field clothes are necessary,
- take care for additional information and changes regarding the bus departures,
- water will be available on all busses,
- **insect repellents** are recommended (we will be walking in the areas populated with **ticks** (*Ixodes ricinus*) that transfer lyme desease and tick-borne meningitis,
- **participation on the excursions is at your own risk.**

Posters:

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

Map of the town centre with important places:

1 – Karst Research Institute at ZRC SAZU, Titov trg 2
2 – Kulturni dom (Cultural Centre of Postojna), Prešernova ulica 1
3 – Start of field trips. At bus station.
4 – Notranjski muzej Postojna, Kolodvorska cesta 3

Places to eat:

5 – Minutka: restaurant with pizza, pasta, Balkan food and daily menu
6 – Hotel Šport: local and "global" food and daily menu
7 – Proteus: restaurant with local and "global" food and daily menu
8 – Bar Bor: restaurant**,** simple but good local food, also serves daily meals
9 – Čuk: restaurant at the sport park, pizzeria, good pasta, local and global food
10 – Špajza: local and "global" food and daily menu

PROGRAMME

Monday, June 18th, 2012

7:30 – 13:00 **REGISTRATION (**Cultural Centre Postojna)

8:30 – 9:30 **OPENING SESSION (**Cultural Centre Postojna)
including a lecture: 20 years of IKS

SESSION 1 **(**Cultural Centre Postojna)
9.30-10.00 **Andrej Mihevc**, *The geomorphology of the Slovene Classical Karst*
10.00-10.30 **Ugo Sauro**, *The landforms of the karst mountains in the middle latitudes: reflections, trends and problems of the research.*
10.30-11.00 ***Coffee Break***
11.00-11.30 **Lukas Plan**, *Karst and Cave Evolution in the Alps*
11.30-13.30 **Neven Bocić**, *Large Dinaric karst plateaus in Croatia – differences and similarities as waymarks to understanding their geomorphology*
Dalibor Paar, *What we know about the longest Croatian cave*
Alena Petrvalská, *Karst of the Yucatan peninsula (Mexico)*
Atef Abdel-Hamid Mohamid, *Limestone Geomorphology in Abu Zneima area, Western, Sinai, Egypt*
Lipar Matej, *Limestone pinnacles in Western Australia – the result of karstic processes and microbial cementation*
Davide Baioni, *Evaporite Karst on Mars: Evidence of global climate change in the recent past*
13.30-15.00 *Lunch break*
15.00-17.00 Poster Session (Karst Research Institute)
18.00-21.00 Field Trip **A:** Evening trip to Postojnska jama
Meeting at the main entrance to the cave, be there few minutes before as the cave-train departs at 18:00.

Tuesday, June 19th, 2012

SESSION 2 (Cultural Centre Postojna)
8.10-8.40 **Mehmet Ekmekci**
8.40-9.10 **Andrew Farrant**, *Role of sediment in speleogenesis; paragenesis and alluviation*
9.10-9.40 **Stein Erik Lauritzen**, *The architecture of big rooms*
9.40-10.40 **Tim Horsfield**, *Speleothems as Archives in the Production of a Holocene Palaeoclimate Record for Slovenia*
Jo De Waele, *Palaeoclimatic significance of a fast growing submerged stalagmite of Grotta Verde cave, NW-Sardinia*
Aurel Persoiu, *From speleothems to glaciers: disentangling between karstic and glaciologic processes in caves*
Bojan Otoničar, *Mravljetovo brezno v Gošarjevih rupah cave: dissolution of dedolomite*
10.40-11.00 ***Coffee Break***
11.00-11.30 **José María Calaforra**, *Gypsum speleothems in gypsum and limestone caves*

11.30-11.45 **Mario Parise**, *Breakdown deposits: characteristics and their significance in the evolution of karst systems*
Ahmad Afrasibian, *The importance of recognition of sink-hole process in water engineering projects in Iran*
12.00-13.30 ***Lunch Break***
13.30-20.00 Field Trip **B**: Planinsko polje and adjacent karst
21.00-21.30 IGU Karst Commission meeting Karst Research Institute

Wednesday, June 20th, 201

SESSION 3 (Cultural Centre Postojna)
8.10-8.40 **Mitja Prelovšek**, *Present-day dissolution rates in stream caves of Slovenia*
8.40-9.10 **Matt Covington**, *Process length scales in karst: from simple models to applications*
9.10-10.40 **Stefano Furlani**, *Limestone lowering rates in the Mediterranean area*
Sara Biolchi, *Intertidal coastal karst morphologies in the Gulf of Trieste*
Blaž Miklavič, *Denudation of eogenetic limestone during the last glacial cycle in a tropical environment*
Nenad Buzjak, *The origin and morphology of submarine spring Vrulja Zečica (Croatia)*
Anja Maglica, *Hydrological Inter-Relations between Cerkniško and Planinsko Karst Poljes –Dynamics of Surface and Groundwater Interaction*
Cyril Mayaud, *New insights into the functioning of the Lurbach system (Central Styrian Karst, Austria)*
10.40-11.00 ***Coffee Break***
11.00-11.30 **Franci Gabrovšek**, *Speleogenetic Processes in Karst Modelling: An Overview*
11.30-12.00 **Nehme Carol**, *Late Pleistocene evolution of Antelias valley (Lebanon): speleogenic approach applied on Kassarat cave system with implication of U/Th datations records*
Simone Milanolo, *Modern calcite precipitation rates on artificial medium from Bijambare cave, Bosnia and Herzegovina*
12.00-13.30 ***Lunch Break***
13.30-20.00 Field Trip C: High Dinaric karst of Trnovski gozd plateau
21.00-21.30 Unresolved Mysteries of karst Karst Research Institute (chaired by Philipp Häuselmann)

Thursday, June 21st, 2012

8.00-19.30 Field trip **D**:Karst geomorphology and hydrogeology of Ljubljanica river
20.00 Reception at the Karst Research Institute

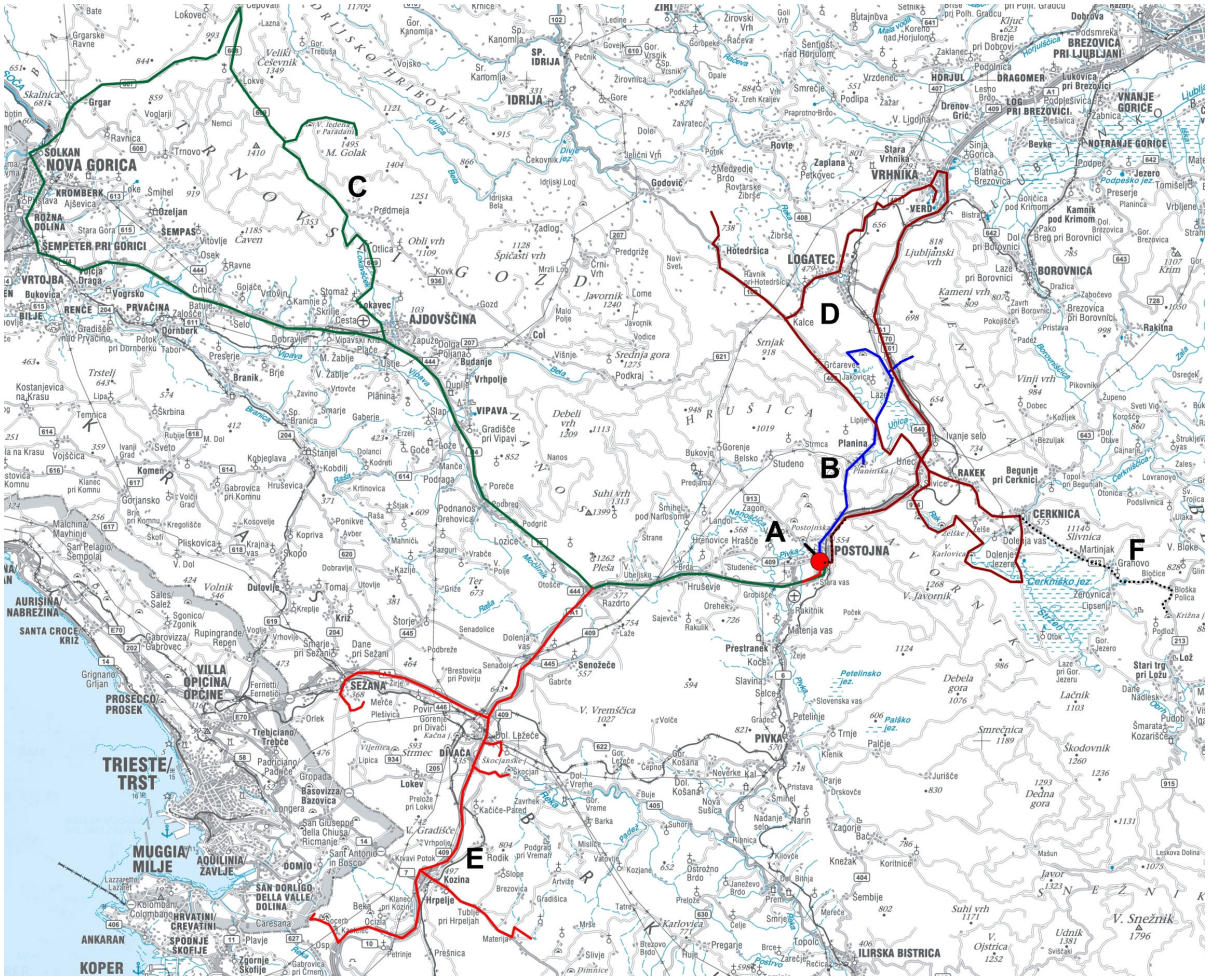
Friday, June 22nd, 2012

8.00-17.00 Field trip **E**: Classical Karst Geomorphology and hydrogeology of Kras plateau

Saturday, June 21rd, 2012

9.00-12.00 Field trip **F**: (Optional) Križna jama
2 hours tour; transport from Postojna is not provided! The trip is conditional and depends on the interest.

FIELD TRIPS



Map of field trips:
*Field trips and visits: Monday evening (**A**), Tuesday (**B**) and Wednesday (**C**) afternoon and whole day excursions on Thursday (**D**) and Friday (**E**). Additional trip to Križna jama is possible for participants on Saturday (**F**).*

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

FIELD TRIP **A**

POSTOJNSKA JAMA CAVE
Monday 18. 6. 2012, 18:00-21:00

Classical Karst

Classical Karst is a part of Dinaric Karst in Slovenia and Italy. It spreads between the coast of Adriatic Sea at Bay of Trieste and the springs of Ljubljanica river in the edge of Ljubljana tectonic basin. It belongs to two large karst river basins: to Reka – Timavo river and to Ljubljanica river.

This karst area has abundance of karst phenomena like large sinking rivers and springs, intermittent lakes, large caves and relief features like dolines, collapsed dolines, uvalas, poljes, levelled surfaces and high plateaus. And the karst surface is mostly rocky and dry.

It was the exploration of the people that were driven by curiosity or science and by land use or water management issues and tourism that make this karst famous. Since 17th century karst phenomena were studied by local and foreign naturalists and scientists. Well researched, mapped and described caves and other karst phenomena in 19th century made this karst as a reference karst. Together with that the name Kras was used to denominate the natural pnenomena itself and a new scientific discipline – karst studies.

Postojna played important role in karst research and is situated in the middle of this area.

Pivka basin

The bottom of the Pivka basin, an area of about 80 km^2, is built 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.

Karstificated limestone surrounds the valley from all sides; at the contact on higher levels there is flysch. Along the 59 km long lithological 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 4 m^3/s, 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 20 km long Postojnska jama cave about 511 m a.s.l. The cave has several levels, the main level being between 520 and 530 m a.s.l., and the lowest between the sink of the Pivka and the outflow sump at 477 m a.s.l. There are still more than 2, 200 m of unexplored galleries before the river re-appears in Planinska jama at 460 m a.s.l.

Postojnska jama

Postojnska jama (45°46´57.79˝N; 14°12´13.18˝E) is the longest cave in Slovenia and 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 already in 13. Century.

Cave developed on N edge of noncarbonate flysch Pivka basin where river Pivka sinks into the Postojnski kras plateau and flows through it towards Planinsko polje where it springs from Planinska jama cave. The gentle fluvial surface of the fluvial basin itself stands out in sharp contrast to the karst lands above the cave and to other higher karst plateaus.

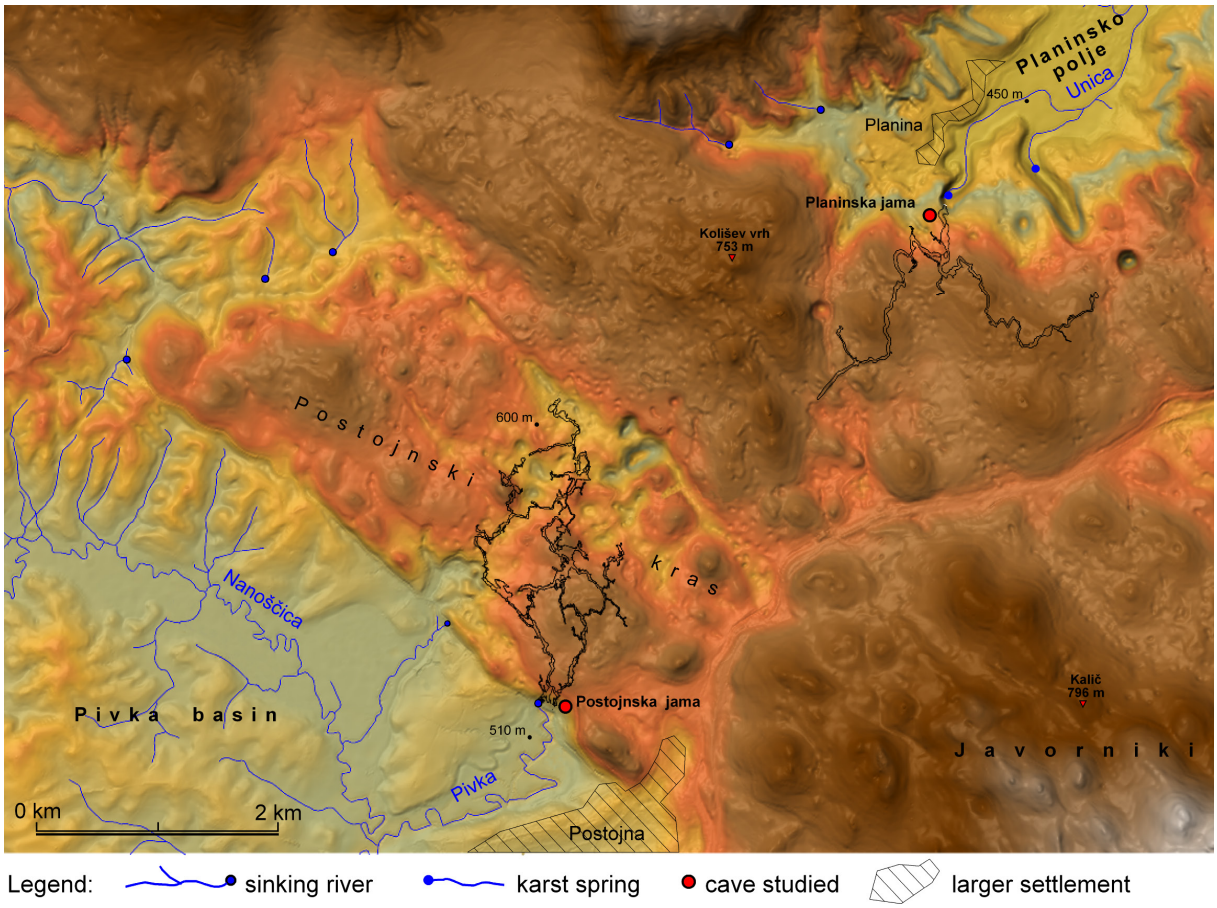


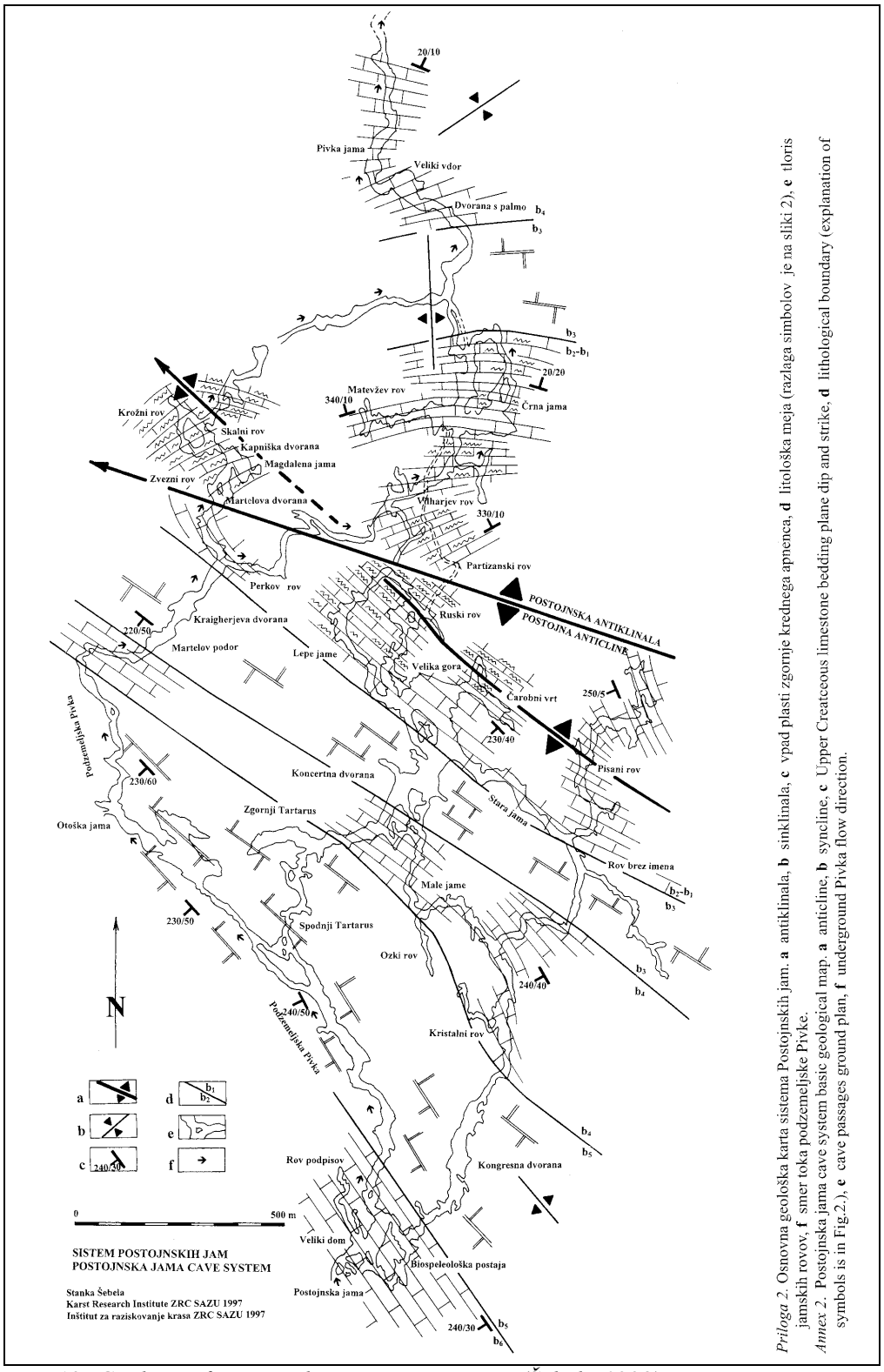
Fig. A1: Map of the karst between Pivka basin and Planinsko polje with cave system Postojnska jama – Planinska jama.

The historical entrance at 527 m a.s.l. is located above the modern ponor (511 m). Other entrances or caves connected to the system: Otoška jama, Magdalena jama, Črna jama and Pivka jama are scattered on the surface in elevations at about 600 to 650 m a.s.l. All these caves are interconnected and form a cave system 20.5 km in length. The cave ends with terminal sump in Pivka jama is at 477 m a.s.l. There is still more than 1.2 km of unexplored galleries before the river re-appears in Planinska jama at 460 m a.s.l.

The entrance to Postojnska jama is situated near the contact between the Eocene flysch and the Upper Cretaceous limestone. The entire cave system is developed in an 800 m thick sequence of the Upper Cenomanian and Turonian to Senonian limestone. The cave passages are formed in the Postojna anticline, which is oriented NW–SE, most of channels being in its steeper south-western flank.

The known passages were formed at two main levels. The upper level is between 529 m a.s.l., at the main entrance to the cave and 520 m a.s.l. in the Črna jama. This level is composed of large passages, generally up to 10 m high and wide. Profiles of these passages are rounded and show also traces of paragenesis (levelled ceilings, side notches and scallops on the walls and ceiling). There are also remnants of sediment fills indicating repeated fillings of the cave and successive erosion of the sediments. Speleothems were deposited in different phases above clastic sediments. The natural floor of the cave was modified by construction of a railway for tourists.

The second level is about 18 m below the upper one, where the modern underground Pivka river flows from its entrance. The river bed has a low gradient and, except for some collapses and narrow parts, there are no natural barriers. It leaves the system through a terminal sump. The active river passages are mostly smaller than the higher ones. The river bed is covered mostly with gravels derived from the Eocene flysch. The mean annual discharge of the river is 5.2 m^3s^{-1}. The water level can rise 10 m during floods.



Priloga 2. Osnovna geološka karta sistema Postojnskih jam. **a** antiklinala, **b** sinklinala, **c** vpad plasti zgornje krednega apnenca, **d** litološka meja (razlaga simbolov je na sliki 2), **e** tloris jamskih rovov, **f** smer toka podzemeljske Pivke.

Annex 2. Postojnska jama cave system basic geological map. **a** anticline, **b** syncline, **c** Upper Creatceous limestone bedding plane dip and strike, **d** lithological boundary (explanation of symbols is in Fig.2.), **e** cave passages ground plan, **f** underground Pivka flow direction.

Fig. A2: Geology of Postojnska jama cave system (Šebela 1998).

The cave is filled by variety of alluvial deposits characteristic of the internal cave facies, such as silts, sands, gravels, covered and/or intercalated by rich speleothems. The entrance cave facies consists of slope-derived debris mixed with the fluvial deposits.

Pleistocene large mammal fauna such as hippopotamus, cave lion and cave bear, were found here as well as Palaeolithic stone tools from the last glacial.

Intensive growth of flowstone is due to high annual precipitation, about 1700 mm, and high mineralization percolating water. Calcite is the main secondary chemical mineral in the cave, others noncarbonate minerals are less than 1 %.

The oldest flowstone in the cave is red one from Pisani rov, which shows the traces of erosion on it and also scallops were found on it. In some speleothems, between separate layers, flood loam was found; this shows on floods during speleothem growing.

Collapse at Velika gora

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 show, that there were probably several phases of collapses and that at present the collapsing is in low intensity.

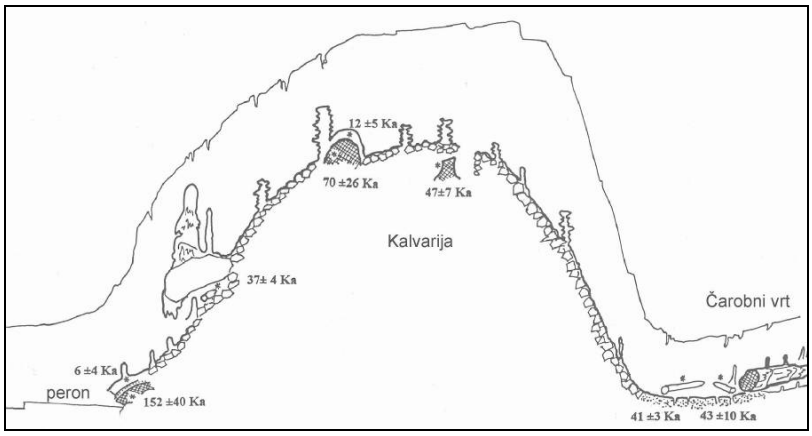


Fig. A3: Schematic cross section trough Kalvarija (Velika gora) collapse. Positions of samples and the age of the flowstone are marked on the sketch.

Samples of flowstone were taken and analysed in U series dating lab at Department of Geology, University of Bergen by alpha counting.

Three periods of flowstone growth were recorded. 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 sediment 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 grey 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 of cryoturbated sediments in the entrance parts of the cave show, that the freezing in Pleistocene was influencing only entrance 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 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

It is 220 metres long and lies at between 20 and 30 metres below the surface. To the north it opens into the Old Cave. To the south it was blocked by rubble. Since it was easily accessible from the Old Cave, eminent visitors in the 19th century were allowed to sign their names on the walls. In 1931 a biological station was set up in the passage. In 2002 the sediments which had closed the former entrance to the passage were removed and cave vivarium was installed.

Passage 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. Two profiles of gravel-filled passage were exposed with similar sequence of sediments. One is in the tunnel for the railway; in them cave bear bones and stone tools dating to Mousterian (~40 ka) were found. The similar profile is exposed to visitors at the entrance of the passage.

Bottom of the profile (6) 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 breccia (5). 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. The white flowstone indicates that it grew in entrance conditions with low winter temperatures causing gelifraction and summer deposition of calcite. The climate was similar to present. This stratum was probably formed at the beginning of the last glaciation (Würm I).

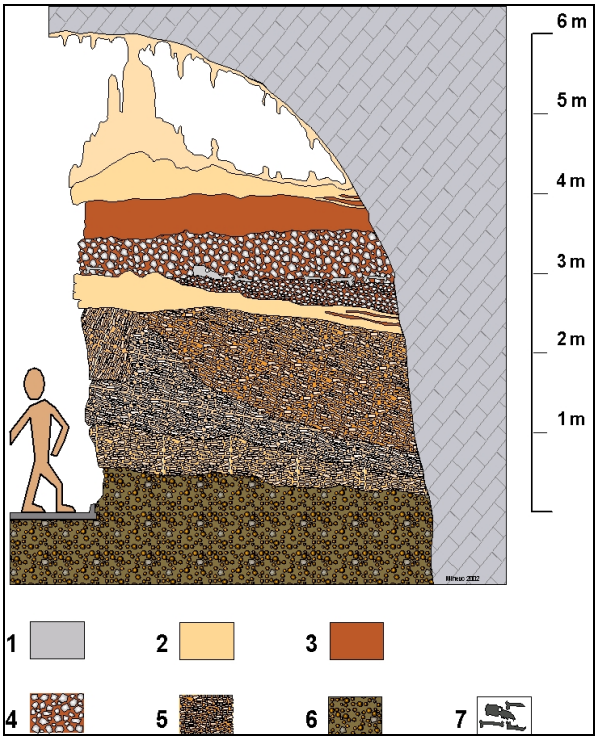


Fig. A4: Schematic cross section of the sediment profile at the entrance part of the Rov novih podpisov passage. Legend: 1. limestone, 2. flowstone, 3. cave loam and clay, 4. limestone rubble mixed with clay, 5. rubble and breccia, mostly of broken flowstone, 6. flysch gravel and clay, 7. bones of a cave bear.

In the Spelebiological station we can still see thick stalactites that are inclined into the cave, indicating strong winds during the growth. Most of them are broken which most likely attributed to the growth of this layer. Later on them new thinner stalactites were formed they are either Holocene in age or formed after the cave entrance was closed.

Porous flowstone and dark coatings (3) that follows shows either warmer humid period or closing of the cave entrance by rubble from the slope above it. Towards the side of the passage the layers is much thinner and intercalated with clays.

Limestone rubble mixed with clay (4). Rocks of the layer show subcutaneous corrosion features. The origin of the rubble is the slope above the cave. Rocks piled up at the entrance and then slide into the cave by cryoturbation. The lower part of the stratum contains the bones of a cave bear. In similar strata in the other profile trough the passage, archaeologists have unearthed Moustérian stone tools, so the stratum formed between 40, 000 years and Holocene.

Clayey layer (3). A stratum of clay up to 50 centimetres thick was washed into this part of the cave from higher parts of passages or clay-filled voids.

The stalagmites and the flowstone (2), which covers the floor developed when the entrance to the cave was blocked for the air circulation and the passage was no longer exposed to freezing, however white flowstone crusts indicates minor impact of winter dry air.

The sequence of sediments in profile represents the climatic oscillations within the last glacial period and also changing of the cave climate because of filling the entrance by surface rubble which slowly minimised the air flow.

FIELD TRIP **B**

PLANINSKO POLJE AND ADJACENT KARST

Tuesday, 19. 6. 2012, 13:30-20:00

Planinska jama

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

Planinsko polje

Planinsko polje developed in a levelled karst surface that follows the Idria fault zone. Its wider surrounding is built of Jurassic and Cretaceous limestone and Upper Triassic dolomite, dolomite also form a part of the polje bottom. Polje is of rectangular shape, 6 km long, 2 km wide. There are two narrow pocket valleys on SW part formed above the springs of Unica river and one on its NW side above temporal springs. Polje is about 50 m deeper then lowest surrounding surface and consists of 16 km^2 flat surface at height about 450 m.

Planinsko polje 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 m^3/s (min. 0, 3 m^3/s, max. 100 m^3/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.

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

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 Najdena jama cave (5110 m), Logarček (4334 m) and Vetrovna jama (700 m).

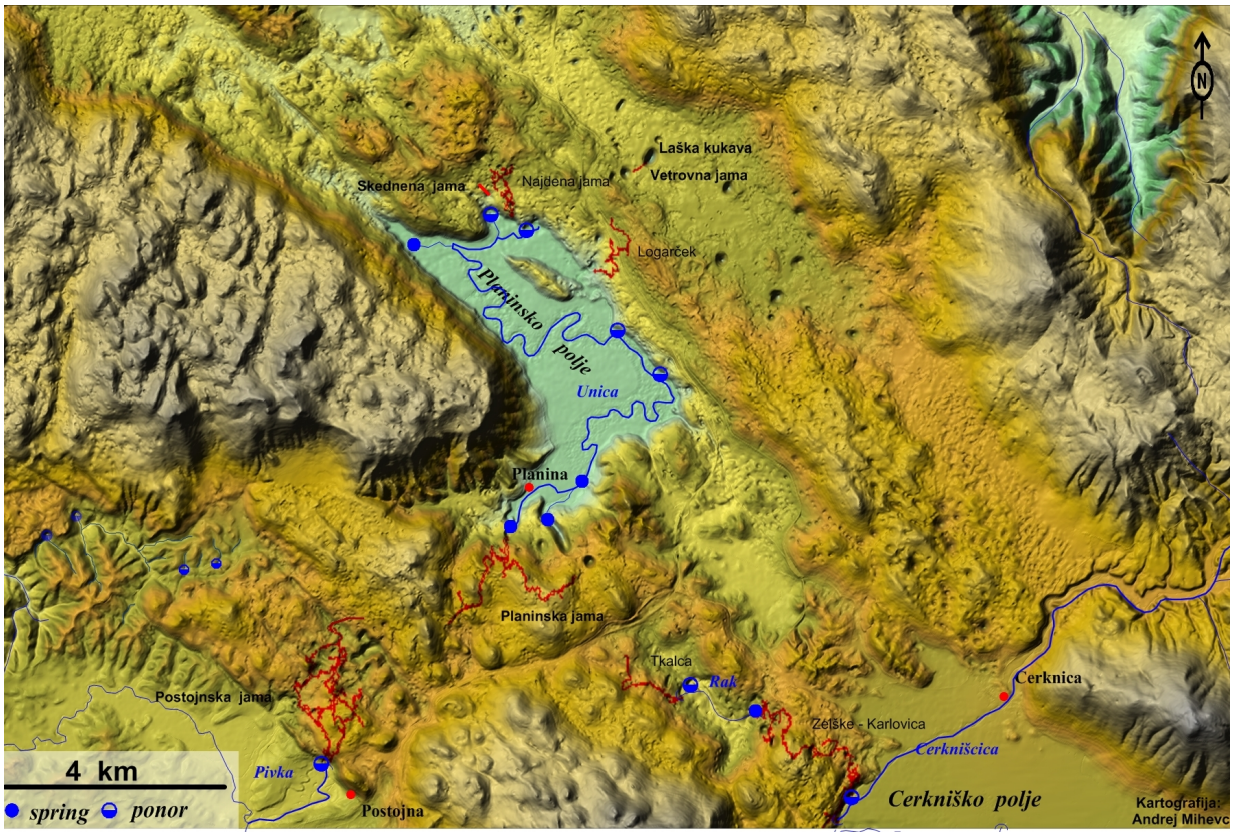


Fig. B1: Planinsko polje and adjacent karst.

Skednena jama

Skednena jama cave is 206 m long and 30 m deep cave situated on N edge of Planinsko polje. Cave is a remnant of an old phreatic passage, 10 m wide and mostly about 5 m high. It has three entrances, which are disposed in different heights. Larger entrance is in the bottom of the collapse dolina; smaller ones are on the surface of the terrain. The gallery floor form clastic sediments: rocks, gravel and smaller particles size of sand and silt. The main part of the cave passage, in the length of more than 100 m, is smooth and levelled to an even surface with inclination of 7-10º and horizontal in cross section.

The mean annual temperature of the area is about 8ºC. The coldest month is January (–1ºC) and the warmest July (+18ºC). During the winter there is a strong air draft in the cave, and the cave temperatures at the floor are for several months below 0ºC. Air temperatures measured at the cave floor are similar to those on the surface, but in domes in the ceiling or in side passages temperatures are much higher, they even do not fall below the freezing point.

Levelled cave floor show recent patterned ground cryoturbation features like sorted stone circles, sorted polygons, stripes and clay hummocks. These features develop due to repeated freezing and thawing of the cave sediments, which cause the shifting, or movement rocks mixed with finer sediments that contain moisture.

Cryoturbation develop due to increasing of the volume of the ground when it freezes and thus expands its volume. This causes the upwards mowing of the whole cave floor. For three seasons we measured the upward movements of the selected stones. The upward movements from 5 – 10 cm in vicinity of the dripping water over 20 cm were measured.

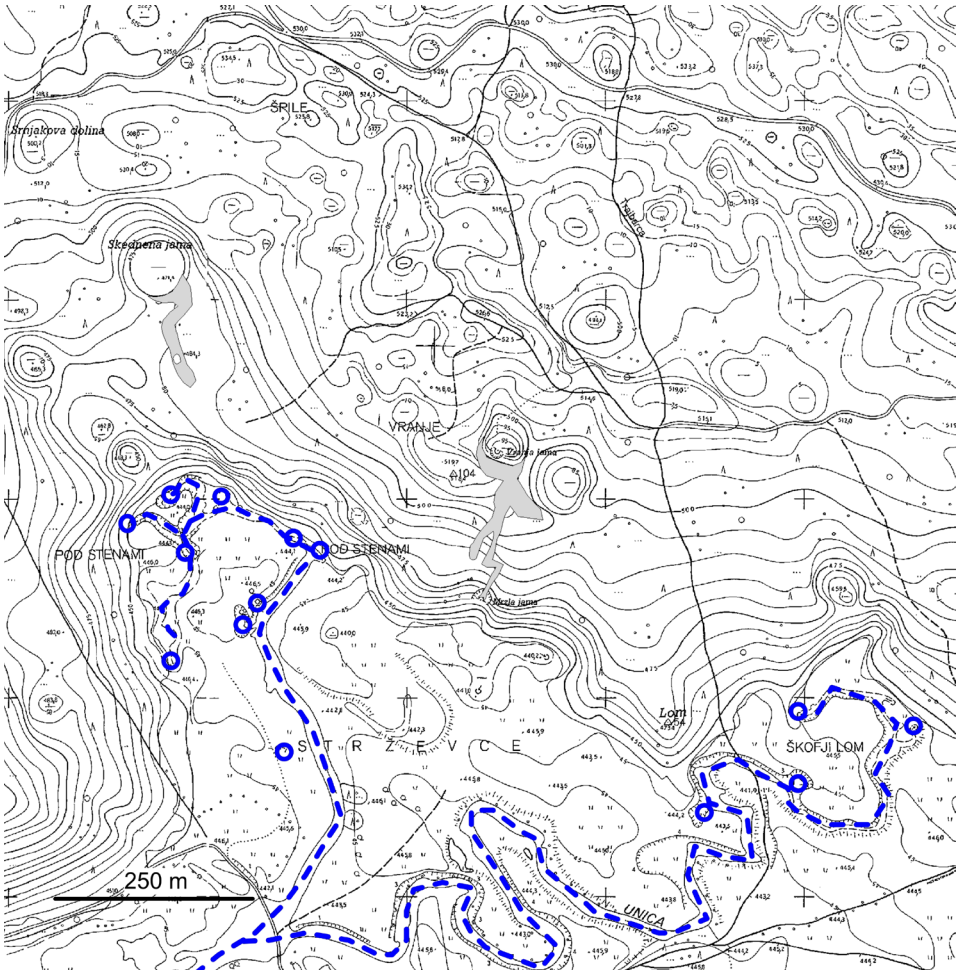


Fig. B2: Topographic map of N edge of Planinsko polje. Skednena jama and Vranja jama are marked. Unica here disappears in numerous swallow holes in alluvium.

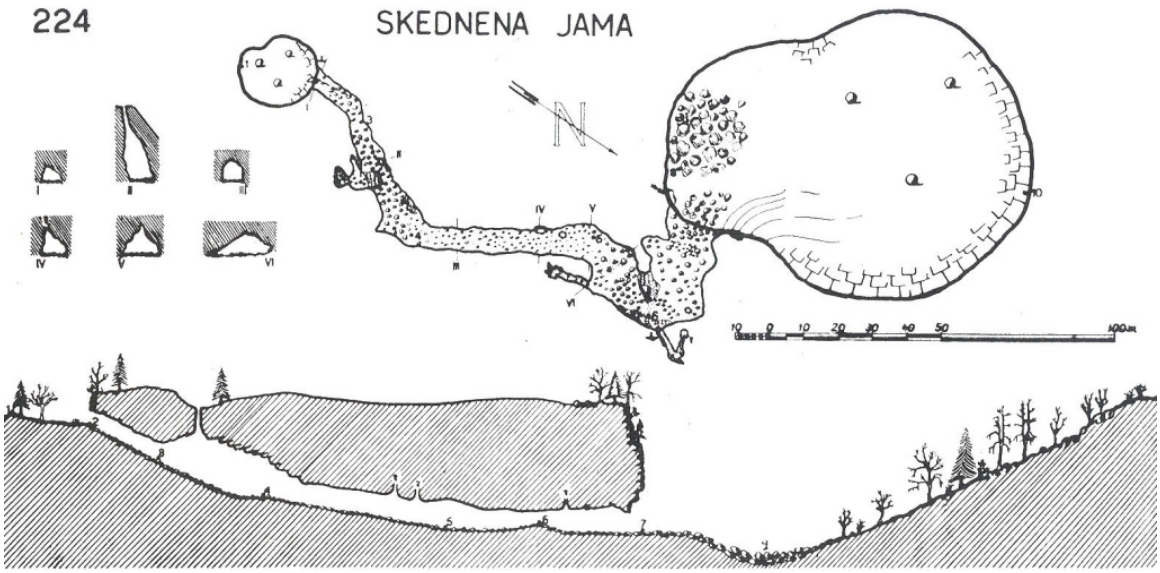


Fig. B3: Cross section through Skednena jama.

Vertical movements are also causing horizontal shifting of the particles down dip, because the particles, which are uplifted perpendicular to the inclined surface, are lowered vertically during the thawing. This is morphologically important, and it levelled the whole cave floor bottom to even dip.

Vetrovna jama

Vetrovna jama is 700 m long and 115 m deep cave. It was discovered after long digging in narrow passages following the strong winds that blew out of cave. The cave reaches underground flow of Ljubljanica river between Planinsko polje and springs at Vrhnika. It is mainly fed by the water coming from the eastern rim of Planinsko polje.

The cave ends under the slopes and close to the bottom of large collapse dolina Laška kukava. Cave and dolina are connected by impassable passages through strong air currents transfer cold air into dolina at summer. Kukava is one of the dolines where temperature inversion was studied by biologists but the low temperatures of the air were attributed to cooling of the air between the collapse boulders on the slopes of the dolina. The inversion of temperature is more pronounced in summer time, when bottom temperatures do not exceed much the cave temperatures of the cave.

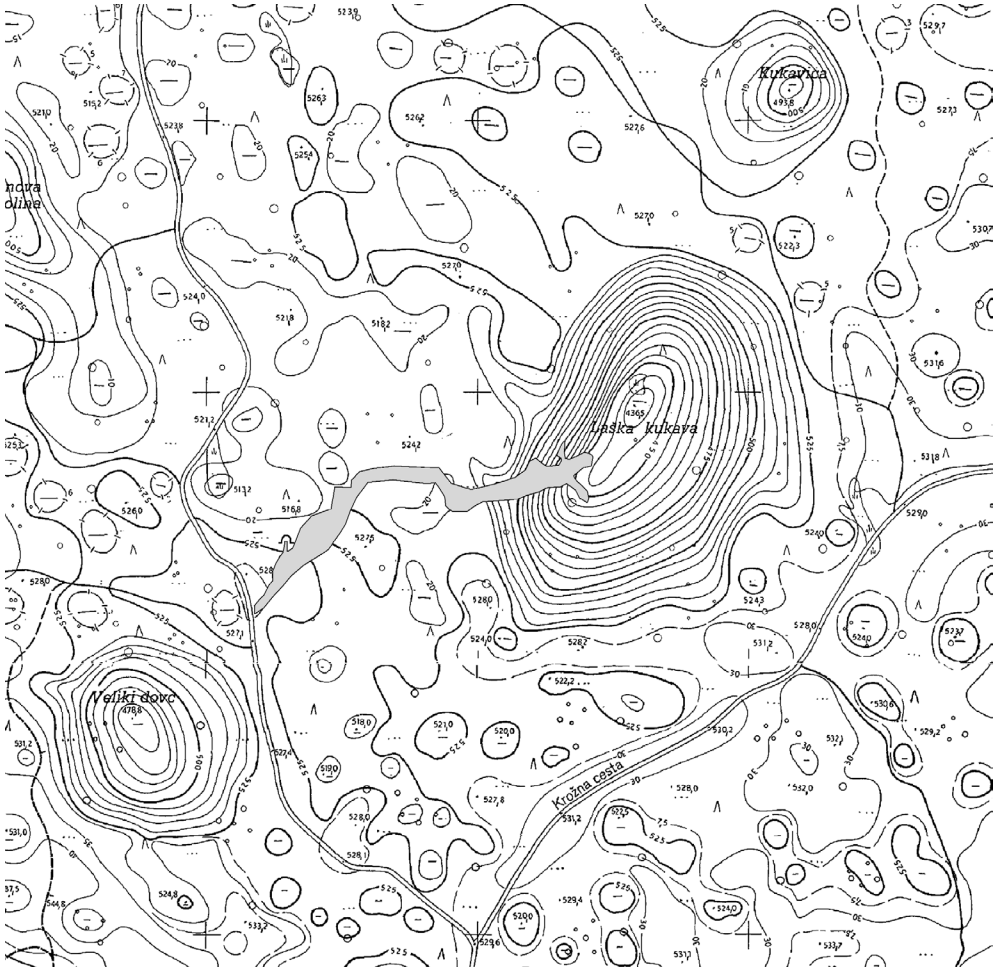


Fig. B4: Topographic map of Laška kukava and the position of the cave. In some other large collapse dolines the summer temperature inversion is also maintained by the cold cave air.

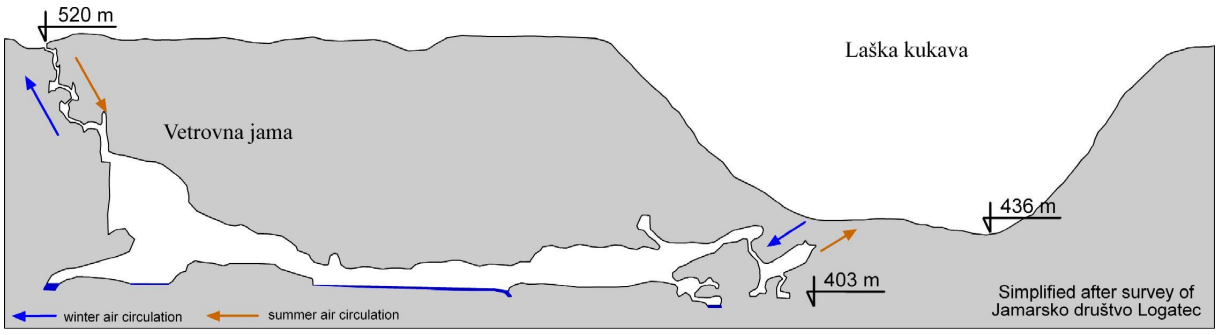


Fig. B5: Schematic cross section through Vetrovna jama and Laška kukava.

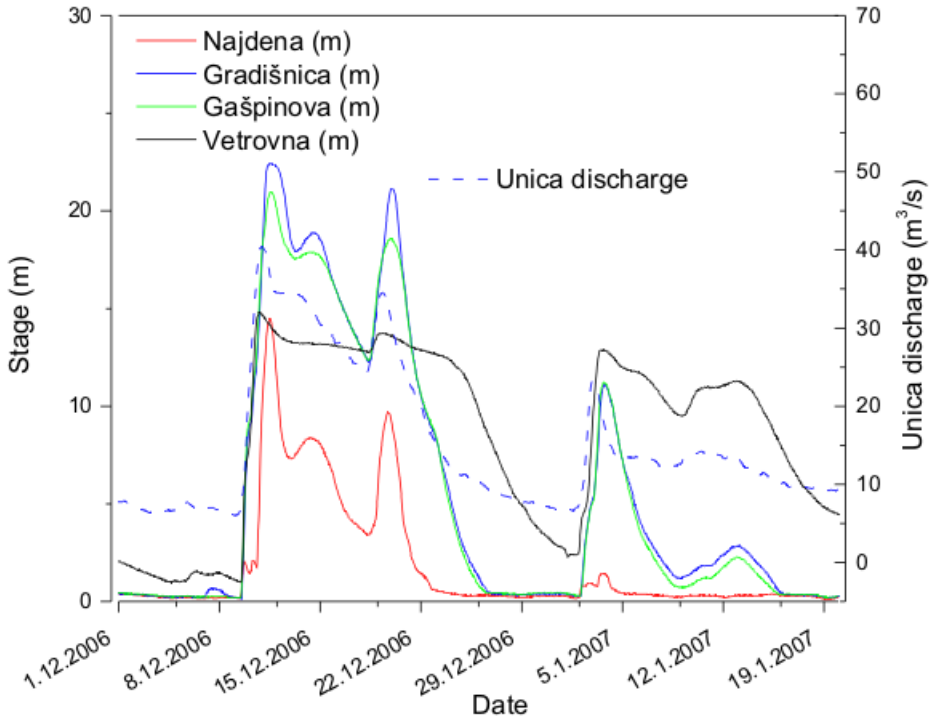


Fig. B6: Stage response to a flood in caves Ne from Planinsko polje. Note the delayed recession in Vetrovna jama.

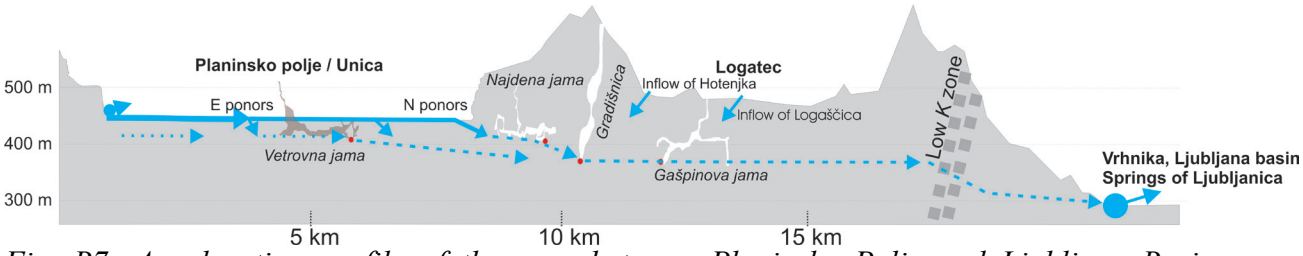


Fig. B7: An elevation profile of the area between Planinsko Polje and Ljubljana Basin approximately in S-N direction. The cross-sections of the caves are generalised and simplified. Vetrovna Jama is shifted to the S, because it would overlap with Najdena Jama if positioned correctly. This way its connection to E ponors is emphasised. Dashed lines show the estimated level and direction of groundwater.

FIELD TRIP **C**

HIGH DINARIC KARST OF TRNOVSKI GOZD PLATEAU

Wednesday, 20. 6. 2012, 13:30-20:00

Trnovski gozd

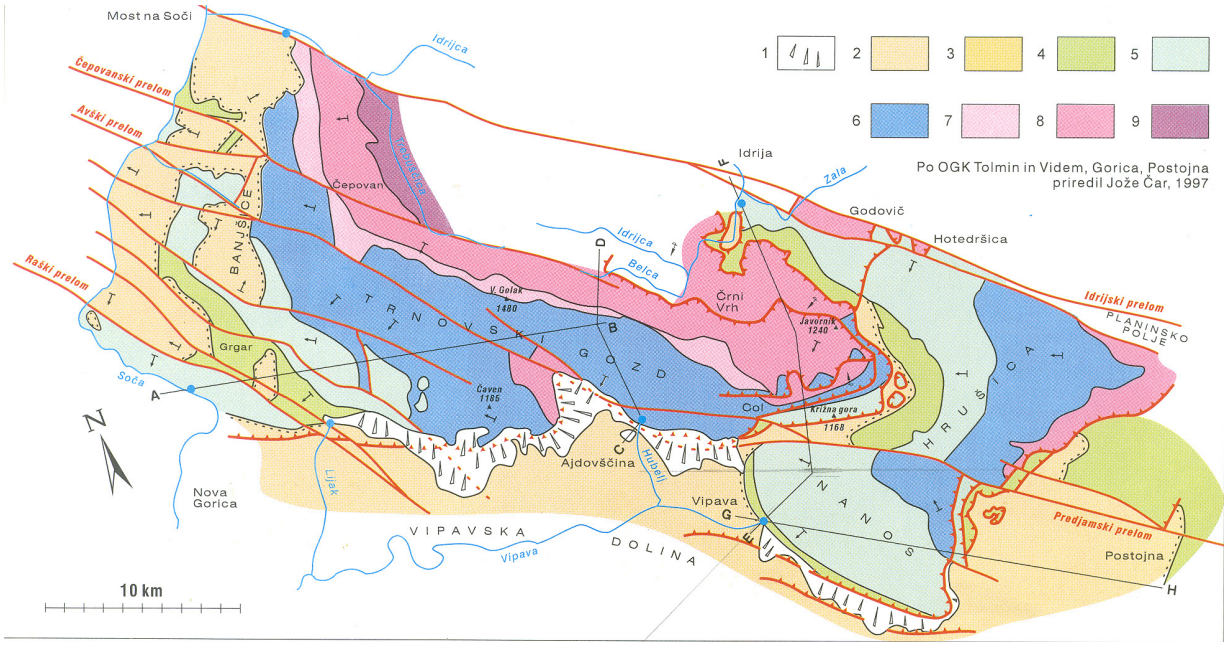
Central part of Dinaric Karst in Western Slovenia comprises a relief of high karst plateaux of total area of approximately 700 km^2. In these plateaus deep karst is developed, through which water is drained towards several karst springs located along the river valleys that border them or to karst poljes that are between them.

Trnovski gozd one of these karst plateaus. It is about 10 km across and 20 km long. On the northern side there are deep valleys of Idrijca river and tributaries, on southern Vipava valley. From Banšice plateau is separated by Čepovanski dol, huge dry valley, while towards E there is more gentle transition to another high plateau Hrušica.

The area of Trnovski gozd geotectonicaly belongs to the Outer Dinarides for which the nape overthrust tectonic is characteristic. Overthrusting started after Eocene. The direction of overthrusting was from NE to SW

The surface of Trnovski gozd is mostly between 800 – 1200 m a.s.l., the highest peaks are 1495 m high Mali Goljak. Surface of the plateau is well levelled but dissected by numerous large dolines and uvalas (Mojska draga, Mrzla draga and Smrekova draga, Velika Lazna and others) and conical hills among them. In cold parts of Pleistocene there were small glaciers on the plateau, but they didn't move much over the rough karst terrain. They discharge their melt water mostly in the karst directly. Some depressions are partly filled with glacial or fluvioglacial sediments.

In the central, highest part of Trnovski gozd the climate is rather cold. Mean temperatures in January are from -4° C to -2° C. Warmest month is July with temperatures 12 - 14° C. Main annual temperature is between 7 - 9° C. There is between 1700 and 2000 mm of precipitations on the plateau but in the central part at Mali Goljak up to 3200 mm. Precipitations are distributed all over the year with maximums in October and November and from April to June.



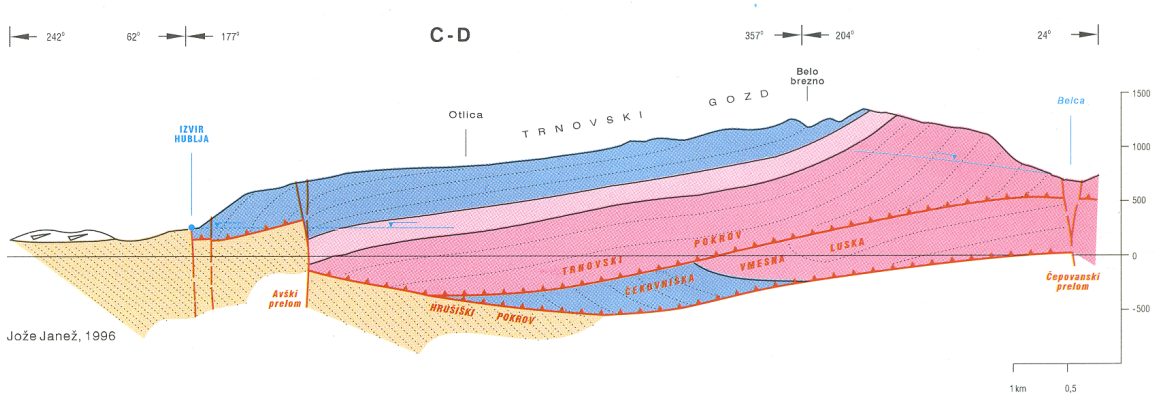


Fig. C1, 2: Geological map and cross-section (1. Periglacial breccia and rubble, 2. Eocene, Palaeocene and Upper Cretaceous flysch, 3. Palaeocene limestone, 4. Upper Cretaceous organogenic limestone, 5. Lower Cretaceous bituminous limestone with dolomite inliers, 6. Jurassic limestone and dolomite, 7. Norian-Rhaetian limestone (Dachstein), 8. Norian-Rhaetian dolomite, 9. Carnian granular dolomite, alternation of siltstone and sandstone) (Janež et al. 1997)

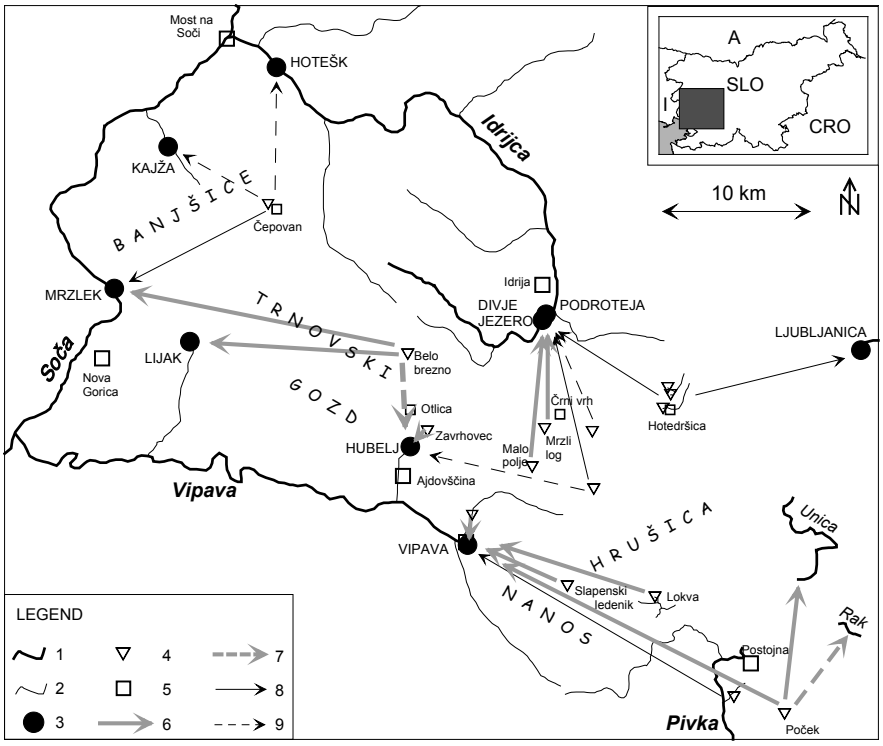


Fig. C3: Proved underground water connections in the area (1. River, 2. Surface stream, 3. Karst spring, 4. Tracer injection point, 5. Settlement, 6. Main direction of underground flow -proved by tracing tests after 1993, 7. Secondary direction of underground flow - proved by tracing tests after 1993, 8. Main direction of underground flow - proved by tracing tests before 1993, 9. Secondary direction of underground flow - proved by tracing tests before 1993)

There is no superficial flow in the area; all waters appear on the edge of the plateau in large springs like Hubelj (discharges from 250 l/s to 60 m^3/s) and Lijak (discharges from 0 l/s to 32 m^3/s) in the Vipava valley, Mrzlek (estimated discharges from 600 l/s to 40 m^3/s) and Kajža (discharges from 7 l/s to 2 m^3/s) in the Soča valley, and Hotešk (estimated discharges from 30 l/s to 6 m^3/s), Podroteja (estimated discharges from 200 l/s to some m^3/s) and Divje jezero (estimated discharges from 0 l/s to more than 60 m^3/s) in the Idrijca valley. These three rivers belong to the Adriatic water system, but a small part in the eastern section of the described area is drained towards the Ljubljanica springs near Vrhnika, which belongs to the Black Sea water system.

There are hundreds of caves in the area, the deepest are Bela griža 884 m and Velika Paradana, 650 m deep ice cave, and there are 18 others deeper than 100 m, but there are no horizontal caves in the whole area.

Smrekova draga

Smrekova draga is about 1 km wide, 1.5 km long and more than 150 m deep closed depression, a large composed dolina. Whole dolina is formed in Triassic dolomites and dolomitic limestone.

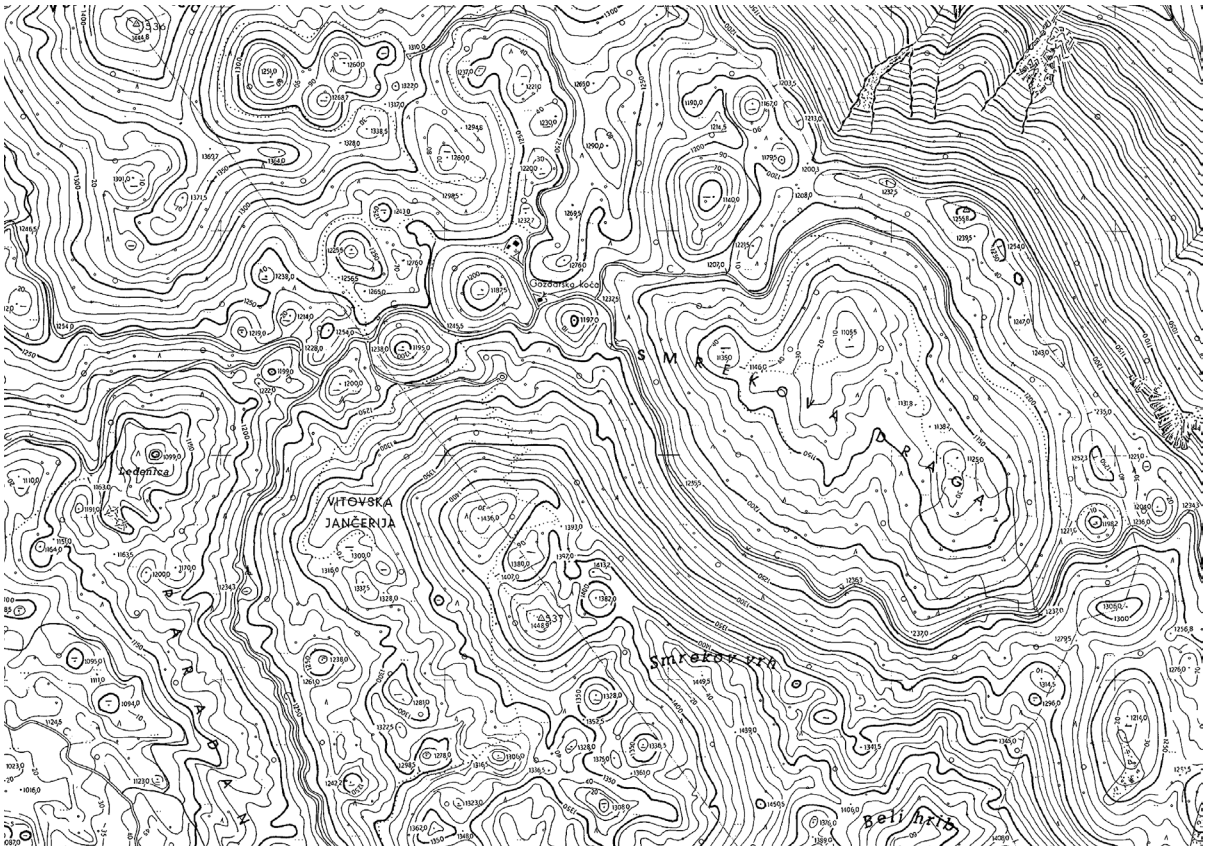


Fig. C4 : Topographic map of central part of Trnovski gozd with numerous large dolines.

The dolina is well known for its and vegetation inversion, a phenomena that there are belts of vegetation according to height, but in inverse order, in this case beech threes at the rim, coniferous trees like *Picea* and *Abies* below and *Pinus mugho* and *Salix* at the bottom. The phenomenon was first attributed to temperature inversion. But from distribution of cold air in vertical and horizontal and low temperatures which maintain low all summer time (about 2-3º C) indicate that the cold air is more likely coming from caves. Only large cave system of the whole massive above the Smrekova draga can provide such a source of cold air

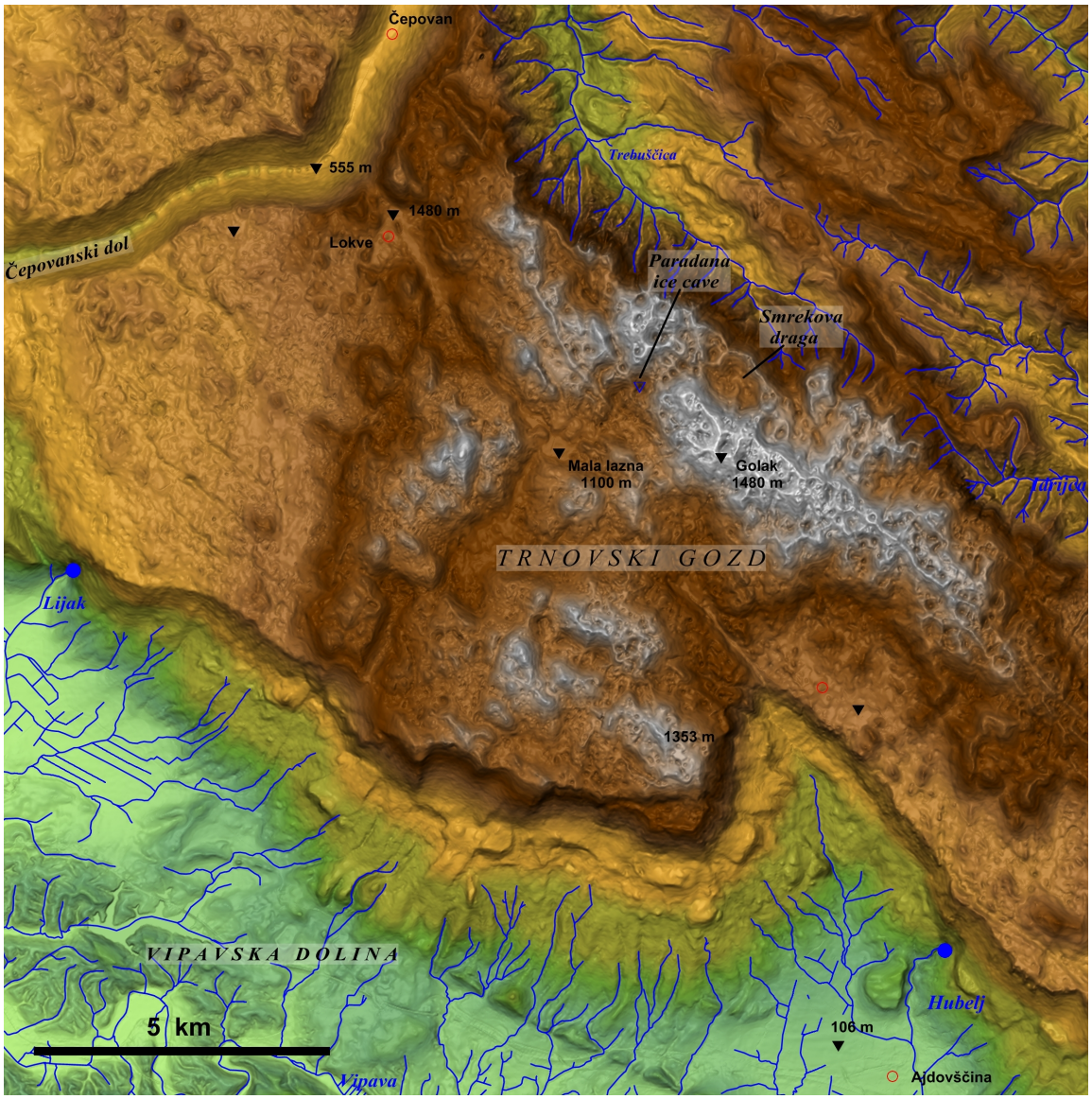


Fig. C5: DEM of the central part of Trnovski gozd karst plateau. Dry valley Čepovanski dol separates it from another plateau on NW.

Ice cave Velika ledena jama v Paradani

Velika ledena jama v Paradani (Great Ice cave in Paradana) or simply Paradana is probably the best known ice cave in Slovenia. The entrance is 1130 m above sea level in the bottom of large, 50 m deep, 500 m long and 250 m wide dolina between peaks that are over 1400 m high.

The cave is 4000 m long and 650 m deep. The entrance part is a funnel-like depression formed by collapse that continues into three chambers and few metres of horizontal passages. From here several series of inner pits continue into the depth.

Sporadic measurements and observations show strong air currents into the cave in winter time and much weaker air movements out of the cave in summer. The air in summer is about 2º C, while winter temperatures are much lower.

Ice (estimated volume 8000 $m^{3)}$ is only in the entrance parts, to a depth of about 100 m, but the cold air currents can cause freezing of water as deep as 200 m. Measurements of temperature at March 28. 2001 are representative for the distribution of temperatures in the cave . In the inner parts the temperature was 4.4˚ C at depth 650 m (480 m a.s.l), 2.2° C at depth 300 m (830 m a.s.l), -1.6˚ C at -50 m and 0° C on the edge of the doline above the entrance.

Ice was thawing between 1950 and 1960 but later it build up again. Ice was melted from below in some parts of cave after 1977, than rebuilt and at the moment in is melting some parts, while in

others it is building up again. It all shows an intrinsic and self-regulating mechanism of the ice forming in the cave. Large opening means strong winter circulation and cooling of the rock and forming of the ice. When the entrance is choked by ice, the warmer air from the depth and surface melt the ice and opens the entrance and start the circle again.

Important is inflow of the cold air in summer from the karst massive above. This cold air is keeping the temperature low and so preventing the melting of the ice.

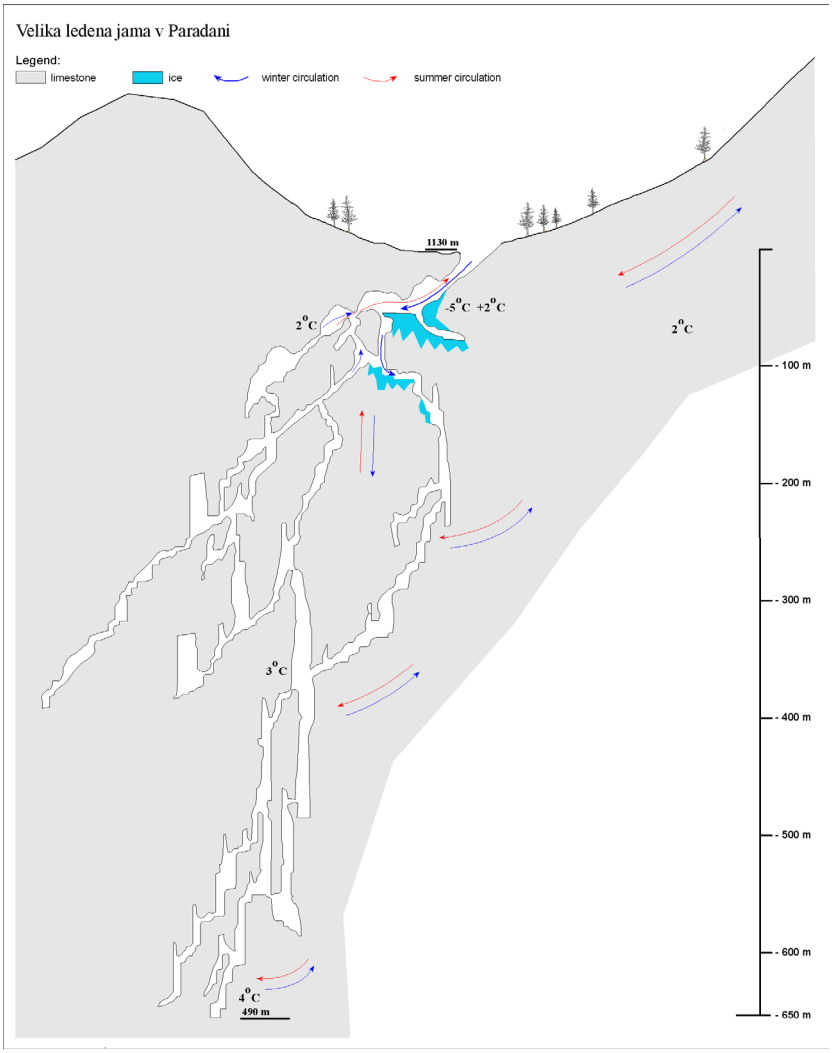


Fig. C6: Schematic cross section and some climatic observations from the Velika ledena jama v Paradani.

The ice was quarried from the cave already in 19. century when the forestry roads were build. Moser (1889) reports that in the year 1867 800 m^3 of ice was extracted from the cave and sold to coastal city Trieste. The ice was used for the supply of the town and the port. It was shipped also to Alexandria, where ice was sold at good price.

In Paradana in 1906 G. Beck (Die Umkehrung der Pflanzenregion in den Dolinen des Kars. Sitzber. Akad. Wiss. CXV. Wien) described the temperature inversion and with it connected vegetation inversion. Later these phenomena were much studied in vicinity in Smrekova draga.

Mala Lazna and Lokve

Along the Avški prelom fault that crosses Trnovski gozd from NW to SE two karst depressions Mala lazna and Lokve formed. In both depressions karst surface was in cold phases of Pleistocene covered with periglacial, glacial and fluvioglacial sediments. The bottom of Mala lazna is at about 110 m a.s.l., it was glaciated and filled with sediments. Those are at the higher parts of

depression already partly washed into the karst. Several sinks, suffusion dolines were already formed in former levelled sediments. The melt water flow from ice and filled Lokve (950) depression with fluvioglacial gravels, here sometimes still surface brook flows, mostly because of more dolomitic rocks and that water sinks into the ponors at the edge of the depression.

Dry valley Čepovanski dol

Dry valley separates karst plateaus Trnovski gozd on E and Banjška planota on W. Dry valley is about 16 km long, 300 – 400 m deep, and is the largest dry valley in Slovenia. It was cut in the limestone and dolomite by the river, which was flowing from the promontory of the Julian Alps, possibly Idrijca river or one of its tributaries.

On N side Čepovanski dol bottom is about 350 m above river Idrijca below, and on it S side about 150 m above the Soča river valley.

The bottom of the dry valley is dissected by numerous dolines, while the slopes are smooth. Near the Čepovan, the largest settlement in valley is small brook collecting its waters on dolomite and sinking after short course in the village.

There are no sediments to date the age of dry valley. Most likely is the same that the age of dry valley that cross Kras plateau. They formed with tectonic uplift and tilting after upper Miocene.

FIELD TRIP **D**

KARST GEOMORPHOLOGY AND HYDROGEOLOGY OF LJUBLJANICA RIVER

Thursday, 21. 6. 2012, 8:00-19:30

Ljubljanica river system

The calculated size of the Ljubljanica drainage basin is 1779 km^2, of which about 1100 km^2 are composed of karstic rocks. The location of the water divide is approximate, but bifurcations have been proved at several boundaries by water tracing. According to studies during the complex water tracing experiments of the nineteen-seventies, the catchment area of the Vrhnika springs, where the main river definitively leaves karst terrain, covers 1108.78 km^2. The mean discharge is 38.60 m^3 sec^{-1}, with a specific run-off of 34.8 l sec^{-1} km^{-2}. Average mean denudation rate is 65 m^3 km^{-2} a^{-1}.

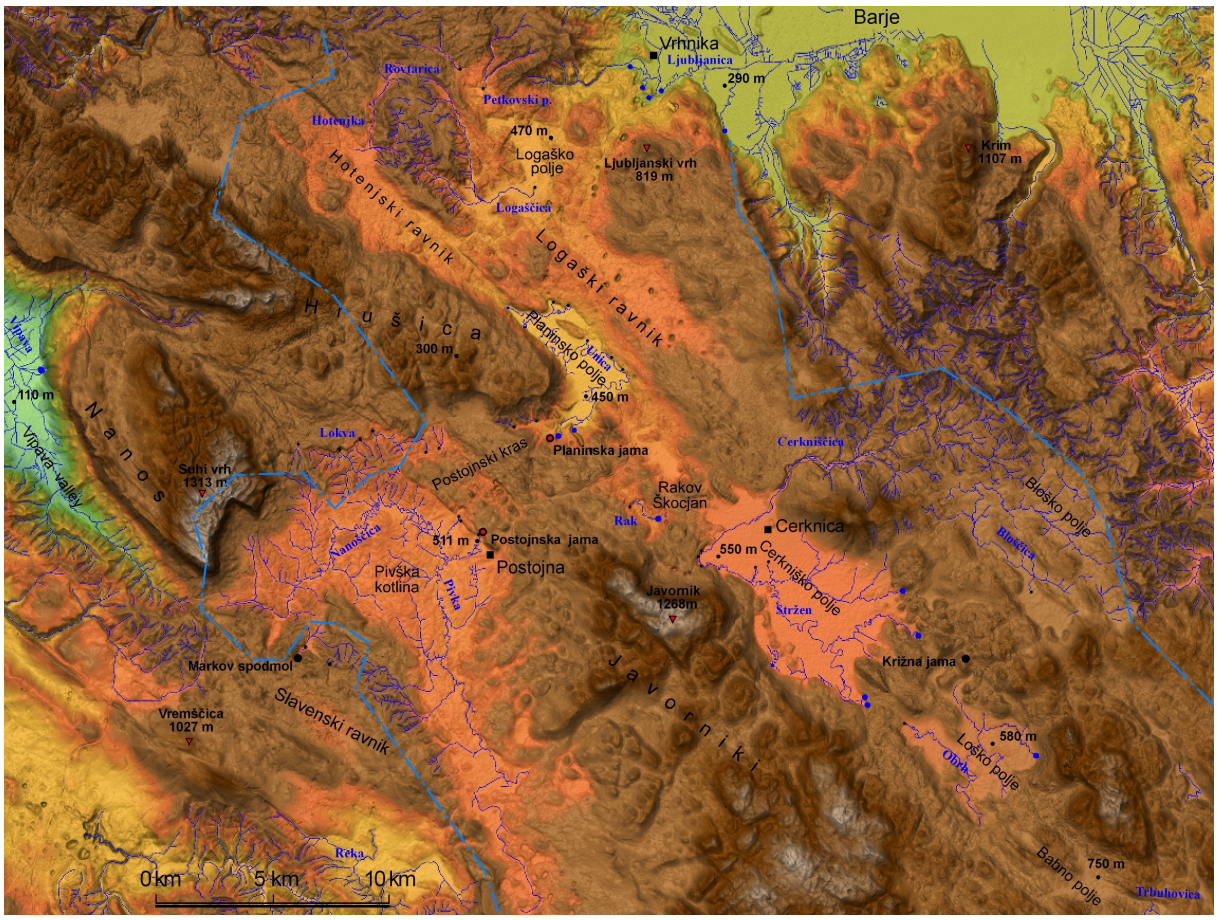


Fig. D1: Water basin of Ljubljanica river. High karst plateaus, lower poljes and levelled surfaces are main characteristics of the relief.

The karstic rocks are generally micritic, locally oolitic, limestone and dominantly late-diagenetic dolomites, mostly of Mesozoic age. They were formed on the Dinaric platform under conditions of continuous sedimentation which enabled high rock purity, generally with less than 5%, but locally as little as 0.1%, insoluble residue. The total thickness of the carbonate sequence is about 6850m.

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

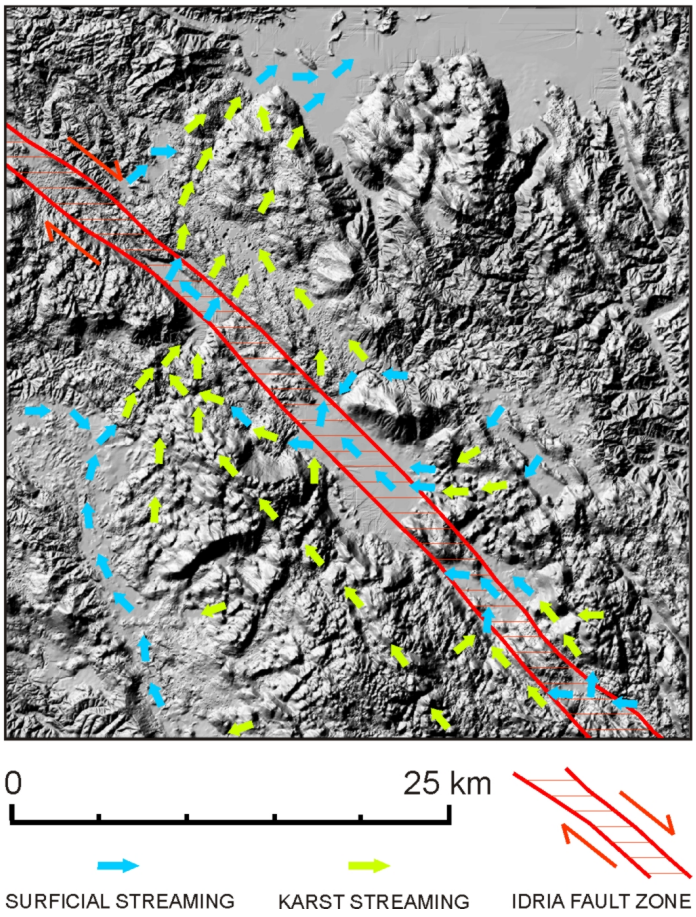


Fig. D2: Influence of the Idria Fault zone upon the karst poljes hydrology

The highest parts of the basin are high karst plateaus Hrušica, Javorniki, Snežnik and Racna gora. On the poljes among them surface rivers appear only, but they have different names: Trbuhovica, Obrh, Stržen, Rak, Pivka, Unica and finally after the springs at Vrhnika the name Ljubljanica. Besides these rivers there are some sinking rivers that are collecting waters from dolomite or flysch. These are Nanoščica, Cerkniščica, Logaščica, Hotenka and Rovtarica and many smaller.

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 Barje, part of Ljubljana tectonic basin, which is connected with gradual tectonic subsidence of the area. Mean annual discharge of the Ljubljanica at springs is 38.6 m^3.

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

Cerkniško polje

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

It is a karst polje developed in the important regional fault zone – Idrija fault. Idrija fault has "Dinaric" direction (NW-SE); in the same fault zone are developed: Planinsko polje, Loško polje and Babno polje. Bottom of Cerkniško polje covers 38 km^2 in elevation of about 550 m. Bottom is formed on Upper Triassic dolomite, which is presented also on the N, E and SE side of the polje, there are some Jurassic dolomites also presented. On W and NW the Cretaceous limestone are presented. Inflows are on E, S and partly on W sides of polje. The largest tributary to polje is Cerkniščica drained the dolomite catchments area. The important karst springs are Žerovnica, Šteberščica and Stržen. Stržen flows on the W side of polje towards the ponors in the middle of the polje, from where water flows directly to Ljubljanica springs, and towards NW side of polje, from where the water flows to Rakov Škocjan. From the foot of Javorniki mountain to the contact with dolomite in the polje bottom is 12 ponor caves. They are connected to Karlovica cave system to which also the highest waters from polje flows. It the system there is more the 7 km of passages. Passages are generally low, because they are filled by alluvia. Thickness of alluvia in Jamski zaliv, before the caves entrances, is about 8 –10 m.

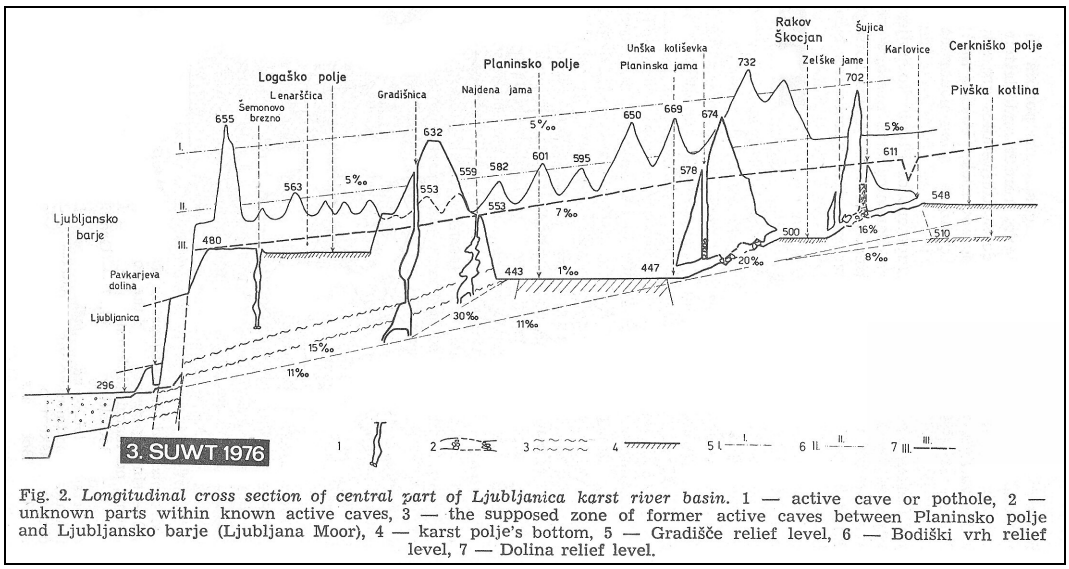


Fig. 2. *Longitudinal cross section of central part of Ljubljanica karst river basin.* 1 — active cave or pothole, 2 — unknown parts within known active caves, 3 — the supposed zone of former active caves between Planinsko polje and Ljubljansko barje (Ljubljana Moor), 4 — karst polje's bottom, 5 — Gradišče relief level, 6 — Bodiški vrh relief level, 7 — Dolina relief level.

Fig. D3: Longitudinal cross section of Ljubljanica karst river basin (Gospodarič & Habič 1976).

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.

Flat 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 grounds 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 with more than 7 km of passable channels. Largest are Velika and Mala Karlovica caves. Most of caves are short; they get narrow or end with breakdowns or sumps.

Outflow from the polje was not oriented to one channel, rather to a mesh of channels, which about 200 m from the edge of polje combine into a couple of larger galleries. They are generally low, because the bottoms are filled with 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.

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.

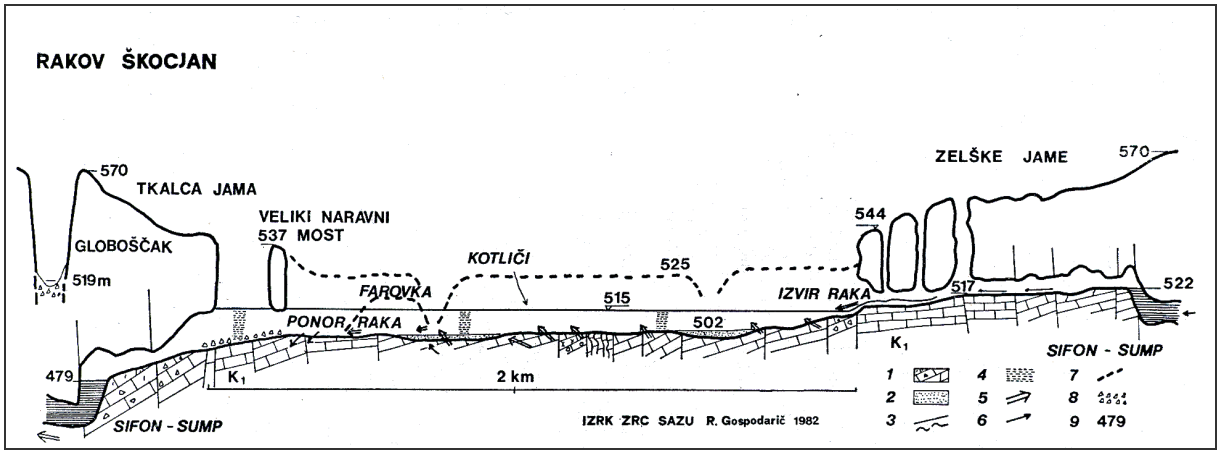


Fig. D4: Cross-section along Rakov Škocjan karst depression between spring at Zelške jame and sink in Tkalca jama. Legend: 1 – rocky bottom, 2 – alluvia, 3- fault zone, 4 – flood in 1982, 5 – karst spring, 6 – water flow directions, 7 – terraces, 8 – boulder rocks, 9 – altitude (Gospodarič et al. 1983)

Žejna dolina contact fluvio karst

About 100 km^2 large N part of Ljubljanica catchment and structurally belongs the south-eastern part of a vast nape structure over trusted on the Mesozoic limestone. The oldest rocks are non-carbonate Palaeozoic and Triassic slate, conglomerates and sandstone. The larger part of the relief is composed of carbonate rock, predominantly upper Triassic dolomite.

Large relief forms are ridges and medium-sized up to 200 m deep fluvial valleys and dry valleys, which extend into levelled karst plains on the edge: to the Logaško polje and the Hotenjsko polje plain. It is characteristic that rivers sink at the bottom of the valleys they flow across; from there dry or intermittently dry valleys extend. Great contact depressions sometimes formed next to swallow-holes, which were later filled with fluvial sediments. Young erosion terraces or alluvial dolines and sinks formed in them later.

In Žejna dolina valley, water from Triassic dolomite and slate is collected by the Žejski potok. The stream cut a wide valley that narrows upon reaching the swallow-holes in the limestone. The water sinks at 549 m a.s.l. into the 340 m long cave Kmetovo brezno, which formed at the contact of Triassic dolomite and cretaceous limestone. The river flows partly to the springs of Ljubljanica and partly to the springs of Idrijca river.

A dry valley extends from the swallow-holes to the south. In it water from the dolomite slopes is collected into the small Hlevišarka stream in this dry valley. It sinks at the contact with limestone next to the first houses in Hotedršica 540m a.s.l.

During the floods that occur every few years, Žejski potok floods the land around the swallow-holes and flows through the dry valley together with the Hlevišarka to Hotedršica, where it sinks in swallow-holes on the karst flats or field.

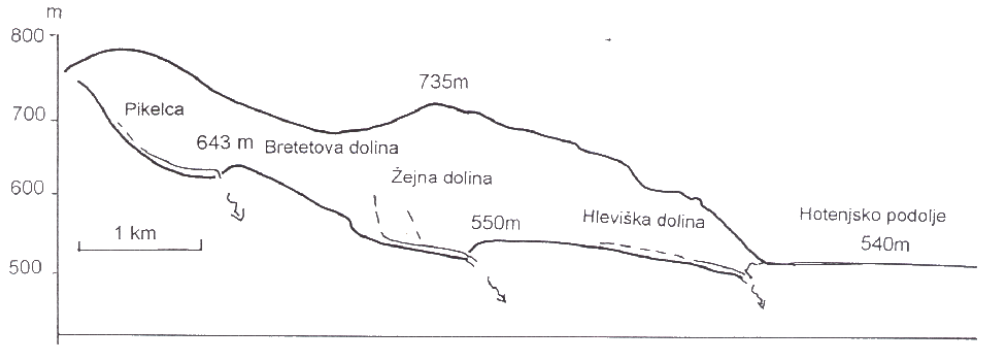


Fig. D5: Schematic cross section trough active valleys of three sinking brooks Pikelce, Žejnski potok and Hlevišarka and dry valleys in between to Hotenjsko polje.

Floods on Hotenjski ravnik

Hotenjsko podolje is 13 km long and up to 3 km wide levelled karst surface, a belt of lower relief between high karst plateau Hrušica (700 – 800 m) on SW and relief of dolomitic fluvial and karst plateaus like Žibrše and Rovte (600 – 700 m) on NE. Surface of Hotenjsko podolje is in elevation between 600 and 500 m that developed within the Idria (dextral strike-slip) Fault, which runs through the area in a NW-SE direction. Podolje is tilted towards SE. Most of podolje is formed on Jurassic and Cretaceous limestone; on NE side is along the fault lines also on Triassic dolomite.

Relief of podolje is in general levelled but dissected by numerous dolines that in some areas cover entire surface. Where brooks from dolomite brought some sediment, no more than 1 m is preserved on the surface, making agriculture in this part possible. Hotenjsko podolje developed as a karst polje, but is now degrading because of drop of the ground water level.

There are several caves, mostly simple vertical shafts. Two of them reach the level of karst water which is about 70 m below the surface. However, when heavy rains, like in September 2010 when in the area in three days fell about 400 mm of rain. Hotenjka and other surface waters flood because the capacity of the ponors was not great enough. Besides karst water level rose for 30 –70 m and more. Main inflow was from karst plateau on SW side where also a groups of springs appeared and created a river with discharge of several m^3s^{-1}.Part of Hotenjsko podolje was flooded too and as last such a flood occurred about 70 years ago, there were also some houses flooded.

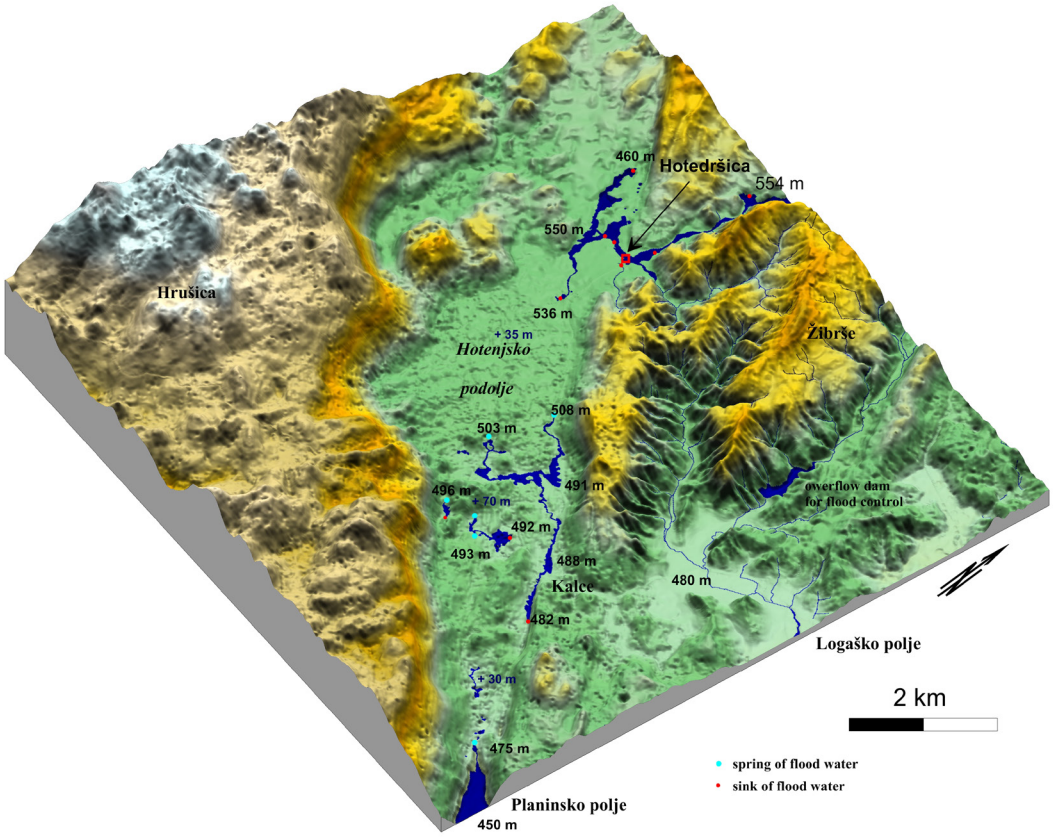


Fig. D6: DEM of Hotenjsko podolje. Marked is high water stand during September 2010 flood. With numbers +35m, +70 m and +30 m is marked the rise of ground water in karst.

Logaško polje

Logaško polje is border polje, developed on the contact of dolomite and limestone between 470 and 480m a.s.l. A number of small streams flow onto it, the largest being the Logaščica, which collects run-off from a dolomite area of 19 km^2. The mean flow is 0.3 m^3/s. Short lasting floods occur at the swallow-holes on the Logaško polje when the flow exceeds 30 m^3/s.

In the past, another large water flow flowed to the Logaško polje – the Petkovski potok brook with the Rovtarica brook. The Petkovski potok flowed across the present dry valley away from Log and deposited thick beds of non-carbonate rubble on the northern part of the Logaško polje. The covered valley relief was already fragmented by transport of the sediment onto the karst.

WHOLE-DAY EXCURSION (**E**)

GEOMORPHOLOGY AND HYDROGEOLOGY OF KRAS PLATEAU

Friday, 22. 6. 2012, 8:00-19:00

Dinaric Karst is the major karst area of Slovenia. The dominant relief features are rather extensive levelled surfaces at different elevations, large closed depressions (e.g., polje), and conical hills. Fluviokarst features like dells are common on dolomites. Karst rivers appear only in the bottoms of poljes, where they result from high level of karst water. Allogenic rivers flowing from non-carbonate regions either sink at the karst boundary forming blind valleys, or cross the karst through deep karst valleys and canyons. There are numerous extensive and complicated cave systems formed by sinking rivers and connected with the surface also by numerous vadose shafts. The surface karst morphology is typified by the abundance of karren, dolines of various diameters and depths, sometimes extensive collapse dolines, cave entrances, unroofed caves, etc.

In past centuries, the Dinarski Kras of Slovenia represented one of the world's prime sites of early scientific exploration of karst phenomena due to the large number of outstanding karst features such as caves, large sinking rivers and flooded poljes. Speleology, karst hydrology and biospeleology were born here. The most prominent phenomena are situated in the north-western part on the plateau named Kras.

In Slovene language, *kras* means a rocky, barren surface. The name is often used as toponym. *Kras* plateau became a textbook example for such kind of landscape because of the extraordinary karst phenomena, and explorations done in the 19th Century. The name Kras in the German form of the word (der Karst) became an international scientific term. The area where these early explorations took place is called the *Classical Karst*.

The Kras is a distinct plateau, especially when viewed from the seaward side. There are steep limestone slopes few hundred meters high rising directly from the sea or from the neighbouring lowlands on the north-west. On the north-east, the plateau ends above the broad and low lying Vipava valley. Higher relief on flysch on the east separates the Kras from the Pivka region. On the south-east, the border of Kras is again well defined by contact with the non-carbonate flysch of the Brkini hills and the valley of the Reka river. Toward the south, the transition to karst ridges and Matarsko podolje karst plateau is less obvious.

Kras plateau

The Kras is a low, 40 km long and up to 13 km wide, NW–SE-trending limestone plateau lying between Trieste Bay, the northernmost part of the Adriatic Sea, Vipava valley in north-east, and Friuli–Venezia Giulia lowlands and river Soča in north-west. The 45°45´´N and 14°00´´E lines of latitude and longitude cross the Kras near Divača village.

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). 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, and ponor have entered to international scientific terminology from here.

Climate is sub-Mediterranean with warm dry summers and most of the precipitation in autumn and spring. Cold winters, with NE wind "burja« (bora = borealis) show strong influence of the continent. Average yearly precipitation on Kras varies from 1400 to 1650 mm, and average yearly evapotranspiration from 700 to 750 mm. 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.

The Kras belongs to Adriatic–Dinaric Carbonate Platform of the External Dinarides composed of shallow marine fossil-bearing Cretaceous and Palaeogene carbonates. Eocene flysch rocks encircle the carbonate plateau. Kras and Matarsko podolje tectonically belong to Komen thrust sheet, which is thrust over Eocene flysch and Palaeocene/Eocene limestone of the Podgorski kras.

The main part of the plateau is essentially levelled, inclined slightly towards the north-west, with numerous dolines, caves and other karst features. About 3490 caves are known on the Kras plateau. In seven of them we can reach 21 km of passages of the underground Reka which flows

between 200 and 300 m below the surface. There is a belt of slightly higher relief in the central part of the plateau, formed by conical hills like Grmada (324 m a.s.l.), and dissected by large depressions. The higher relief divides the Kras into two separated levelled surfaces. In the north-western part, the plateau descends to below 50 m a.s.l. on the edge of the Friuli Plain; on its south-eastern edge altitudes are about 500 m a.s.l. There is about 300 m of accessible vadose zone with caves formed at all altitudes from the surface to the sea level and below it.

No superficial streams occur on the Kras surface, because all rainwater immediately infiltrates to carbonate rocks. There are two dry valleys crossing the plateau and some NW–SE-trending belts of lower relief which are result of young tectonics.

Fig. E1: DEM of the Kras plateau in centre and adjacent karst and fluvial relief.

The age of the karst of Kras plateau can be defined as the time when the karst rocks were uplifted out of the sea. For the most of Dinaric karst in Slovenia this occurred after the Eocene, since after that there is there is no evidence of younger marine sediments. As soon as the carbonate rocks

were exposed, we can expect that the karst was formed, but there are no remnants of karst features from that time. Most likely denudation has already destroyed them.

The oldest features in the karst relief are unroofed caves. They were caves that were formed by sinking rivers, bringing allogenic sediments to caves in Kras. At the end of the morphogenetic phase all these caves were filled with fluvial sediments. This indicates the diminishing of the gradient in the whole area. Diminishing of the gradient which ended with planation could mean tectonic phase which ended at about 6 Ma ago. After that a new tectonic phase started. Three areas faced uplift and tilting for several hundred meters. The uplift was stronger in the SE part of the area. Karst denudation was evenly lowering the surface, so the surface remained well preserved, dissected on central parts of karst with dolines, which represent few per cent of total area only. The even denudation exposed former old caves to the surface. Some of them are filled with sediments, from some sediments were washed away or were never filled.

On the surface, they are expressed as narrow and often meandering shallow trenches, shallow oblong depressions, and doline-like forms in rows and collapsed dolines.

The appearance of old unroofed caves and their fills resulted from denudation, erosion and chemical dissolution of limestone above the cavities. Fills exposed on the present surface include speleothems and cave fluvial deposits. The ancient directions of flow, different catchment areas of sinking rivers and different organisation of the ancient underground drainage were reconstructed from several unroofed caves opened during highway construction in the Divaški kras. The thickness of rock overburden removed above cavities was established to have been 50–100 m. The age of cave fills was calculated from denudation rates and the expected thickness of missing overburden to 0.7–5 Ma. This large time range resulted from the expected minimum (20 mMa^{-1}) and maximum denudation rates (50 mMa^{-1}) calculated or measured in the area.

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 Divača. It is built mostly by Cretaceous and Palaeogene limestone. The surface is levelled 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 Divaški 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 m^3). It is followed by the 122 m Sekelak, the volume of which is 8.5 million m^3 and Lisični dol (6.2 million m^3). Then there are: Globočak (4.6 million m^3), Bukovnik (1.7 million m^3), Risnik (1.5 million m^3) and others. As rooms as big are not known in the Kras, 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 rocks 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 cave at Lipove doline

Unroofed caves are an important part of the surface morphology of Divaški kras where 2, 900 m of the unroofed caves was mapped.

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, allochtonous sediments and morphology are testifying their cave origin. Several unroofed caves were studied and sediments were analysed; clastic sediments are dated to 1.6 - 1. 8 Ma or/and 3.8 to 5 Ma.

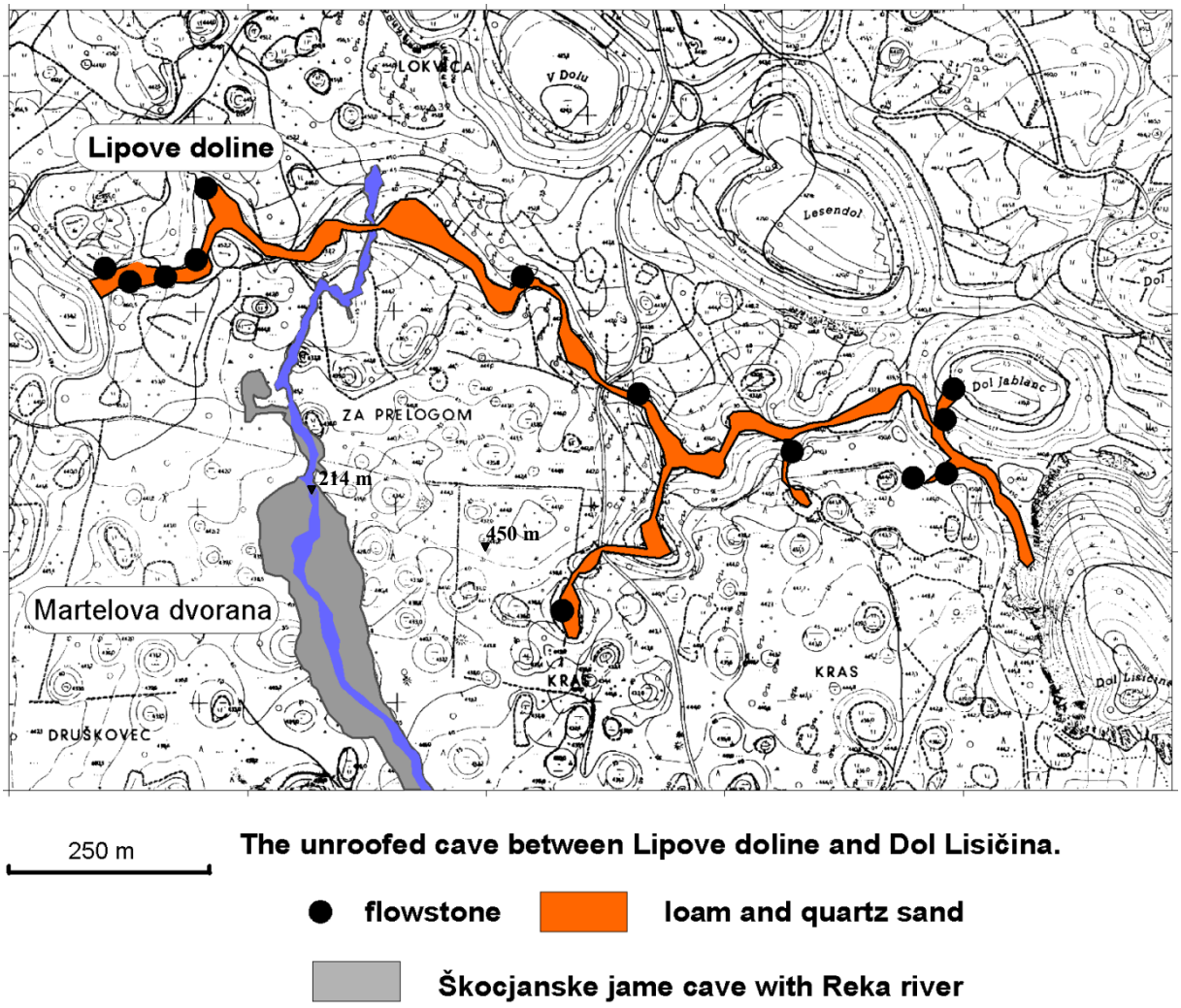


Fig. E2: Position of the unroofed cave and Škocjanske jame beneath it. The red lime is the location of the profile from the next Figure.

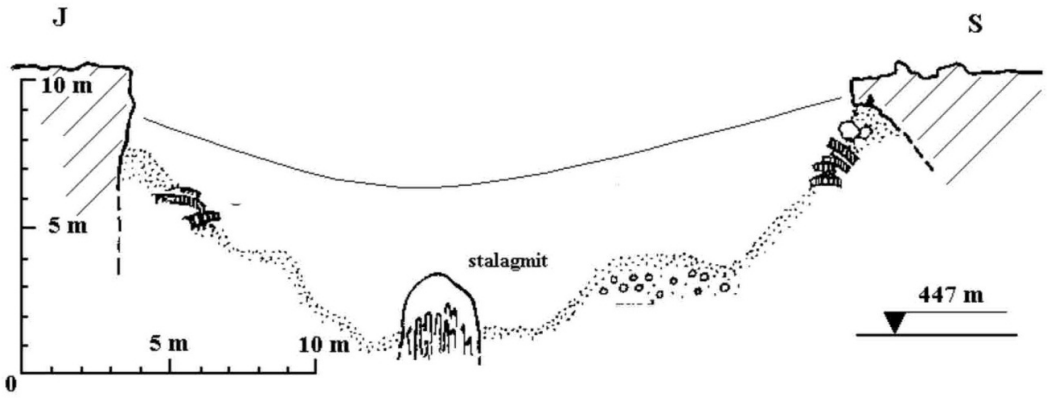


Fig. E3: Cross section of the unroofed cave at Lipove doline.

Reka River

The Reka river is the main sinking river of the Kras edge. It gathers the water from the area of more than 350 km^2. 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 m^3/s and the mean

discharge 8.26 m^3/s. In the time of extremely high waters its discharge can reach up to more than 300 m^3/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 m^3/s are on the coast are connected by a network of passages that reach a depth of about 80 m below the sea level.

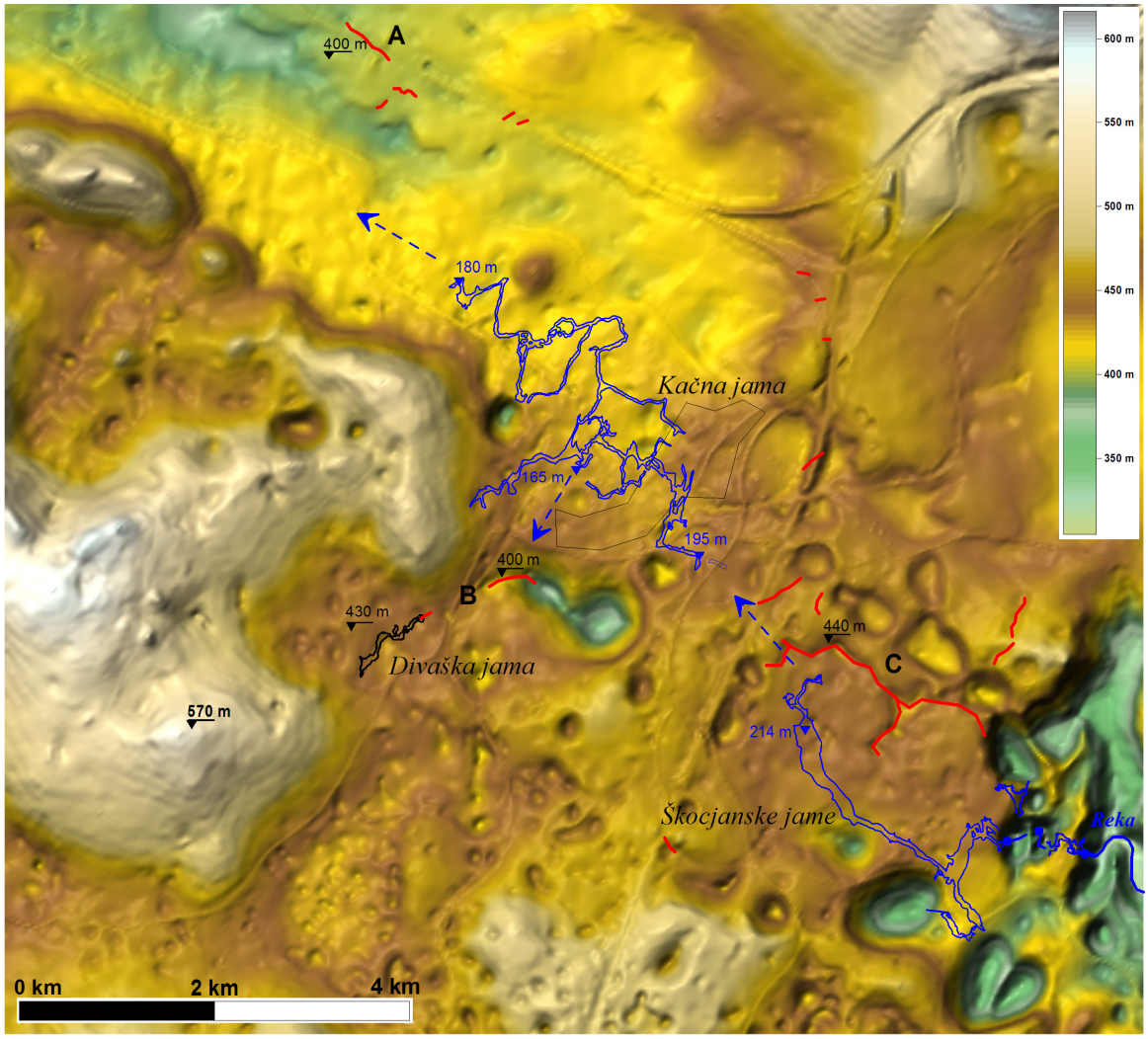


Fig. E4: The map of the Divača karst. On the levelled surface the large collapse dolines are dominating features, solution dolines are frequent, but they represent only small proportion of the surface. The outlines of the main caves and the main unroofed caves are marked. On the map made of DEM with 12.5 m grid the road cuts or causeways are also seen.
Legend: 1. Outline of the active river caves, 2. Divaška jama cave, 3. Unroofed cave, 4. Unroofed caves mentioned in the text: A: Unroofed cave near Povir, B: Unroofed cave in doline Radvanj, continuation of Divaška jama, C: Unroofed cave above Škocjanske jame, 5. Height of the surface, 6. Height of the water level in caves, 7. Reka river and ponors, 8. The supposed direction of water flow, 9. Outline of the town Divača.

Škocjanske jame

The Škocjanske jame caves are 5.8 km long. The Reka river, mean annual discharge 8, 26 m^3/s enters the cave at an altitude of 317 m; in the Martelova dvorana room, it is 214 m above sea levelled at terminal sump at about 190 m a.s.l. (i.e. 127 m lower). At low waters Reka sinks 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. Most primary channels developed along tectonized bedding-planes.

Škocjanske caves are composed of phreatic tunnels and gravitational or paragenetic reshaped galleries. The proto-channels developed in phreatic conditions, formed along tectonized bedding-planes. The water flow demanded a high degree of phreatic rising and falling between individual bedding-planes which are in the area of the chambers Svetinova dvorana and Müllerjeva dvorana approximately 175 m. Large quantities of water could flow through all these tunnels, but meanwhile, rubble was transported through caves above them. Remnant of 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 towards SW. 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 was done by cavers of DÖAV (Litoral section of Austrian Alpinistic club) from Trieste. The most important explorer was Anton Hanke. In 1891 they already reached the final sump in the cave.

The largest chambers are Martelova dvorana, with a volume of 2, 100, 000 m^3, and Šumeča jama (870, 000 m^3). 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.

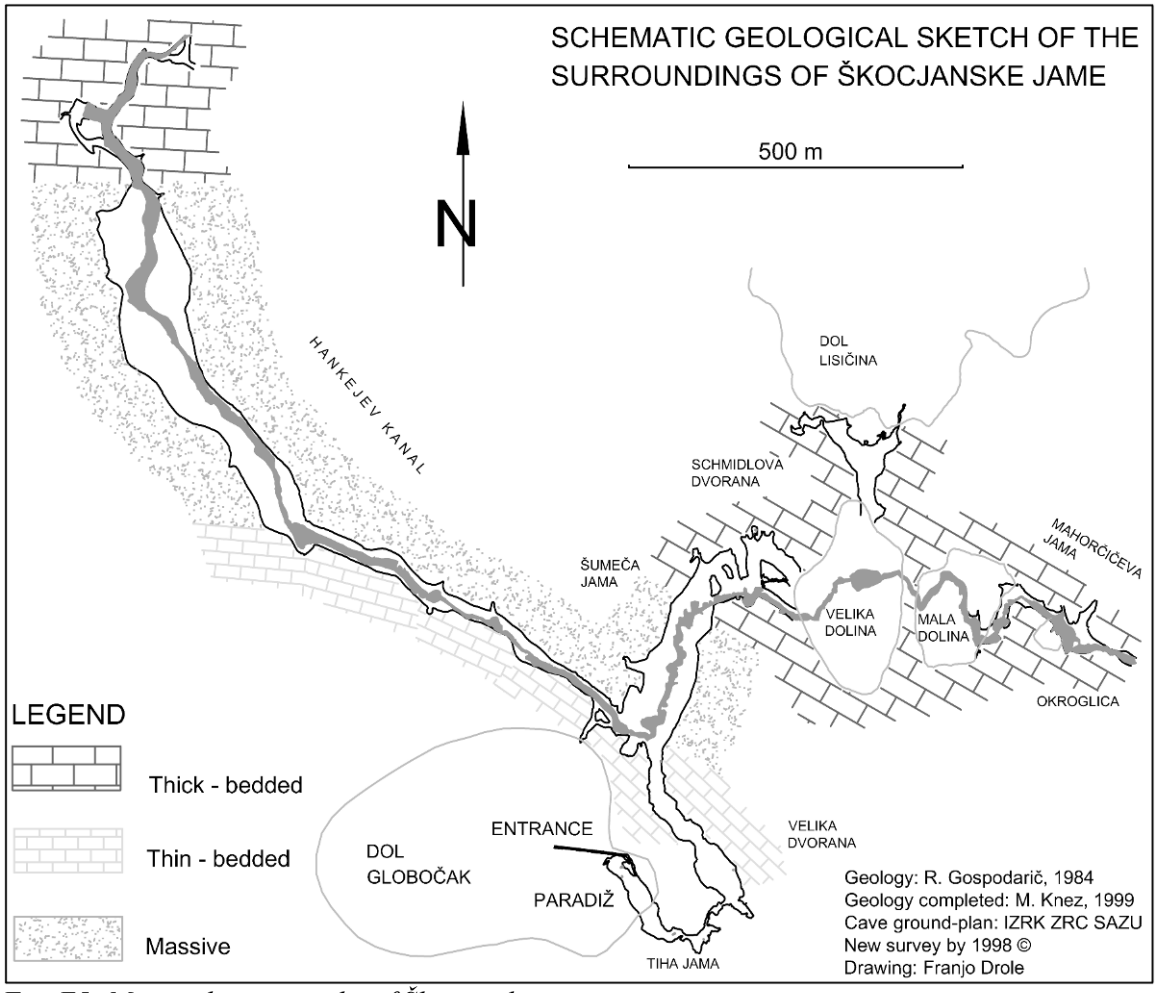


Fig. E5: Map and stratigraphy of Škocjanske jame.

Bestažovca and Perkova pečina caves

The main part of the Kras plateau is essentially levelled inclined slightly towards the north-west. There is a belt of slightly higher relief in the central part of the plateau, named Taborski griči. It divides the Kras into two separated levelled surfaces. The southern one is Nabrežinsko podolje, which southern part is S of Sežana in elevation about 400 m is named Lipiški ravnik.

In Taborki griči there are some interesting old caves. Most important is 250 m long and 45 m deep cave Bestažovca. The cave is located near the ridge between hills on the in altitude 460 m (45°41'34.92"N, 13°53'30.22"E). At the entrance to the cave there are two deep shafts that lead to the main part of the cave. This consists of about 150 m long and about 10 m wide nearly horizontal passage. In this passage the rock art was found.

The passage was in past accessible through another cave, today just a large abri Perkova pečina. The traces of visits of prehistoric people, a fireplace with charcoal and ashes, pieces of charcoal which is remnant of torches, bones and Neolithic pottery are preserved on the surface of the passage floor. The connection between the two caves was later closed due to the sediment creep caused mostly by frost heaving. Present climatic conditions in the main passage are stable, mean annual temperature is about 9° C, and oscillations of temperature and humidity are small.

Cave paintings consist of drawings made with red ochre on the walls and black dots on the passage ceiling. Besides drawings there are on three places remnants of grass or some another plants that were on purpose placed where drip water deposited on them thin layer of calcite and preserve their shape.

Fig. E6: Neolithic drawings.

Radiocarbon dating of charcoal from a drawing, from fireplace and from a torch show narrow time span of about 500 years, between 7289 - 6730 BP which matches with the age of pottery found in cave. The drawings from Bestažovca cave present at the moment the only known Neolithic cave art this time in the wider area of Dinaric mountains and neighbouring Alps.

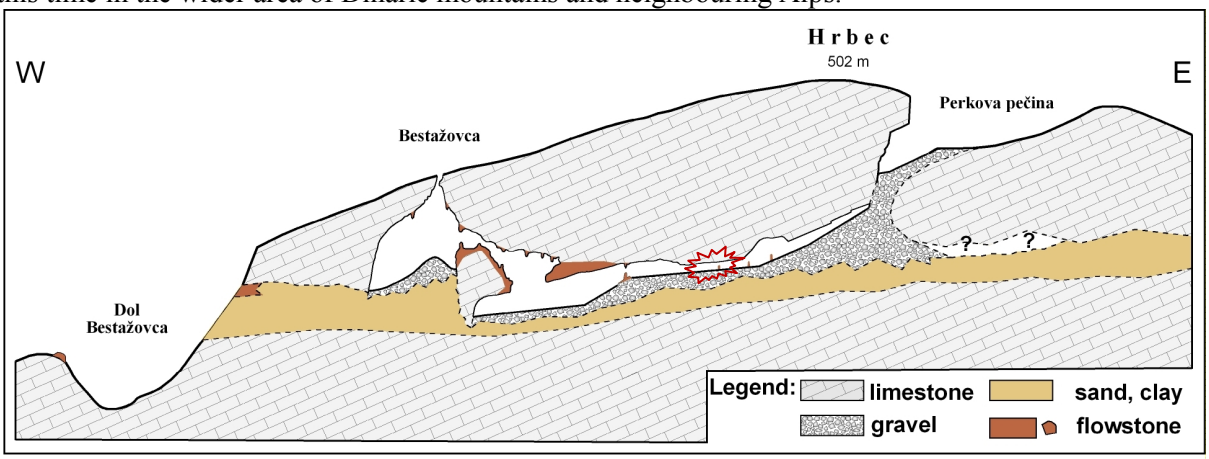


Fig. E7: Schematic cross section trough Hrbec and remnants of an old cave. Cave with mostly filled passages was transformed during its long speleogenesys by denudation of surface, collapse and sediment creep. Position of Neolithic drawings cave is marked.

The main passage of Bestažovca is after some 30 m exposed in a slope of the hill as a large unroofed cave that ends in large dolina. Cave is filled with cave sediments, clays and flowstone from which also some Pleistocene fauna was extracted, but so far no datation of the cave sediments was possible.

The system Perkova pečina – Bestažovca cave and unroofed cave are good example of the transformation of old caves to a collapse, unroofed cave and cave entrance.

Brezno v Kanjeducah and flood winds in caves above the underground Reka river

The aquifer of Kras is as complex as a karst aquifer can get. More than 300 m deep vadose zone, huge underground cavities, all possible flow regimes, complex recharge and discharge conditions and multiphase evolution are enough to believe that the system is far from being resolved.

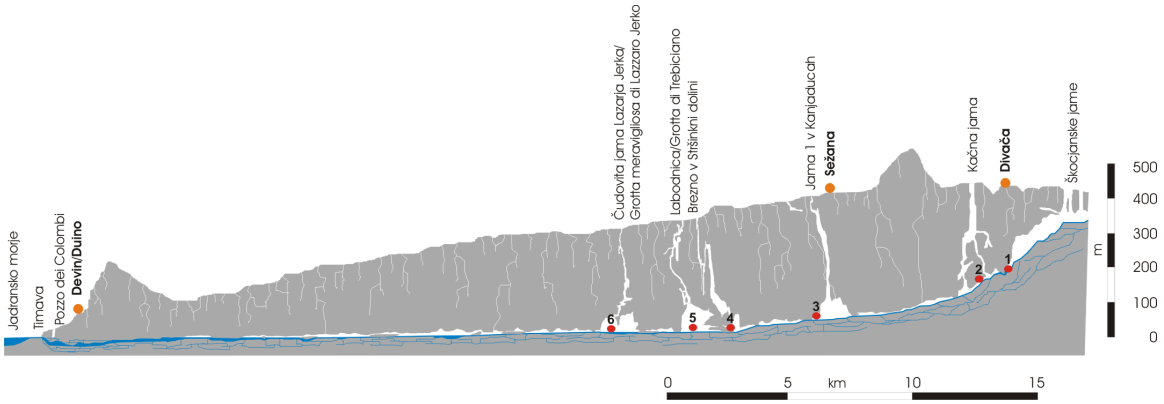


Fig. E8: Simplified cross-section of the Kras plateau with main caves and measurement points.

The epiphreatic zone is characterized by high flow variability of the Reka river. At the moment we know five caves leading to the active subsurface flow: Kačna cave and Labodnica/Grotta di Trebiciano are well known and have already been thoroughly investigated. Recently, three additional caves were pushed down to the depths of active Reka flow: Lazzaro Jerko in Italy; Jama 1 v Kanjaducah and Brezno v Stršinkni dolini in Slovenia. The river has also been reached through Brezno 3G, which turned out to be a possible second entrance of Kačna cave.

In Škocjan caves and Kačna cave it is possible to follow several kilometers of the underground while only small fragments are accessible in other caves as the confining siphons are not far apart, therefore further exploration is left to cave divers.

In 2005 we have established a monitoring of water level, temperature and electrical conductivity in all known caves that reach the Reka river. It is based on Schlumberger's CTD Divers which enable unattended long term, high frequency record of given parameters. The water level in selected caves responds vigorously to the floods. The highest known stages are more than 100 meters above the base flow stage.

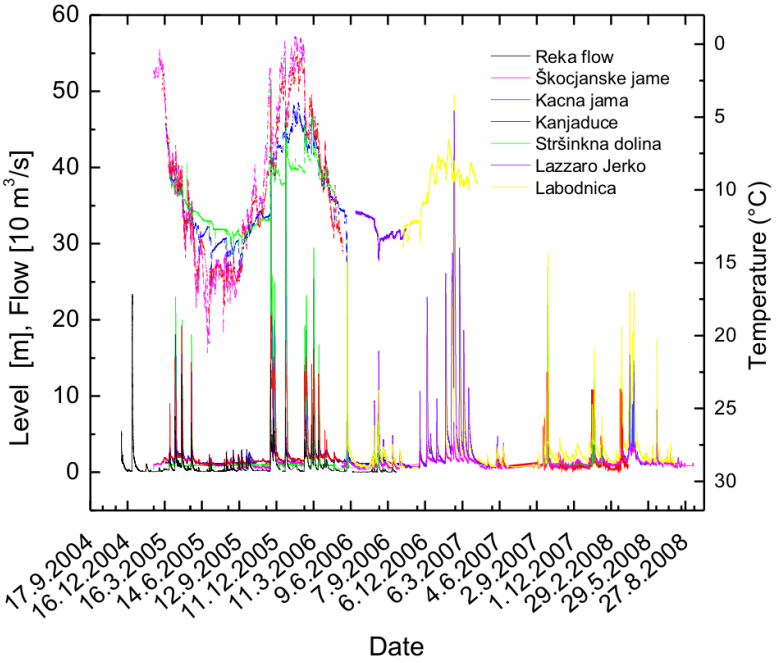


Fig. E9: Part of the recorded time-series showing the seasonal temperature variations and response to the flood events.

Figure 4.6 shows the response of stage, temperature and SEC in Škocjanske jame during a flood event in December 2009, the largest flood since the beginning of monitoring. The stage rose for

66 meters at maximum flow of Reka 255 m^3/s. The rising rate reached 6 m/h, while during the recession period; the water level was dropping up to 11 m/h. Data in other caves have not been collected yet.

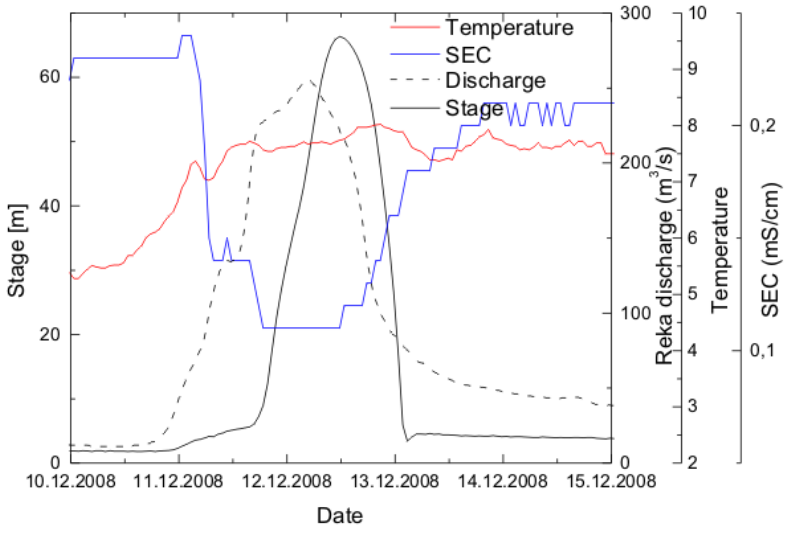


Fig. E10: Discharge, stage, temperature and SEC of Reka during the flood event in December 2008. Discharge is measure at the gaging station about 6 km upstream from Škocjanske jame.

The morphology of caves (i.e. large voids connected to the surface with series of shafts and small entrances) combined with vigorous stage response to the flood inputs also dictates extreme ventilation in these caves. Four of these caves have been explored by following the leads along openings, where strongest air currents were sensed during the flood events.

One of these is Jama 1 v Kanjaducah, where the exploration breakthrough to the Reka river was done in 2003. The cave is 310 m deep. Most of the entrance part is in the fractured zone with boulder-chocks, where small passages have been excavated following the main air currents. The cave continues with large inclined/vertical gallery down to the level of Reka. Large passages have been found in the upstream and downstream directions along the Reka river. Recent diving revealed another large dry gallery behind the terminate siphon.

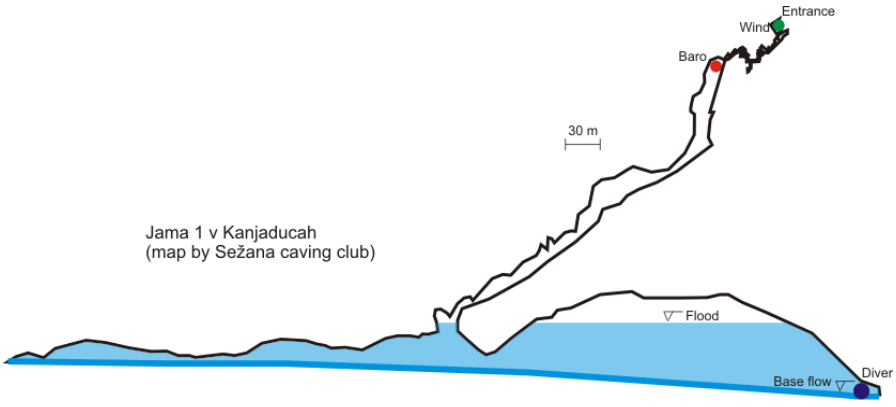


Fig. E .11: Extended elevation of Jama 1 v Kanjaducah with the positions of instruments.

To follow the air during the flood event we have installed Schlumberger's barologger at the top of big gallery to measure the air pressure and anemometer close to the entrance, additional to the diver in the terminate lake (see figure 4.8). Figure 4.9 presents the results of measurements. Stage rose to 50 m, with maximal rate of about 1 m/s. This pressed the air out through the caused the rising of the air pressure rise for 30 cm_{H2O} approc. 30 mbar) in 8 hours. A rough estimation (assuming area of 5 m^2)

gives, that about 0.6 x 10^6 m^3 of air was squeezed through the entrance. The "negative" pressure difference and wind speed was recorded during the flood recession.

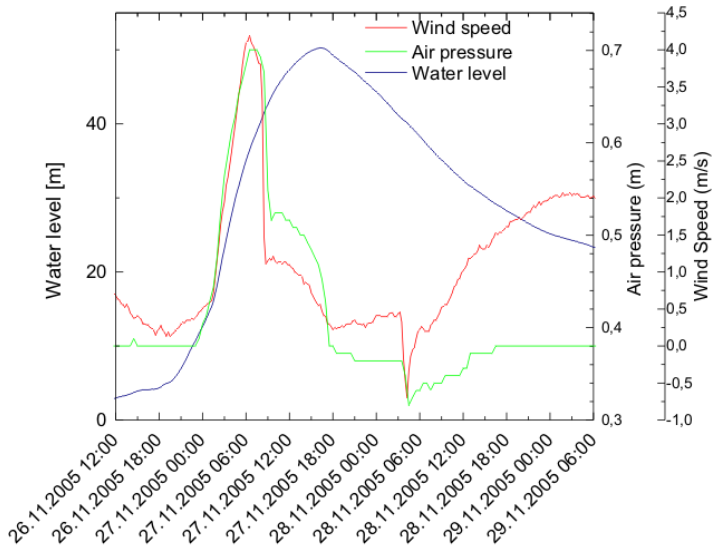


Fig. E .12: Water level, air pressure and wind speed during the flood event in November 2005.

Blind valleys of Matarsko podolje

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 it lowers on the distance of 2 km for 200 m towards SE to leveled surface ob 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 applanation 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. Alochthonous rivers no longer affected surface. 3. Surface has been lowered since for several hundred meters and is now cutting trough many old caves. This has created unroofed caves or new entrances to caves. In some such a features old sediments are preserved.

More than hundred vadose caves are known in the karst plain. Great oscillation of karst ground water was observed. Water tracing showed that the sinking streams flow to three groups of springs.

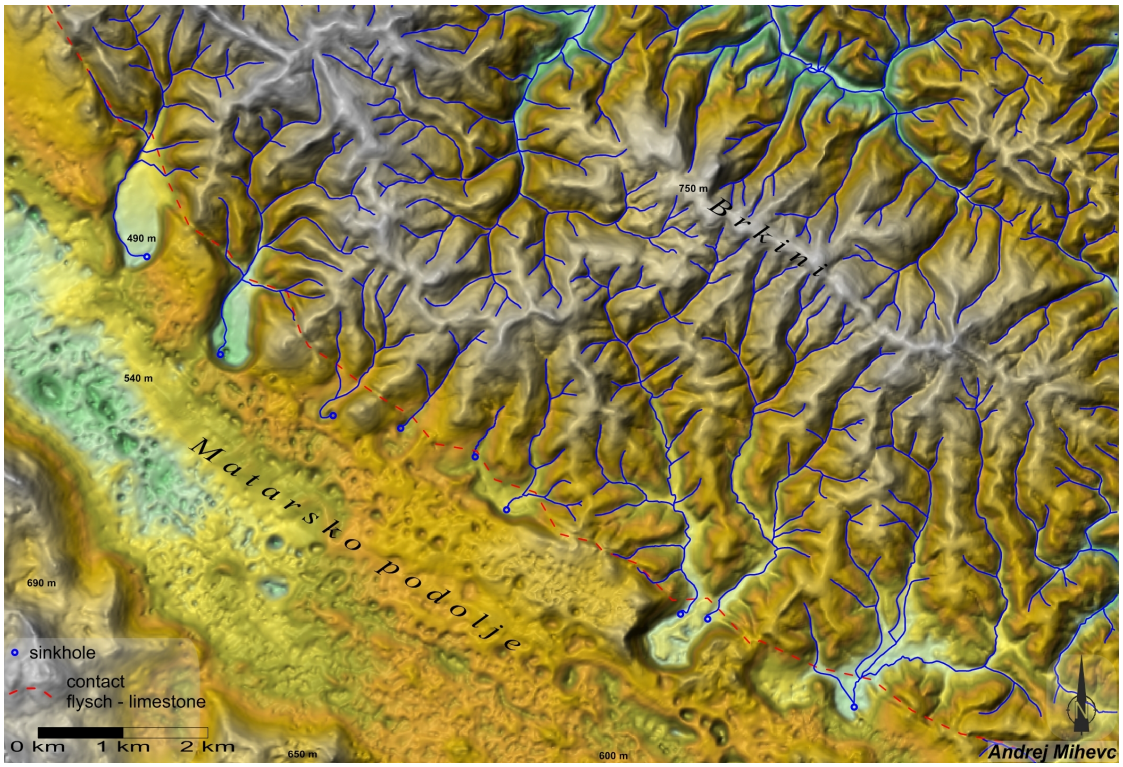


Fig. E .13: Row of blind valleys along the southern edge of the Brkini hill and very clear difference between karst and fluvial relief. From left to right are: Brezovica, Odolina, Hotična, Slivje, Velike loče, Jezerina, relict one and Male loče blind valley.

Podgorski kras and Socerb castle

The Podgorski kras (Podgora karst) is about 5 km wide and up to 15 km long karst plateau between Slavnik mountain (1025 m a.s.l.) on the north-east and littoral flysch hills of the Koprska brda on the south-west. The plateau represents the continuation of the Kras towards the south-east, but is separated from it by an important tectonic line with a drop of about 50 m.

The area belongs to the Čičarija imbricated structure. Several flysch and limestone thrust slices are elongated in NW–SE, with a dip of about 20–30^{o} towards the north-east. The sub-thrusting is well expressed in the relief as an escarpment at the south-western edge of Podgorski kras, where carbonate rocks are thrust over marl and flysch. The plateau is planned at 500 to 450 m a.s.l.

Numerous shallow dolines with flat bottoms in which some sediments are preserved represent the principal surface karst forms. There are also several unroofed caves, remnants of larger cave systems indicating that the karst is ancient. Old caves both, empty and filled, are dissected by younger vadose invasion shafts in places.

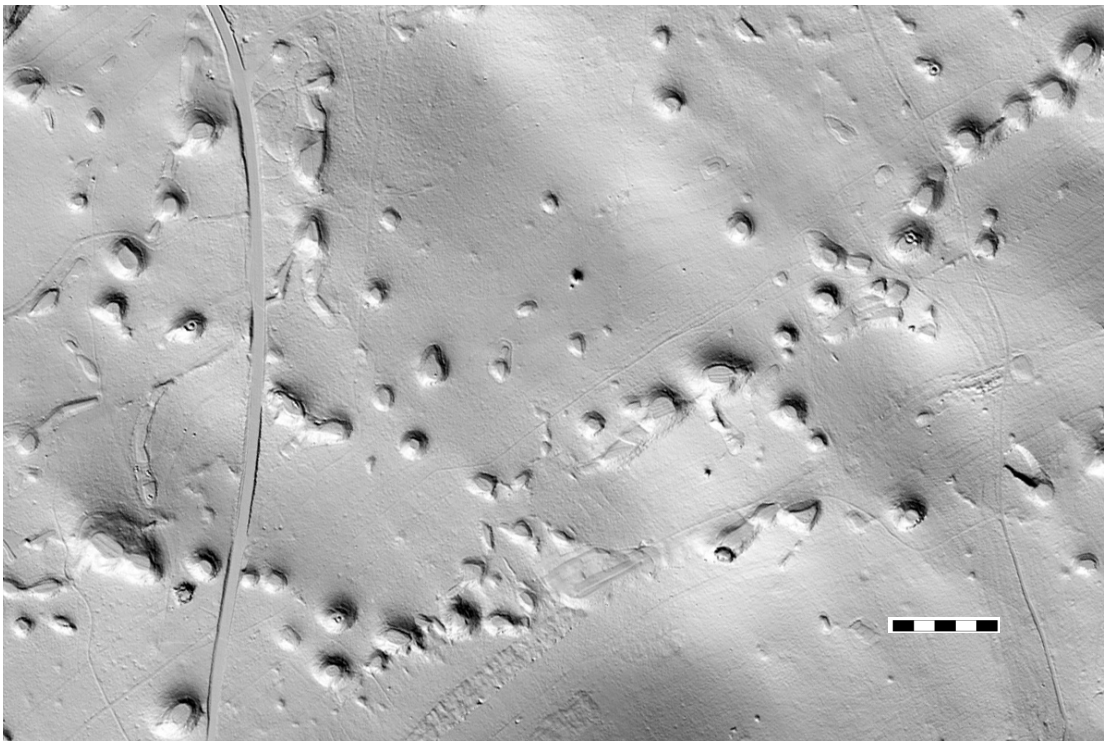


Fig. E14: LIDAR image of dolines and unroofed caves on Podgorski kras plateau (0.5 m grid). The scale bar is 100 m.

Socerb

On the edge of the Podgorski kras there is a willage and a castle, which were named after Sanctus Servolus, who was a Roman Christian martyr. According to legend Saint Servolus lived here in a cave Sveta Jama (Holly Cave). Cave is 231 metres long and 44 m deep. Its entrance part was transformed to the only underground church in Slovenia.

Selected References

Čar J. & Gospodarič R., 1984: O geologiji krasa med Postojno, Planino in Cerknico. Acta carsologica, 12(1983/1984), 91-105.

Cucchi F., Forti F. & Ulcigrai F., 1994: Lowering of karst surface by corrosion. Acta carsologica, 3, 55-62.

Dreybrodt, W., Gabrovsek, F., and Romanov, D., 2005, Processes of speleogenesis: A modeling approach: Carsologica, v. 4: Ljubljana, Založba ZRC, 375 p.

Gams I., 1974: Kras. Slovenska matica, 359 pp., Ljubljana.

Gams I., 2003: Kras v Sloveniji v prostoru in času. Založba ZRC, ZRC SAZU, 516 pp., Ljubljana.

Gospodarič R., 1976: Razvoj jam med Pivško kotlino in Planinskim poljem v kvartarju. Acta carsologica, 7, 5-139.

Gospodarič R., 1981: Generations of speleothems in the Classical Karst of Slovenia. Acta carsologica, 9 (1980), 90-110.

Gospodarič R. & Habič P. (Eds.), 1976: Underground water tracing, Investigations in Slovenia 1972-1975. 3th Symposium on Water Tracing (SWT) Ljubljana–Bled 1976, Institute of Karst Research, 312 pp., Ljubljana.

Grund A., 1914: Der geographische Zyklus im Karst. Geschichte der Erdkunde, 52, 621-640.

Habič P., 1982: Kraški relief in tektonika. Acta carsologica, 4, 23-43.

Kranjc A., 1997: Introduction. In: Kranjc A. et al., Eds: Kras. Slovene Classical Karst, 11-17, Znanstvenoraziskovni center SAZU, Inštitut za raziskovanje krasa, Ljubljana.

Krivic P., Bricelj M., Trišič N. & Zupan M., 1987: Sledenje podzemnih vod v zaledju izvira Rižane. Acta carsologica, 16, 83-104.

Melik A., 1955: Kraška polja Slovenije v pleistocenu. Dela Inštituta za geografijo SAZU, 3, 163 pp., Ljubljana.

Mihevc A., 2001b: Speleogeneza Divaškega krasa. Zbirka ZRC, 27, 180 pp., Ljubljana.

Mihevc A., 2007: The age of karst relief in West Slovenia. Acta carsologica, 36/1, 35-44.

Placer L., 1981: Geološka zgradba jugozahodne Slovenije. Geologija, 24/1, 27-60, Ljubljana.

Placer L., 1999: Contribution to the macrotectonic subdivision of the border region between Southern Alps and External Dinarides. Geologija, 4, 223-255, Ljubljana.

Placer, L., Vrabec, M., Celarc, B., 2010: The bases for understanding of the NW Dinarides and Istria peninsula. Geologija. 53/1, 55-86.

Prelovšek, M., Šebela, S., Turk, J., 2012 Spremljanje temperature zraka in CO2 v Postojnskem jamskem sistemu ob povečanem številu obiskovalcev. V: KUHAR, Miran (ed.). 17. strokovno srečanje Slovenskega združenja za geodezijo in geofiziko, Ljubljana, 26. januar 2012. Raziskave s področja geodezije in geofizike2011, 31-35, Ljubljana.

Radinja D., 1985: Kras v luči fosilne fluvialne akumulacije. Acta Carsologica, 14-15, 99-108.

Roglič J., 1957: Zaravni u vapnencima. Geografski glasnik 19, 103-134, Zagreb.

Shaw T., 1992: The History of Cave Science, the Exploration and Study of Limestone Caves, to 1900. Sydney Speleological Soc., 338 pp., Broadway.

Stepišnik U., 2004: The origin of sediments inside the collapse dolines of Postojna karst (Slovenia). Acta carsologica, 33/1, 237-244.

Šebela S., 1998b: Tektonska zgradba sistema Postojnskih jam. Založba ZRC, 18, 112 pp., Ljubljana.

Šebela S. & Sasowsky I., 2000: Paleomagnetic dating of sediments in caves opened during highway construction near Kozina, Slovenia. Acta carsologica, 29/2, 23, 303-312.

Turk, J.: Dynamics of underground water in the karst catchment area of the Ljubljanica springs. Carsologica 11, ZRC Publishing, 136, Ljubljana.

Zupan Hajna N., 1992: Mineralna sestava mehanskih sedimentov in nekaterih delov slovenskega krasa. Acta carsologica, 21, 115-130.

Zupan Hajna N., Mihevc, A., Pruner, P., Bosák, P., 2008: Palaeomagnetism and magnetostratigraphy of karst sediments in Slovenia, Cartologica 8, Založba ZRC SAZU, 266, Ljubljana.

Mihevc, A., Zupan Hajna, N., Prelovšek, M., 2010: Introduction to the Dinaric Karst. Karst Research Institute at ZRC SAZU, 49-66, Ljubljana.

ABSTRACTS

Inside-out solution of carbonate clasts - an analogue model for hypogene karstification

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Voids in Miocene (Badenian) limestone of the Medvednica Mt. in Croatia, locally known as "Litavac", were recognized as solution casts of Upper Triassic dolomite fragments by Zebec (1975). These voids are actually micro-caverns since they occur inside partly dissolved dolomite clasts. Identical micro-caverns are also recognized in limestone cobbles of Jurassic age in Pleistocene coarse-grained deltaic conglomerates of Seline in Northern Dalmatia. The clasts in Litavac are dark grey, commonly bituminous dolomites, whereas those at Seline are grey bituminous crystalline limestone. In both cases their sedimentary bodies are deltaic, although the age is markedly different; Middle Miocene (Badenian) on the Medvednica Mt. and Middle Pleistocene at the Seline locality. The matrix of Litavac limestone is micritic calcite with abundant corallinaceans which are originally aragonitic, whereas the matrix of Seline conglomerate is micritic calcite, but locally the conglomerate is cemented by dog-tooth calcite spar. The clasts are apparently dissolved from the centre outward, and in most cases the solution was only partial, leaving outer shell of the host rock preserved, which allowed for recognition of their lithology. There is no evidence of any solution of the clast surface, and in the Litavac limestone the matrix, as well as aragonite fossils do not show any traces of karstification. The carbonate debris commonly contains calcite veins which by the rule remain undissolved in the solution voids. The voids thus represent differentially dissolved host rock, and the aggressive brine must have originated within the clast itself. The high H2S content in clasts at both localities suggests that the acidification of connate water was most likely a consequence of its solution in formation water. The margins of voids are lined by small sparry calcite which resembles secondary cavern infill. Partial solution of bituminous carbonate debris thus represents a possible small-scale analogue to formation of large hypogene caverns of Dinaric Alps where formation waters with dissolved H_2S (sulphuric acid) dissolved fractured bituminous host rocks. Highly bituminous rocks in Dinaric Alps are attributed to Middle and Late Permian, Middle and Upper Triassic, Jurassic, and Early Cretaceous age, although locally there also occur bituminous limestone of Palaeocene and Early Eocene, even Miocene age, which provides wide stratigraphic "window" for formation of hypogene karst.

References:
Zebec V. (1975): Kalcit i dolomit iz okolice sela Bizek i Dolje kod Podsuseda u Medvednici (Zagrebačka Gora). Acta Geol. 8, Prirodosl. istraž. 16, 287-314.

The importance of recognition of sink-hole process in water engineering projects in Iran

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The recognition of sinkholes is an important part of the water projects in karst regions. The direct and most noticeable result of karstification is a special morphology that makes karst regions quite different from any other non karstic region. One of the most representative geomorphic forms characteristic of karst regions is the sinkhole (doline). The direct and the most noticeable result of karstification is a specific morphology that makes karst regions quite different from any other non karst region. Since these karst forms and their evolution are an immediate consequence of the water solution work on soluble carbonate media, therefore the full understanding of their morphology is required The most representative morphological forms associated specifically with karst regions are: karren, dolines (sinkholes), dry valleys, shafts (pits) caves, poljes, and karst plains. Dolines (sinkholes) aside from karren are the most represented morphological forms in karst. In most cases, they are the result of chemical action of water on soluble rock. This is the most important, but not the only factor that influences the formation of sinkholes. The aim of his paper is to outline this problem. As case study the result of research done in Hamadan. Area in S.W. of Iran where more than 40 sinkholes which were a great hazard in the area is discussed. It is finally concluded that in these project area beside limestone solution the over exploitation of ground water has great influence in creation of these sinkhole in the region.

Evaporite Karst on Mars: Evidence of global climate change in the recent past

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The presence of soluble evaporite minerals on Mars has been provided by OMEGA instrument on board Mars Express and by the Mars Exploration Rovers. Many authors suggested the development on Mars of evaporite karst similar to that observed on the Earth and karstic terrains with associated possible caves. Moreover, the presence of karst landforms and processes in the evaporite deposits in different regions of Mars has been confirmed by recent works based on the observations of new HiRISE (High Resolution Image Science Experiment camera) images available. The observed karst landforms strongly resemble the terrestrial karst morphologies and appear to be formed as a result of flowing water as do similar landforms on evaporite rocks observed on Earth. On Mars, several evidences suggest that possible ice-rich deposition from the atmosphere that may occur as the result of changes in the obliquity of the planet. The melting of ice provided the necessary liquid water for the solution and collapse processes observed. The evaporite karst indicate that the environmental conditions on Mars have been much different from those that exist today, highlighting the presence of ice in the equatorial region and providing evidences that climate change also occurred in the recent past history of the planet, probably in the Amazonian age.

Protection of karst caves in Kosovo

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Kosovo is located in the central part of the Balkan Peninsula, with the surface of 10.908 km^2, and with over 2 million inhabitants. It has a favourable geographical position and is located at important transversal and longitudinal roads of the Balkan Peninsula. The geological structure, relief, climatic conditions, hydrography and biological diversity are special features of the territory of Kosovo. From geological perspective, Kosovo is located in a very specific area. It is characterized by a distinguished diversity of geological formations. It starts from the old crystalline rocks of Palaeozoic up to quaternary rocks, including various types of sedimentary and magmatic rocks and metamorphic rocks that are less prevalent. Karst terrains in Kosovo are built from karstified limestone of Triassic and Cretasic ages and of Palaeozoic marble. These terrains include an area of 1.300 km2 or 11% of Kosovo's territory. There are created numerous surface and underground forms of relief, where caves are the most important. Caves in Kosovo are quite common, but very few of them are researched and opened for visitors. The largest number of caves is found in the massifs of Bjeshket e Nemuna Mountains, Sharr Mountains, Zatriq Mountains, Drenica Mountains and along the downstream of the Mirusha River. Among the most important caves in Kosovo are: Cave in Gadime, Grand Canyon Cave, Cave in Radavc, Cave in Panorc, Cave in Dush, Peshterri Cave in Zatriq, etc. Among the most important caves in Kosovo that are known to the general public is the Cave in Gadim, which due to the aragonite crystals of various shapes and sizes is considered as a rare cave in the world. Caves in Kosovo are distinguished with numerous stalactites and stalagmites, characterised with columns and lunette decorations. These ornaments in different shapes and sizes with astonishing colours are present in most of Kosovo caves. Kosovo caves are distinguished also, for the rich fauna (especially on bats and insects) but still not sufficiently researched. Cave protection in Kosovo is regulated by the Law on Nature Protection (Nr; 03/L-233). So far, five caves have been taken into legal protection in Kosovo: Cave in Gadime, Cave in Radavc, Cave in Gllanasellë, Cave in Baicë and Cave in Kishnarekë. Several Initiatives and proposals are made for taking under legal protection the following caves: Grand Canyon Cave, Cave in Pjetershticë, Cave in Panorc, Bozhuri Cave, Cave in Lladroviq, Cave Temeqina, etc.

Large Dinaric karst plateaus in Croatia – differences and similarities as waymarks to understanding their geomorphology

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Karst plateaus are, together with karst poljes, the biggest karst landforms in Dinaric karst. They are characterized by polygenetic and polyphase morphogenesis. In the small scale karst plateaus are big flat areas with very low relative relief, but in the large scale there are a lot of differences in the micromorphology. Dinaric karst plateaus

can stand by itself like big plateaus or can be parts of the karst-polje depression bottoms or can be small tectonic fragmented and uplifted plateaus in mountainous area. In the Croatian part of the Dinaric karst there are three big karstic plateaus: Istrian plateau (~1400 km2), Karlovac plateau (Una-Korana plateau, ~1300 km2) and North Dalmatian plateau (~1200 km2). This large plateaus spread over almost 4000 km2 (7% of Croatian territory and 15% of Croatian kart area). Past researches were directed on exploration of processes and time of karts plateaus morphogenesis. There were three groups of the theories of the karst plateau genesis: erosion, corrosion and abrasion theories, while time of plateau genesis were assumed in range from Mesozoic to Pleistocene. This research is directed to the comparison of location properties, morphogenetic types and morphometric, geotectonic, geologic, macro and micro geomorphologic characteristics of these three large plateaus. According to differences and similarities of these properties one can make some conclusions of the conditions of the karst plateau genesis.

Detection of filled dolines by 3d surface modelling

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This paper presents a method for determining filled dolines through modelling digital surface model (DSM) of the former landscapes. Starting from the thesis that anthropogenic terrain changes are a lot stronger and faster than natural karst processes, there are less dolines today than they were 50 years ago. We created a DSM of the former landscape for 1972 using archival aerial photographs. The sampled area of Logatec covers five sequential stereo-pairs. We applied digital photogrammetry methods to perform image triangulation and surface modelling. The DSM was analysed with different geomorphometric methods (combination of different GIS programs) and quantitatively compared with the recent surface and terrain (DEM5, © GURS, 2006). We determined the potential filled dolines, their depth and volume. The results were verified and complemented with field measurements.

Shallow-water carbonate succession from Jazvina locality (Gorski kotar, Croatia): an example of typical late Jurassic sedimentary events on the Adriatic carbonate platform

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At the Jazvina locality, five facies units have been recognized; the Jazvina 1 unit (Jz-1), with mudstones and pelletal wackestones; the Jazvina 2 unit (Jz-2), with bioclastic floatstones and grainstone/rudstones; the Jazvina 3 unit (Jz-3), with peloidal-skeletal wackestones and packstones; the Jazvina 4 unit (Jz-4), composed of shallowing and coarsening-upward cycles with mudstones or pelletal wackestones as the lower cycle types, fenestral mudstones or pelletal wackestones as the middle cycle types, and ooid grainstones as the upper cycle types; and the Jazvina 5 unit (Jz-5), composed of shallowing- and coarsening-upward cycles that differ from the underlying Jz-4 cycles by the presence of the pisoid-intraclastic grainstone/rudstones as the upper cycle types.
The depositional environment for the Jz-1 unit is interpreted as a shallow, low-energy lagoon below the fair-weather wave-base, situated in the inner platform region. The Jz-2 unit is typical example of bioclastic carbonate sediments deposited on a carbonate platform in high energy shoals, in which large quantities of fossil debris, transported by waves and tidal currents, have been accumulated. High carbonate mud content within the Jz-3 unit suggests a subtidal depositional environment. However, contrary to the depositional environment of the Jz-1 unit, rich foraminiferal content (particularly in the packestones) indicates better water circulation above the fair-weather wave-base and thus more favorable ecological conditions than those in the Jz-1 unit. Within the Jz-4 unit, three sedimentary environments with different depositional styles can be recognized. By periodically changing conditions, ranging from shallow subtidal to oolite shoals, series of shallowing- and coarsening-upward cycles have been produced. The first two facies types of the Jz-5 unit originated under similar conditions as the first two cycle types of the underlying Jz-4 unit. However, after the final emergence of the middle cycle types, carbonate detritus (mainly intraclasts), thrown onto the emergent surface from the adjacent subtidal environments by action of storm waves and high tides, was exposed to vadose diagenesis. During these periods, some intraclasts developed pisoid envelopes, and internal sediment was produced.

Jurassic carbonates of western Gorski kotar (Karst Dinarides - Croatia) as sedimentary signature of geodynamics within the inner Adriatic carbonate platform realm

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The Jurassic succession of Gorski Kotar reveals typical sedimentary signature of inner Adriatic carbonate platform realm. Due to its facies characteristics, eleven informal lithofacies units can be distinguished. Their origin is grouped into three depositional settings that alternated over the spacious Adriatic platform area during the Jurassic. These are: (1) subtidal below the fair-weather wave-base to higher-energy subtidal above the fair-weather wave-base; (2) subtidal below the fair-weather wave-base with episodic higher-energy influences; (3) peritidal. The alteration of depositional settings reflects periods of intensive regional large-scale tectonic movements during the geodynamic evolution of the Western Neo-Tethys region, such as the opening/closing of the Dinaridic branch of the Neo-Tethys and opening of the Adriatic basin.

Jurassic carbonates of western Gorski kotar (Karst Dinarides - Croatia) as sedimentary signature of geodynamics within the inner Adriatic carbonate platform realm

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The shallow-water carbonate succession of Gorski kotar (Karst Dinarides - Croatia) contains typical sedimentary signature of Jurassic inner Adriatic carbonate platform depositional events. During the most of the Early Jurassic, deposition was characterized by the periodic sea-bottom oscillations around the fair-weather wave-base when successive series of autocycles were formed. As these environmental conditions existed throughout the platform, the uniformity of sedimentary events and their apparently simultaneous alternation took place.
From the late Early Jurassic till the end of the early Late Jurassic, platform sedimentary environments experienced a slight deepening, when micritic limestones were predominantly produced in great amount all over the platform. They were sporadically and irregularly intercalated with the coarser-grained intercalations of varying structure and thickness as a consequence of sporadic storms and/or higher tides that triggered progradations from the neighboring topographic highs, characterized with more favorable ecological conditions for abundant inhabitance of various organisms. This long-term micritic dominated sedimentary interval was a reflection of geodynamics within the Peritethyian region, caused by opening of the Dinaridic branch of the Tethys on the NE side of the Adriatic carbonate platform, and the opening of the Adriatic basin on the S-SW side of it. Namely, this extensional events at both platform sides caused slight and steady deepening of the Adriatic platform interior, with predominant carbonate deposition within the subtidal below-the fair-weather wave-base when predominant micritic-rich limestones originated.
The establishment of long-lasting peritidal conditions observed within the late Upper Jurassic part of the succession, indicate the shallowing of the Adriatic platform realm. This was a consequence of advanced NE platform margin shifting towards the S-SW, which triggered simultaneous and gradual uplift of S-SW platform margin. This uplifting stopped when further shifting at the NE Adriatic carbonate platform margin stopped, i.e. at the end of the Late Jurassic when closing of the Dinaridic branch of the Tethys began. This led to predominance of a slight subsidence rate within the sedimentary environment that, combined with global eustatic sea-level rise, enabled the pronounced drowning of the S-SW Adriatic platform margin as well as the inner platform area during the transition from the Late Jurassic to the Early Cretaceous.

Facies characteristics of the upper Jurassic limestones along the road Banska vrata-Breze (Karst Dinarides, Croatia)

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The facies succession exposed along the road Banska Vrata-Breze suggests that after deposition of the Early Upper Jurassic shallow subtidal deposits of Facies A, synsedimentary tectonics caused the formation of a regional connected with the open basin. On the margin of such a deeper-water sedimentary environment below the fair-weather wave-base, deposits of facies B slowly accumulated simultaneously influenced by pelagic material brought from the open sea area. By periodic shedding of the shallow-water carbonate material from the reefal/perireefal margin of the intraplatform trough by mechanisms of the gravity flows, triggered by periodical storms and/or, more likely, smaller earthquakes, the deeper-water marginal part of the trough was progressively

filled up when normaly graded bioclastic intervals of facies C were deposited. When this shallowing reached the shallow subtidal the shallow-water allochems and bioota of facies D was developed. Therefore, once, the shallow subtidal environment was re-established, the rate of carbonate accumulation was rather high capping the thick bioclastic unit of facies C, resulting in further shallowing which reached the low tide and even intertidal levels with sporadic subaeral exposure.

Middle lower Jurassic coarsening-upward sedimentary signature within the carbonate platform succession of Velika kapela mt. (karst Dinarides, Croatia)

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The middle Lower Jurrasic sedimentary succession has been formed within the interior of the isolated Adriatic carbonate platform area. It reveals successive coarsening-upward trend from the subtidal below the fair-weather wave-base as the predominant response to the autocyclicity in the sedimentary environment. Gradual aggradation of the muddy carbonate material, deposited below the fair-weather wave-base reduced accommodation space, causing the sea-bottom to rise above the fair-weather wave-base. Here, more grainy carbonates were deposited, creating one coarsening upward cycle with mudstones or peloidal-bioclastic wackestones as the lower cycle member and peloidal-bioclastic wackestones/packstones to grainstones as the upper cycle member. During the "lag phase", the sea-bottom has sunk below the fair-weather wave-base, which enabled the formation of the next coarsening upward cycle. The progradations of the neighbouring oolitic shoals periodically and randomly interrupted this process. Oolitic shoals sporadically formed on topographic highs within the subtidal area, progradated over the surrounding environment below or above the fair-weather wave-base, producing sporadic coarsening-upward cycles with ooid grainstons and/or ooid-bioclastic packestones to grainstones as the upper cycle member. Therefore, the middle Lower Jurassic coarsening-upward arhitecture of Velika Kapela Mt. resulted from interplay of repeated sediment aggradations, interrupted by periodical and random oolitic shoal progradations.

Gypsum speleothems
(in gypsum and limestone caves)

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Gypsum speleothems developed in both gypsum and limestone caves had been scarcely studied until recent decades. Recently some research groups related to the study of such caves have started a detailed analysis to see which kind of information these speleothems can provided especially from the paleoenvironmental point of view. In particular, formations such as "Gypsum Hollow stalagmites" , "Gypsum Balls", "Gypsum Trays", "Gyspusm Christmas Trees", Gypsum anemolites, Gypsum "Chandeliers" or huge selenite megacrystals are described in this work with some proposals on their speleogenesis. Examples come from limestone karsts related to sulfide oxidation origin and hydrothermal water uplifting such as Lechuguilla (USA) and Kup-Kutan Sytem (Turkmenistan) where the development of subaerial gypsum speleothems is extremely spectacular. Other examples are from the study of large megacrystals as in the case of Naica (Mexico) and Pulpí (Spain) generated in thermal underwater conditions. Special emphasis on the information provided by subaerial speleothems are also taken into account, such as peculiar genesis of the hollow gypsum stalagmites where the precipitation of carbonates in the form of calcite (Kart Sorbas, Almeria, Spain) and / or aragonite (Lechuguilla and Turkmenistan) controls the speleogenesis of such formations. On the other hand, condensation, evaporation and corrosion processes control the genesis of many gypsum speleothems reaching a chemical-physical equilibrium in which deposition conditions are kept very peculiar for hundreds and thousands of years, as is the case of the trays, "Christmas Trees" and gypsum stalactites (anemolites type). In summary, this article attempts to collect the information that gypsum speleothems can provide from examples all around the world. The gypsum speleothems can become a good paleoclimatic proxy where peculiar paleoenvironmental situations are detected and can supplement the information supplied by other cave proxies like the carbonate speleothems or sediments.

Cave minerals and their potential to trace past sea-level changes

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In a non-cave environment, sea-level fluctuations are recognized based on a variety of geomorphological, geochemical, clay mineralogy, and trace element proxies. Clay mineral assemblages recovered from various marine and terrestrial sites reflect climate evolution and associated sea-level fluctuations (Steinke et al., 2008).
Caves are natural underground laboratories where crystal growth processes can be directly observed. Because the cave environment typically maintains constant temperature, relative humidity, and CO2 partial pressure, cave minerals provide invaluable insights into the chemical and physical conditions existing within various cave environments at the time of their precipitation (Onac, 2012). Studies of cave minerals and their relationship with changes of sea level are scarce. So far, calcite and aragonite were documented to precisely pinpoint past sea-level positions when precipitated in the form of phreatic overgrowths on vadose speleothems (Ginés et al., 2012). Onac et al. (2001) first interpreted a 5-cm thick fluorapatite/chlorapatite crust in Lighthouse Cave (San Salvador) as possibly representing sea-level fluctuations. The layers composed of fluorapatite were precipitated during sea-level lowstands due to the reaction of fresh guano with the limestone bedrock. Chlorapatite was deposited in relation with sea-level highstands when Cl- from seawater becomes available.
Csoma et al. (2006) pointed out that by closely investigating the mineralogy, fluid inclusions, and stable isotopes of such carbonate deposits, the difference between precipitations under vadose or mixing zones conditions (brackish) becomes decipherable.
This presentation is an attempt to summarize past and ongoing studies aiming to link the presence of certain cave minerals with present and past sea-level stands.
References:
Csoma, E.A., Goldstein, R.H., Pomar, L. 2006. Pleistocene speleothems of Mallorca: implications forpalaeoclimate and carbonate diagenesis in mixing zones, Sedimentology, 53: 213-236.
Ginés, J., Ginés, A., Fornós, J.J., Tuccimei, P., Onac, B.P., Gràcia, F. 2012. Phreatic overgrowths onspeleothems (POS) from Mallorca, Spain: Updating forty years of research. In: Ginés, A. (ed), Mallorca. A Mediterranean benchmark for the study of Quaternary. Mon. Soc. Hist. Nat. Balears, 18:xxx-xxx.
Onac, B.P. 2012. Minerals. In: Culver, D. & White, W.B. (eds), Encyclopedia of Caves, Elsevier, 499-508.
Onac, B.P., Mylorie, J.E., White, W.B. 2001. Mineralogy of cave deposits on San Salvador Island, Bahamas. Carbonates and Evaporites, 16 (1): 8-16.
Steinke, S., Hanebuth, T.J.J., Vogt, C., Stattegger, K. 2008. Sea level induced variations in clay mineral composition in the southwestern South China Sea over the past 17,000 yr. Marine Geology, 250: 199-210.

Change detection analysis of karst areas: the case study of the Classical Karst and Sardinia (Italy)

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The remote sensing image change detection analysis of important karst areas allows us to the identification of landuse and land cover changes from the recent past (after the 2nd WW) to present, as a consequence of the human population needs. Through aerial and satellites image processing is possible to highlight if and where such changes occur and their impact on the environment. The absence or a lesser impact of the anthropic pressure might be also displayed. This procedure is an effective tool for achieving sustainable development indicators as presently required to avoid irremediable damages. Two case histories of typical karst areas, Classical Karst and Sardinia which are characterised by different geographical and cultural conditions, are here considered. The trend of the anthropic and environmental evolution is examined in order to guide towards a sustainable development of the speleological treasures of these regions.

Process length scales in karst: from simple models to applications

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Simple models often provide insight into the function of natural processes. Here I will introduce a framework for the treatment of the physical, chemical, and biological processes that occur along karst flow paths. [1] Central to this framework is the concept of a process length scale. Process length scales have been discussed previously within a variety of karst disciplines, but the concept, particularly as a quantitative tool, has been underutilized. I will show how one can obtain length scales associated with the damping of conductivity and temperature signals

within karst conduits. These length scales allow one to make explicit connections between the signals observed at a karst spring and the properties of the flow paths in the system. However, process length scales have quite broad potential applications beyond the interpretation of spring signals. I will demonstrate how they can be used to interpret field data of longitudinally changing dissolution rates observed along the Lekinka cave stream in Slovenia. In particular, calculation of the length scales associated with different processes allows discrimination between various mechanisms that could be responsible for the observed changes. The results of this theoretical analysis suggest that the systematic decrease in dissolution rates along the Lekinka stream is due to the degassing of CO_2. This was then confirmed through the focused collection of further field data. Ultimately, the results of this study suggest the presence of feedback mechanisms that act between stream CO_2 and the incision process.

Covington, M.D., Luhmann, A.J., Wicks, C.M., and M. Saar,"Process length scales and longitudinal damping in karst conduits," 2012, Journal of Geophysical Research - Earth Surface, 117, F01025, doi:10.1029/2011JF002212.

Palaeoclimatic significance of a fast growing submerged stalagmite of Grotta Verde cave, NW-Sardinia.

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Sardinia is the most relatively stable island of the Mediterranean and along its coast are preserved caves that represent a unique heritage to understand both the eustatic and the palaeoclimatic history during the Quaternary. In this work, Early Holocene palaeoclimatic conditions were reconstructed for the western Mediterranean region through an oxygen and carbon stable isotope record in a submerged speleothem from Grotta Verde cave (Alghero, North-West Sardinia). In this cave, a wide and steep gallery developed within Cretaceous limestones of Capo Caccia descends from 90 m asl up to sea level, where a sump is located. The submerged part has been explored for over 50 m of depth below present sea level. The entire cave, in both its subaerial and subacqueous passages, contains several interesting continental records.

A 6.7 cm long white and well laminated calcite stalagmite has been sampled at 10 m water depth. U/Th dating has given ages of 11.8 and 11.9 ky, at 66 and 10 mm from the bottom of the stalagmite respectively, placing the speleothem's growth right before the Younger Dryas.

The speleothem shows a very rapid growth rate, around 560 mm in 1000 years, one of the fastest ever recorded in speleothems. Although this growth rate is only indicative, it records an extremely rapid deposition of calcite, as the one occurred during the early to middle Holocene in the East Mediterranean. The stable isotope signal, moreover, shows an increase in both $\delta^{18}O$ and $\delta^{13}C$, suggesting a rapid climate change towards colder and more arid conditions. The oxygen isotopic composition directly reflects the temperature of deposition with a $\delta^{18}O$ value around -4 ‰ relative to V-PDB rising to a $\delta^{18}O$ value of about -1 ‰.

Also the carbon isotopic composition with values that fall in the range of -9 ‰ to -7 ‰, reflects changes of the vegetation type reflecting a low activity in the soil during a drier and colder period (-1 ‰ V-PDB).

This would be in agreement with an onset of the Younger Dryas in N-Sardinia around 11.8 ky BP, some centuries later than what happened in areas located a little more to the North.

Speleogenetic Processes in Karst Modelling: An Overview

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An overview over concepts of speleogenesis and their implementation into numerical models of cave evolution is presented. Basic concepts of speleogenesis are presented in an evolution of a single plane-parallel fracture. Such fractures can be composed into different fracture networks, which enable numerical calculations of Ford's classical High-dip and Low-dip models of karstification. In these networks, we focus on the role of exchange flow between fractures of the karst aquifer as an important mechanism of enhancing karst evolution. Transition to vadose flow presents new mode of karst network evolution. We present a model which accounts for the relative importance of phreatic and vadose speleogenesis. From these telogenetic settings in mature fractured rock we turn to eogenetic karst in young porous created by mixing corrosion, e.g. flank margin caves in carbonate coasts and isolated caves in Florida. Further more we present an outline of recent modelling of

speleogenesis in different settings such ad hypogene karst in the gypsum rock of the Western Ukraine, modelling of karst aquifers with interdispersed non-soluble rocks and the evolution of collapse dolines.

GIS modelling of karst landscape change

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The research area is southern slope of Svilaja mountain, situated in the interior part of central Dalmatia, Croatia. It is a typical karst landscape, with the considerable human impact in the human-environment interrelations. Coping with scarcity of water, soil and regular summer droughts, as main constraints related to Dalmatian karst, pastoralism has been the most adaptable economic activity and lifestyle throughout the centuries. Excessive pastoralism in the conditions of Mediterranean climate, thin soil cover and especially steep slopes eventually led to the deforestation. However, abandoning of land due to the process of litoralization in the littoral zone of Dalmatia in the second half of the XX.th century, initiated the process of natural succession and re-afforestation. The research is tracing the environmental and landscape change of southern slope of Svilaja mountain since the XIX.th century, through three main periods: initial (1830-1846), transitional (1975) and recent period (2004-2010). The application of GIS model in analysing the landscape change is based on the original cadastral sources (State Archives of Split, Map Archives of Istria and Dalmatia), on the Institute for Adriatic Crops and Karst Reclamation database and Hrvatske šume (Croatian Forests) database, on CORINE Land Cover Croatia, as well as on fieldwork data. Landcover has been the main criterion used in classification of the landscape types. The GIS model of landscape change is organized around three levels: 1. landscape types, 2. types of landscape change and 3.trends of landscape change. GIS technology enabled the comparison of main areas of landscape change and the areas of most intensive population pressure. Overall results show the importance of human impact in landscape change, both in the processes of degradation, deforestation, as well as re-afforestation, due to the depopulation and rural exodus, and in the process of deliberate reclamation and protection of previously degraded and eroded slopes.

Gravimetric measurements in the Grotta gigante site

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As well as the georeferenced survey and the planimetry of the Grotta Gigante area, the Bouguer anomaly contours are highlighted by means of many surveying stations (about 200). The gravimetry is faded and superimposed onto the planimetric map of the surveyed area. Gravimetric measurements are one of the results obtained thanks to the topographic and georeferenced survey carried out in 2011 with laser scanner technology, by means of aerial scanning for the outside area and terrestrial scanning for the underground area. They were carried out by means of a Lacoste&Romberg microgravimeter (mod.D45).

Role of sediment in speleogenesis; paragenesis and alluviation

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Although the effects of sedimentation in caves have been recognised for many years, its role in speleogenesis has been widely underestimated. Influxes of sediment into a cave system fundamentally alters the way cave passages develop, either by alluviation in a vadose environment, or upwards dissolution in a phreatic environment through a process commonly known as paragenesis. This presentation will give an overview of the mechanisms of cave sedimentation, describe how the process of alluviation and paragenesis affect speleogenesis and identify the characteristic meso- and micro-scale features that can be used to recognise paragenetic development. The geomorphological situations where alluviation and paragenesis are most likely to occur are outlined.

Pocket valleys on the Nullarbor escarpment

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The Nullarbor Plain is well known for its karst, especially caves and blow holes. However, on the edge of the Nullarbor escarpment pocket-valley-like karstic features occur, which have not been studied yet, neither have they been mentioned in the literature. They are most visible where the escarpment slopes to Roe Plain. Based on the remote sensing and detailed field work, these features have been identified as pocket valleys, which functioned in past wetter climate conditions and were controlled by elevation of the regional water table. In present climate condition, intermittent karstic outflow is still recognisable in certain pocket valleys, however, dominant slope processes influence their morphology.

Intertidal coastal karst morphologies in the Gulf of Trieste

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The Eastern part of the Gulf of Trieste is characterized by rocky coasts, in particular limestone plunging cliffs and collapsed limestone blocks of the cretaceous-tertiary carbonate sequence or sandstones and marls belonging to the Flysch of Trieste Formation. The structural setting of the study area, consisting in the overlay of the carbonate platform succession on the turbiditc one and in a trend of subsidence toward NW, is responsible of the outcropping of limestones only in the Northwestern sector of the Gulf (Sistiana and Duino). Other outcrops are represented by olistholites (Miramare) and collapsed blocks from slopes (Canovella de Zoppoli and Marina Aurisina). Morphological features of the limestone coast overlooking the Gulf of Trieste are influenced by geological or physical/chemical factors: the coastal slope, the structural setting, the textural characteristics of the limestones and the meteoclimatic and hydrological conditions. We present new and published data collected in the gulf on the karstic forms outcropping in the intertidal zone. Morphometric parameters of coastal karst landforms and lowering rates, measured using the micro erosion meter, have been compared to study the evolution of the limestone intertidal forms The studied landforms are mainly characterized by small morphologies (<2 cm) related to the bioerosion, such as pits, microrills, etc, while large karst features (1 m), such as tide pools and shore grikes etc, are usually rare. Where the topography is favorable, pinnacles and grooves, characterized by irregular morphology and sharp contours, occur. Locally, the intersection between different discontinuity systems favor the development of small terraces on which potholes or pools occur. A submerged tidal notch can be observed along the carbonate coast of the gulf, at depths increasing towards NW, from -0.6 m (Miramare) to -1.2 m (Canovella) on the blocks, and from -1 m (Sistiana) to -2.8 m (Duino) on the plunging cliffs. Limestones lowering rates indicate that they are one order of magnitude higher than those measured in the inner karst and they range from 0.145 mm/year to 0.349 mm/year (Furlani et al., 2011). Their variability seem to be the result of the complex pattern of distribution of the intertidal morphologies in the Gulf of Trieste. The relative lack of coastal karst features > 1 m could be due to wide-ranging factors: (1) the high vertical tectonic rates which affect the area (Antonioli et al., 2007; Furlani et al., 2011), since they could prevent the development of intertidal karst morphologies, (2) the subsequent short exposure of local limestones to intertidal processes, (3) the morphological structure of the coast, dominated by steep to vertical.

References:

Antonioli, F., Anzidei, M., Lambeck, K., Auriemma, R., Gaddi, D., Furlani, S., Orrù, P., Solinas, E., Gaspari, A., Karinja, S., Kovacic´, V., Surace, L., 2007. Sea level change during Holocene from Sardinia and northeastern Adriatic (Central Mediterranean sea) from archaeological and geomorphological data. Quaternary Science Reviews 26, 2463–24.

Furlani, S., Biolchi, S., Cucchi, F., Antonioli, F., Busetti, M., Melis, R. (2011). Tectonic effects on Late-Holocene sea level changes in the Gulf of Trieste (NE Adriatic Sea, Italy). Quaternary International, 232, pp. 144-157.

Limestone lowering rates in the Mediterranean area

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Limestone lowering rates have been measured all over the world in different environmental contexts since the seventies. Limestones are said to provide more reliable lithologies than other rock types because of the processes and forms that characterize their rock surfaces. Micro erosion meter (MEM) stations are widely distributed also in the Mediterranean area, both along the coasts and in the inland karst settings and are commonly used to study the evolution of limestone surfaces. MEM stations have been installed on a range of geomorphological sites such as shore platforms, plunging cliffs, caves, karst surfaces. The rock type is also thought to be significant in this context.
In this paper we review studies about limestone lowering rates in the Mediterranean area and we present new data collected in more than 600 stations using the Micro Erosion Meter (MEM), Traversing MEM (TMEM) or laser scanner other in situ instruments (limestone tablets, laser scanner, etc).
We compare limestone erosion rates measured in the study areas. In particular, we highlight some correlations over time and space and between processes and their related environments. We also discuss the impact on the evolution of limestone surfaces.
Our results suggest that limestone surfaces are affected by erosion over the mid- to long-term while more complex behaviour affects the limestone surfaces in the short term. Peaks in erosion rates are affected by contingency. Despite the large amount of measurements in some areas, micro erosion data are still now spatially limited. Moreover, data collected on steep slopes or vertical surfaces should be used with caution because not all the methods can be correctly applied on the aforementioned surfaces. It is recommended to use a combination of methods in order to compare the data.

Distribution and classification of springs in Western Desert of Egypt

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Karst springs in Egypt have a vital importance to all life activities in this region of hyper-arid climate inside the Great Sahara. Egypt has more than 1440 springs, where97 % of them located in Western Desert. The classical landform and geomorphic unit comprising the desert springs is the oasis/depression landscape. The most famous depressions are Dakhla (564 springs), Bahariya (495 springs) Siwa (226 springs) Kharga (102 springs) and Farafra depression (22 springs).
Methods of spring's classification in the area of study are not easy, since all classification criteria are applicable; the major methods used in our research are: geological origin, geochemical analysis, geomorphological characteristics, and rate of deterioration.
Based on these criteria, 33 springs around western desert depressions have been classified. Water temperature of sampled springs ranges between 47 C and 22 C. ; PH ranges between 4, 4 and 8.4, and TDS ranges between 264 and 7560 mg/L. Elevation of spring's sites ranges between -16 m and 150 m below/above sea level.
In order to prepare detailed maps of distribution and classification, Baharia depression was selected as a case study in this stage of research . This oasis/ depression area is very important for various economic and environmental issues. The area comprises a national park, ancient Egyptian monuments, traditional cultivation activities, and recent touristic destinations.

Record of anthropogenic (urban) pollution in sediments of the karst lake Modro jezero, Croatia

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Modro jezero (Blue Lake) is a karst lake formed as a collapse doline. A Lake was probably formed, together with a neighboring Crveno jezero, at the edge of a late Miocene lake. It is surrounded by the the town Imotski located in Dalmatia, southern Croatia. The wider area is inhabited since Neolitic. During the 9th century AD a fortress was built at the edge of a lake's steep southeastern slopes. A highest edge of a lake is at 527 m a.s.l., and

the lowest at 385 m a.s.l. It is 350 x 920 m wide, with very steep, almost vertical northwestern and southeastern slopes. Other slopes are less steep. A lake bottom is located at 242 m a.s.l., and is 195 x 75 m wide. The highest recorded water level was at 345 m a.s.l. Through the 20th century the lake has dried out 7 times. The drought period, which started in summer 2011, provided the access to the lake bottom, and therefore a possibility for a drilling campaign, performed in January 2012. A 8,2 meter long undisturbed sediment core was extracted from a Lake bottom using a Eijkelkamp percussion drilling equipment. Preliminary analyses of magnetometric susceptibility, mineralogical and chemistry measurements were performed on sediment samples. Bulk mineral analysis of surface sediments showed that they are highly calcareous. They are mainly composed of high- and low-Mg calcite. The highest magnetic susceptibility was measured in a 10 cm thick red clay layer at the depth of 30 cm, which corresponds probably to the activities when access walking paths were made to the lake waterfront. The increased values gradually drop down core to the depth of 1,30 m indicating anthropogenic activity and soil erosion in the catchment. The rest of the sediments show low magnetic susceptibility, characteristic for carbonate/calcite rich lake sediments.

Speleothems as Archives in the Production of a Holocene Palaeoclimate Record for Slovenia

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Much attention is focussed on reconstructing and monitoring climate on both very long (i.e. >10^6 years) and very short (i.e. hourly and daily observations) time scales. However, climate records on the yearly to decadal scale are more elusive, particularly from times which predate the routine observation and recording of climate using instruments, (pre-seventeenth century). Ice cores provide excellent resolution records for high latitude areas, but cannot be arbitrarily applied to the entire globe. As such, high-resolution records from areas such as the Mediterranean are scarcer, especially covering the Mid-Late Holocene period. Due to the lack of availability of ice cores in the area of study, speleothem studies offer the only means of palaeoclimate reconstruction in the North West Balkans.
Where ice cores are unavailable, climate records obtained from speleothems often offer the next best possibility. Speleothems offer many advantages over other archives for palaeoclimate records; for example, the relatively straightforward growth geometries of stalagmites in particular make constraining the resulting data to an age model less complicated than for other archives such as lake cores. Speleothems collected from carefully chosen locations can be free of effects of varying cave temperature and humidity, making it easier to relate the variations in signal to climate effects above ground and speleothems contain multiple useful proxies, including stable isotopes and trace elements, from which climate signals can be derived. They can also be dated accurately by multiple methods, the most common of which is U-series dating.
Here, we present a late Holocene climate record derived from two stalagmites, SLO-1 and SLO-2, which were collected from Jazbina cave, Slovenia. SLO-1 and SLO-2 are clean, with little sign of detritus. They also grew at exceptionally high growth rates (~0.28mmyr-1) to impressive lengths (2.2m and 1.4m, respectively) and show little kinetic effects (Hendy tests show $R2 < 0.3$). Together, they promise a remarkably clear record of Slovenian climate. A 1mm-resolution (~3-4 years/sample) stable isotope record for the period ~2000-590 years BP has been collected, which displays evidence of documented climate variations, in line with documented glacier fluctuations. A higher resolution (0.1mm) record is also presented for the period ~625-590 years BP, as well as trace element data collected by Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES).
Exploited down their entire length, the two stalagmites together form a long continuous record stretching back to the beginning of the Holocene, with a period of overlap from ~4.5-9.1ka BP, which allows for cross validation of the data between them. This will result in a highly resolved, continuous climate record for the region.

Environmental changes during Late Pleistocene and Holocene in the karstic lakes along eastern Adriatic coast

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Environmental changes can be tracked based on informations from a variety of sources in lakes and lacustrine sediments. These sediments contain paleoenvironmental information that can reflect changes on local or regional scales. Such changes can be better understood by mineralogical and geochemical studies. Observations of the clay minerals were made from three lakes along the eastern part of the Adriatic Sea: Vrana Lake (northern Adriatic), Bokanjačko blato and Baćinska lakes (southern Adriatic). Vertical cores were approximately 7-10 m long. The multyproxy study of the period spanning the transition of the Late Glacial to the Holocene included studies of change in clay composition between glacial and interglacial lake samples assuming transformation

processes in the soils from the catchments. Clay mineral assemblages were determined by X-ray diffraction (XRD analysis) in order to model the environment. Dominant clay mineral phases are illite, chlorite and kaolinite. Clay mineral abundances and clay-mineral ratios are used to reconstruct the weathering conditions. In sediments, clay minerals may be originally detrital, diagenetic or neoformed. Mineralogical results are compared with palaeomagnetic-derived time scale. Clay data are further compared with diatom and pollen core material. The evolution of clay derived climate proxies (kaolinite/chlorite ratio) is compared between locations. The cold and dry periods during the glacial times were responsible for physical weathering and thus contribution of higher amounts of chlorite and illite, as they are less sensitive to chemical weathering. The abundance of kaolinite is good indicator of warm and humid interglacial period caused by extensive chemical weathering. Therefore clay mineralogy has become more significant in understanding the changes in paleoclimate conditions and sediment source.

Surface analysis of the karstic landforms in the karst of Abaliget-Orfű (Mecsek mountains, Hungary) with GIS

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The karst of Abaliget – Orfű are rich in karst forms: it has many dolines, ponors, caves and gorges, too. It is a typical karst covered region: the significant part of its karstic bedrock is covered with several meters of pleistocene loess sediments.
We used geoinformatics analyses to get to know the morphometric parameters of the most representative karst forms, the dolines, and the connection between dolines and structural, geological and relief conditions. We made three groups of the dolines with cluster analysis and collected the differences between them.
Because the real doline density is higher than what is figured on the topographical map, we selected one sample area near Orfu. On this place we measured coordinates and the most important morphometric parameters of all dolines and compared the dolines by size.

Preliminary studies of freshwater tufa and cave deposits in Mecsek Mts., Hungary

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Annually laminated carbonate deposits such as freshwater tufas and speleothems are of particular importance in paleoenvironmental studies as a result of their suitability for high-resolution analyses. Our main aim is to reconstruct the Holocene paleoclimate of Mecsek Mts by using freshwater tufa sites combined with data gained from speleothems. The basic physicochemical parameters of eight carbonate depositing tufa streams have been monitored on a regular basis since September 2011. Rock samples were collected for stable-isotope analyses at all sites and core drillings were carried out in four cases. Furthermore, in order to do a comparative analysis two actively forming speleothems were selected for future investigations. The present study focuses on our preliminary results in Mecsek Mts.

Ice mass balance – examples from Slovene ice caves

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Ice mass balance – variation of ice volume over time can tell us about past conditions inside the cave, whether the ice is shrinking or accumulating. We must distinguish between annual and multiannual or decadal mass balance. Annual cycles are normal and correlate with temperature changes inside the cave, while decadal changes indicate changes of caves microclimate. Mass balance can be measured with simple measurement indicators, embedded in the ice. For past ice levels older photographs are essential.

The origin and morphology of submarine spring Vrulja Zečica (Croatia)

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The occurrence and characteristics of submarine springs along Adriatic coast in Croatia are determined by the geological and hydrogeological conditions of the littoral and its higher hinterland, geotectonic relations, karst porosity and climate. Due to favorable conditions, Velebit Channel located between Velebit Mt. and large islands of Krk, Rab and Pag is very rich in different types of submarine springs (vruljas) and coastal springs. They are outlets of well developed karst aquifers fed by high precipitation in the mountain area and water from sinking zones, mostly in Lika region.
The submarine spring Vrulja Zečica is located in the SE part of Velebit Channel 7.8 km SE from Starigrad. Although it was known to the divers and researchers for decades ago, from 2011 it is an object of intensive speleological and geomorphological researches. It is a branched cave with vertical (shaft) entrance. The entrance is located on an inclined sandy sea bottom at a depth of 6-9 m. It is followed by the vertical passage of spiral-shaped plan. The start of horizontal passage is at the depth of 37.5 m. The lowest passage bottom point is at the depth of 43 m. After series of cave diving explorations total length of known passages is 650 m and 197 m was surveyed. In surveyed part it is up to 17 m wide, and up to 5 m high.
The cave is located in the area build of intensively karstified Cretaceous and Tertiary carbonate beds (limestone and breccia). The passages were formed along fissure systems of E-W, NE-SW and NNE-SSW direction. All observed horizontal passage parts have typical phreatic cross section. But the abundant speleothem accumulation indicates changes in hydrological regime of the cave in geological past. Termination of speleothem deposition is the result of groundwater level rising and the gradual penetration of sea water due to Late Plesitocene/Holocene transgression. Based on the size of stalagmites (>1.5 m long) and columns (2.5 m in height and 1 m in diameter), it can be concluded that vadose phase lasted relatively long. Apart from speleothems in their primary position of growth, along the horizontal passage numerous broken speleothems can be found. It is a result of strong mechanical action of flowing water throughout the hydrologic activity of the spring. It is periodically active only during the wet season, as a result of abundant precipitation or snow melting in higher mountain hinterland.

The architecture of big rooms

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The morphology, stress relationships and collapse mechanisms around passages of unusually large cross-sections is ("Big Rooms") is discussed. Several large passages in Norway, Slovenia, the US and in Mexico have been mapped with laser techniques at various levels, ranging from simple hand-held laser rangefinders with clinometer to full LIDAR scans of great detail. Several rooms which appear as "perfect vaults" by the naked eye, are in fact quite dominated by rock structure and are far from "circular", "parabolic" or "elliptic". The most common and probably strongest compromise is the A-frame structure, where one wall is a prominent fracture (fault-plane) or a bedding plane. The work presented builds on support from a large number of colleagues and friends up through the years.

Limestone pinnacles in Western Australia – the result of karstic processes and microbial cementation

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Limestone pinnacles in Western Australia occur abundantly in Nambung National Park. They are up to 5 metres high and up to 3 metres wide and usually occur in dense fields with an average spacing between 0.5 and 5 metres. They vary in shape (conical, cylindrical with rounded top, mushroom-like, or multiple peaks) and material (laminated, bedded, palaeosoils). Most often they have been described as karstic feature, resulting from widening and coalescence of solution pipes. However, their formation has also been interpreted as a result of focused cementation, trace fossils of trees, or cemented filling of solution pipes.
Based on detailed field work, morphometrical analysis of the pinnacles, thin section examination, and mineralogical, chemical and isotopic analysis of rock samples, karstic weathering was recognized as a process which has modified the pinnacles' shapes multiple times during their genesis. However, the process of

lithification by microbial cementation in a freshwater lake has played the major and basic role in the formation of the pinnacles.

The hydrodynamic profile of subsurface flows reflected by drip water in the cave, Velika Pasica, Slovenia

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The hydrodynamic flow characteristic of the vadose zone was studied in detail in a small epikarstic cave, Velika Pasica, located south of Ljubljana (Slovenia). Hydro-meteorological data has been collected from four permanent drips (designated as VP1-VP4) from the cave since June, 2006. At each dripping site, continuous measurements of the percolation water, which discharged from the cave ceiling, were collected at one-hour intervals by means of sensors connected to a data-logger. Another data-logger with a sensor for precipitation was established on the surface near the entrance to the cave. The hydrodynamic of the drip water in the cave is a functional response to the precipitation, epikarst storage capacity, and non defined underground structures. According to the speed and intensity in response to the precipitation, the drips can be divided into four types: "rapid response without hysteresis" (VP1); "no response with congest discharge" (VP2); "fast response with lag" (VP3) and "rapid response with congest discharge" (VP4). These drip water discharge patterns indicate different groundwater flows within the vadose zone, most of them pertain to the seasonal flow, while the extreme events of individual drips were clustered in distinct groups, which provided additional information on the cave cover structure.

Hydrological Inter-Relations between Cerkniško and Planinsko Karst Poljes –Dynamics of Surface and Groundwater Interaction

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The paper presents results of the conducted hydrological analyses of surface waters and groundwaters in Cerkniško and Planinsko karst poljes, both at a long-term and intra-annual scale. The focal point of the analysis is the rate of surface and groundwater reaction and establishment of inter-relations under extreme conditions. Long-term values of characteristic annual discharges and their trends were also analyzed. During the conducted analyses, both original weather data series as well as their modular values were used.

Appraisal of Environmental Conditions In Postojna Cave, Slovenia

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In order to investigate stable environment conditions for carbonate precipitation in Postojna Cave, Slovenia comprehensive one year monitoring of geochemical, physical and spatial conditions has been undertaken.
Special attention has been appointed to characterization of stable isotope composition of speleothems (old, modern and recent carbonates), drip and river water, together with cave and outside air.
Postojna Cave is one of the most famous karst caves in South Eastern Europe visited by numerous tourists. There is evidence of vegetation change during the past and recently also of land use change, as well as of modification of a cave structure itself.
The appraisal of these changes can give us information whether they influence on speleothem formation, and if it is possible to determine stable chemical and isotopic composition to interpret the proxy-data stored in speleothems and to estimate paleotemperature and other paleoenvironmental conditions.

Discontinuity surfaces related to subaerial exposure of shallow-water platform carbonates (Early Jurassic of Gorski kotar and Velebit Mt., Croatia)

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Area of Gorski kotar and Velebit Mt. are mainly built of Mesozoic carbonate deposits, which were formed on a vast Adriatic Carbonate Platform (AdCP). From the late Early Jurassic until the end of the Cretaceous, the AdCP was an area of carbonate production that resulted in an up to 5 km thick succession of shallow marine carbonates and was punctuated by periods of subaerial exposure and several pelagic drowning episodes. The subject of this research is Lower Jurassic carbonate succession with common discontinuity surfaces, which is nowadays well exposed in the area of Gorski kotar (locality Gornje Jelenje) and Velebit Mt. (localities Kubus and Mali Alan). The biostratigraphic age of the studied succession ranges from the latest Hettangian to the Late Pliensbachian. The aim of our work is to describe and interpret macro- and microscopic features observed on discontinuity surfaces (DS), which can be related to ancient subaerial exposure of this shallow-water platform carbonates. In the studied section, emersion surfaces are characterized by subaerial exposure ranging from (1) occasional influence of meteoric waters (development of diagenetic discontinuities), (2) intermittent subaerial exposure (inter- to supratidal hardgrounds) to (3) prolonged exposure leading to pedogenesis and/or karstic dissolution [palaeosols (3a) and paleokarst/microkarst (3b)].

(1) Diagenetic discontinuities show meteoric influence visible only in thin-sections as dissolution and recrystallization of skeletal and nonskeletal particles, and vadose cements (pendant and meniscus cements). These features indicate periods of occasional influence of meteoric waters without subaerial exposure. Diagenetic discontinuities are overlain by rocks showing features of marine diagenesis.

(2) Inter- to supratidal hardgrounds (HG) show circumgranular and desiccation cracks (macro- and microscopic scale), sheet cracks, brecciation, birdseyes, black pebbles, and pisoids. These diagenetic features imply formation by repeated sediment drying and wetting in subaerial conditions. Fillings of the polygonal desiccation cracks are preserved on many bedding surfaces, but tepee structures have been seen only rarely. Many microbial and fenestral limestone laminites are capped by dolomitic crusts with dolomitization being most intense in the upper part of the bed and penetrating downwards for about 10 cm. Some bedding surfaces covered by such stromatolites show strong reddish-brown to dark reddish staining (possibly by iron oxides) indicating oxidation during subaerial exposure. Stained surfaces often show laminated microcrystalline carbonate in thin-sections, i.e., incipient calcretization. However, the possibility that this alteration is due to outcrop weathering should also be taken into account. Possible vertebrate footprints have been found on the top of one inter- to supratidal HG.

(3a) Palaeosols show features of incipient soil development, plant activity, and vadose conditions indicating prolonged subaerial exposure. In the field, they show irregular relief and a brecciated appearance due to dissolution processes and rhizoturbation. The alteration of limestones (dissolution, recrystallization, and calichification) reaches 10–20 cm into the strata below the DS and is characterized by reworked lithoclasts within a brownish to yellow clayey matrix. Preliminary XRD analyses of clayey matrix show the presence of illite. Contact with the overlying bed is mostly sharp and a thin clayey covering is rarely preserved on the upper bedding plane, probably because of the erosion during the following marine flooding. Blackened clasts comparable to the black pebbles typical of pedogenic settings are observed. Microfacies analysis revealed characteristic circumgranular cracking, solution vugs, and root-related structures (tubular branched voids of decayed roots filled with sparite, alveolar-septal and nodular fabrics, i.e. glaebules).

(3b) Paleokarst (microkarst) surfaces show dissolution vugs and fissures penetrating not more than 15–20 cm into the bed and never reaching into the underlying bed. Irregular cracks and fissures pervade the bed perpendicularly in relation to the upper bedding plane, indicating their paleokarst character and excluding the possibility that they result of Recent karstification. Fissure walls are sharp, indicating that dissolution occurred in completely lithified rock. The fissure infill contains many angular millimetre to centimetre sized fragments of host rock and, on rare occasions, yellow to brown clayey to marly sediment. Small dissolution cracks and voids seen in thin-sections sometimes have a brownish coating preserved on their walls, indicating ancient corrosion in subaerial conditions.

Discontinuity surfaces related to subaerial exposure, recognized in the studied succession, represent breaks in sedimentation occurring periodically on the shallow marine carbonate platform. Their formation is dependent upon many interrelated factors, such as platform morphology, subsidence rate, high-frequency and low-amplitude sea-level changes, action of waves and currents, climate and other locally active processes such as wind patterns and nutrient levels. It can be assumed that the duration of emergence events that produced palaeosols, paleokarst or inter- to supratidal HG-s was not long, due to the fact that features of mature palaeosols or paleokarst were not found. Nevertheless, common subaerial exposure - related discontinuities bring into question the stratigraphic completeness of the studied succession and give valuable information about carbonate

platform evolution. Also, parts of the succession with abundant discontinuity surfaces (e.g. the one of earliest Pliensbachian age) can be used as useful field markers for stratigraphic correlation.

New insights into the functioning of the Lurbach system (Central Styrian Karst, Austria)

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Karst aquifers are widespread (~20% of the ice-free emerged areas are constituted of limestone or similar other karstifiable rocks; FORD & WILLIAMS, 2007) and well-known for their large heterogeneities essentially due to a triple porosity, a duality in their storage and a dual flow behaviour. These features need to be addressed in groundwater modelling. Because karstic waters represent an important part of the water supply for the world's population (20-25%; FORD & WILLIAMS, 2007) but are highly vulnerable to chemical and bacterial contamination, and under pressure by an intensive agricultural use, it is necessary to improve the global understanding of processes which govern flow through karst aquifers and to assess how changes in these systems might influence the spring behaviour over time. The here investigated aquifer belongs to the Lurbach system, a 22.3 km2 binary karst catchment located 15 km north of Graz, in the Central Styrian Karst, Austria. The Lurbach drains the upper low-permeable part of the catchment and disappears into the Lurgrotte cave, some hundred meters after it enters the karstified area. Then, the water flows through the limestone massif and resurges at the Hammerbach spring and the Schmelzbach outlet at the western border of the catchment. Spring hydrograph analyses suggest that a change in behaviour happened in the system between 2005 and 2009. Previous work showed that a redistribution of sediments within the conduits of the Hammerbach network could explain this temporary behaviour (WAGNER et al., 2011; MAYAUD et al., 2011). The present study uses MODFLOW to investigate whether the behaviour can be reproduced using different hypotheses like a reservoir filling and emptying water over the time. The role of turbulent flow is also investigated using the equivalent porous media approach of the Conduit Flow Process, a MODFLOW-compatible package developed by the USGS (SHOEMAKER et al., 2008). The study focuses first on the behaviour of the Hammerbach spring where long continuous time series are available; then we investigate the interactions of the Hammerbach/Schmelzbach system where overflow from the Hammerbach system to the Schmelzbach system is known to occur at high water levels.

References:

FORD D., & WILLIAMS P. 2007. Karst Hydrogeology and Geomorphology. John Wiley & Sons, Ltd.

MAYAUD C., WAGNER T., BENISCHKE R., & BIRK S. 2011. Changes in the hydrological behaviour of a karst aquifer (Lurbach system, Austria). Proc. H2Karst, 9th Conference on Limestone Hydrogeology, Besançon (France) 1-4 Sep. 2011, pp. 331-334.

SHOEMAKER W.B., KUNIANSKY E.L., BIRK S., BAUER S., & SWAIN E.D. 2008. Documentation of a Conduit Flow Process (CFP) for MODFLOW-2005. U.S. Geological Survey Techniques and Methods 6-A24.

WAGNER T., MAYAUD C., OSWALD S., RINDER T., LEIS A., STADLER H., BENISCHKE R., & BIRK S. 2011. Understanding intercatchment flow in a karst aquifer – using the Lurbach system example (Eastern Alps – Austria). Geophysical Research Abstracts, Vol. 13, EGU2011- 7962, EGU General Assembly 2011.

Karst systems relationships and their influence on transport of potential leachate contamination at Mole Creek, Tasmania, Australia.

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The Mole Creek Karst of northern Tasmania is an internationally recognised system of high conservation value, encompassing the UNESCO World Heritage listed Marakoopa Cave. However, land tenure is highly fragmented in the region, arising in conflicting land uses that impact significantly on water quality and cave biodiversity. Poor management practices have threatened the environmental integrity of this karst system for many decades, including the siting of a municipal landfill within solution sinkholes. The decommissioned Mole Creek Refuse Disposal Site (RDS) is located on a surface drainage divide within highly karstified Gordon Group limestone of Ordovician age. Continuing leachate development within the landfill pits may be flushed directly into the aquifer through a largely unfiltered pathway. This aquifer has long been hypothesised to drain via Bachelors Spring into Sassafras Creek, an untreated domestic and agricultural water supply and important habitat for several species of cave fauna. As a result of the incomplete understanding of active processes affecting the landfill, the local environmental authorities could not establish how it may be continuing to influence the karst system.

A hydrogeological study was designed to identify the karst catchments potentially being influenced by the landfill, and determine whether contamination attributable to the Mole Creek RDS is affecting the chemistry of water supplies within Sassafras Creek. This was achieved through (1) a water tracing experiment to demonstrate the hypothesised groundwater flow path beneath the landfill; (2) a hydrogeochemical investigation to detect contamination of the water supply, and to constrain the location of any contaminant source(s); and (3) a geophysical electrical resistivity survey to model the subsurface structure of landfill pits and their likely drainage paths. Geochemical analyses provided strong evidence for the groundwater flow path below the Mole Creek RDS, with iron and manganese concentrations indicating a connection between the sinking point of surface waters upstream of the landfill, and the water that resurges downstream from the landfill. Although the hydrogeochemical results showed no leachate contamination, geophysical modelling identified direct drainage pathways below one of the largest refuse pits, and suggests that leachate may still be flushed into the drinking water supply under varying flow regimes.
Combining several methods, this study characterised the forms and processes of the localised karst system and contributed to the overall understanding of the systems relationships of the protected Mole Creek Karst. It also served to highlight the environmental legacy problems inherited by our generation, which are largely due to a lack of understanding of karst systems relationships in the past. Despite the fact that the Mole Creek Karst is of international conservation significance, knowledge of the processes affecting the system remains incomplete and poses an ongoing challenge for environmental authorities.

The geomorphology of the Slovene Classical Karst

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Descriptions of Classical karst in Slovenia can be traced back to the 17th century when first good descriptions and questions about the curiosities like caves, unusual hydrological phenomena and the stony character of the surface and lack of water appeared.
In the second half of the 19th century karst and karst relief as such was discovered and characteristic forms were identified and described. The geographic cycle model of karst evolution introduced later failed to contribute to a better understanding of karst. This paradigm was later modified with climatic geomorphology that emphasise the importance of changes of warm and cold climate with time.
Less schematic approach to karst geomorphology in recent decades enabled the development of new measurement methods and the general progress in earth sciences and better understanding on the processes involved in formation of karst features.
The latest understanding of karst geomorphology in the north western part of the Classical karst is based on considering the gradual and differentiated development of individual units of karst in conditions of active tectonics. This development has been taking place since the Oligocene when marine sedimentation stopped, leading to the exposure of karst rock and the beginning of the current phase of karstification:
Individual structurally-conditioned segments of karst were gradually included in the karst's development and then began to form under varying hydrological conditions. Thus larger karst relief units or forms such as levelled surfaces, karst poljes, or karst plateaus and mountains were created.
Easily recognizable and diagnostic forms appeared on larger units, including various depressions like dolines, blind valleys, pocket valleys, dry valleys and conical hilltops. These forms are mostly result of locally enhanced corrosion and can define the age and evolution of larger units.
Besides the enhanced corrosion during this period, general denudation removed several hundred meters of rock. Because of that the current surface cuts across older underground karst features. On that manner unroofed caves and the majority of cave entrances were formed. Through these entrances it is possible to enter relict or reach still active water caves. Collapse dolines, which in places are the dominant relief form, formed from the bottom up due to speleological processes that locally caused the ceilings of caves to collapse.
This approach to karst geomorphology requires the study of individual relief forms, study of combinations of forms in space and time and study of small segments of karst. It also calls for studies of individual processes, primarily of corrosion or the local factors that accelerate or direct dissolution of rock.

Denudation of eogenetic limestone during the last glacial cycle in a tropical environment

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The research was done on Guam, tropical west Pacific. Theoretical considerations as well as field data were used in order to estimate the denudation on reef limestone that has retained most of its primary porosity and aragonitic composition.
The equation used to estimate the maximum denudation rate takes into account rock composition and density (porosity), temperature, CO2 levels, rainfall and evapotranspiration. For the given present conditions on Guam it ranges between 0.034 mm/yr (barren rock) and 0.155 mm/yr (rock with organic-rich tropical soil cover) which would account for ~4 to 19.5 m for the period of the last glacial cycle (~125 000 yrs). However, more conservative values of the above range should be considered as the soil layer is thin and it took some time for the soil cover to develop after the exposure of the limestone, and the rainfall was lower during the ice age.
The research area, in northern Guam, is dominated by a MIS 5e coral reef terrace and adjacent ~150 m high Plio-Pleistocene limestone cliff. On the MIS 5e terrace, tropical Karrentische (singular Karrentisch) were observed. The term Karrentisch was coined for the analogous phenomena occurring in previously glaciated areas and is strongly associated with deglaciation, where erratic blocks lie on limestone pedestals created by post-glacial denudation. In order to distinguish the two phenomena we refer to the features discussed here as tropical Karrentische. The tropical Karrentisch pedestals are formed of the MIS 5e reef limestone while the capping boulders consist of the Plio-Pleistocene limestone. Such Karrentische began to develop after boulders fell off the cliff on the MIS 5e reef terrace after its deposition and exposure following the sea-level drawdown after the peak of the MIS 5e interglacial (~ 125 ka). As the ground around the boulder has been subject to denudation, the surface immediately under the boulder has been protected from denudation and consequently a pedestal has been developing under the boulder forming a tropical Karrentisch. The sooner after the exposure of the MIS 5e a boulder fell on the terrace, the higher is the pedestal and the better approximation of denudation since MIS 5e sea-level fall it represents. The pedestal of the tallest tropical Karrentisch found in the research area is 5 m high but gives still just the minimum denudation since the exposure of the MIS 5e reef as we do not know exactly when after the exposure of the reef terrace the boulder fell. In order to determine the elevation of the original surface of the MIS 5e terrace, sea-level indicators such as sea-level notches proved to be useful as the upper limit of a reef terrace deposition is the sea level at the time of notch formation. Indeed, a sea-level notch is found 8 m above the modern surface of the terrace indicating the original position of the MIS 5e terrace.
From the above it can be concluded that the denudation on Guam since the end of the last interglacial MIS 5e was at least 5 m but most probably 8 m (0.064 mm/yr). Field estimates fall within the expected lower range of theoretically predicted values.

Karst groundwater potential for water supply of settlements on Zlatibor mountain massif (Western Serbia)

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In recent decades tourism has been developed significantly in the region of the Zlatibor mountain massif, consequently qualitative drinking water requirements have increased. Settlements in the Zlatibor region use water from the public water system, as well as from rural and individual systems for the needs of water supply for population and industry. The water supply of large settlements in the Zlatibor region is outlined to use the water from the surface reservoir on the Crni Rzav River which, as to quality, meets the needs of the Zlatibor Tourist Centre and the settlement of Cajetina as the administrative centre of this tourist region.
The water from this reservoir is, unlike its satisfactory quantity, of relatively poor quality (increased muddy brown colour, unstable regime, the presence of heavy metals), thus significant means are being invested in this water treatment. Small rural settlements on the Zlatibor mountain massif, mainly, have not solved the problem of centralized water supply adequately; this especially refers to settlements situated in karst parts of the terrain. In addition to the absence of a centralised water system, the deficit of water quantities during hydrologic minimums and incorrectness of the water required for water supply represent the water supply problem as well. Settlements on the eastern border of the Zlatibor mountain massif, where the problem of water supply has been solved successfully by tapping of the Zmajevac Karst Spring, make an exception.

The Zlatibor mountain massif is mostly made of Mesozoic age rocks. There have been singled out ultramafic rocks, a diabase-horn formation, and a carbonate rock complex of Triassic age within the Mesozoic rock complex. The distribution of a karst aquifer being the most significant one from the aspect of groundwater reserves and the potentiality of their multi-purpose utilisation is related to the Triassic carbonate complex whose thickness in the Zlatibor region varies from 150 m to 750m. The karst aquifer in the Zlatibor mountain massif region is drained by numerous springs occurring at the contact of Triassic limestone with Neogene sediments along the border of Neogene basins.
The most abundant karst springs in the Zlatibor mountain massif region are the Susicko Spring, Dobroselička Springs, Zmajevac, the Ljubisko Spring, the Gostilje Spring, Kotren, and the Golovsko Spring. Except for Zmajevac, which is utilised for the needs of water supply, the remaining karst springs are not utilised for the purpose. Overall karst groundwater reserves draining the Zlatibor mountain massif are estimated to over 1000 l/s, which with relatively good qualitative properties impart regional significance to this resource. Aiming to resolve the issue of centralised water supply for small settlements in the Zlatibor mountain massif region, detailed hydrogeological explorations in the most abundant karst spring in the Zlatibor mountain massif region-the Susicko Spring have been initiated. Past explorations have pointed out that the minimal yield of this spring is about 200l/s, which gives opportunity to solve, successfully, the problem of water supply for small settlements in the Zlatibor mountain massif region by karst groundwater tapping. The significant yield and relatively good quality of groundwater from the Susicko Spring have given opportunity to connect central settlements in the Zlaibor region to the Susicko Spring water system, which will bring significant ecological and economic benefits to this tourist region.

Modern calcite precipitation rates on artificial medium from Bijambare cave, Bosnia and Herzegovina

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Calcite precipitation rates over glass tablets located under three drip sites in Bijambare cave (Bosnia and Herzegovina) have been recorded almost monthly for around one year. Recorded rates range from 0.2 to 4.7 mg d-1. Results are compared with several potential predictors including external temperature, rainfall, drip rate and composition. Differences between sites have been found to be correlated mainly to drip flow while only within one site correlation with calcium concentration is significant. Theoretical predicted values overestimate experimental value on average of a factor two and fail to predicted correlation with drip rate. It has been proposed to modify standard theory by considering an effective drip rate lower than measured drip rate by a factor Φ1. This factor accounts for drip water by-passing the glass tablet due to drop splashing. Best fit of experimental data is obtained when around 99.9% of water is ejected during drop impingement. The order of magnitude is confirmed by additional laboratory experiment and comparison with literature data.

Limestone Geomorphology in Abu Zneima area Western Sinai, Egypt.

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Abu Zneima area (600 km2) is a structural headland of Gulf of Suez, some 150 km south east of Suez. The study Zneima area is dissected by old fluvial networks and influenced by folding and faulting-associated landforms. Few locals contain current geomorphic process and landforms under the hegemony of hyper arid climate. The aim of this paper is to analyze the geomorphic characteristics of fluvial and structural effects on the development of the study area. Various techniques of data collection and interpretation have been followed, especially field survey, GPS data collection, digital cartography and remote sensing methods.

The speleological complex of the Ponikva cave and Stijene quarry

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Sarajevo's speleologists have been active in the Vareš region and Mt. Zvijezda for a long time. One of the most important sites is the complex consisting of the Stijene quarry and the Ponikva cave (now also a tunnel).
There are a number of caves in the Stijene quarry, some of which have become completely filled with sediments in the course of geological history. The quarry workings have cut through some of the channels and totally destroyed others, but some still survive in their original form. Damage from the use of dynamite in the quarry

can also be seen in some of the other speleological features. The location of the various caves in the quarry reveals that this is a complex speleological feature with several levels.
Apart from being an extremely important and valuable speleological complex, the Stijene quarry is known to be one of the rare sites where bones of the cave bear, Ursus spelaeus, have been found. There are just a handful of such sites in Bosnia and Herzegovina.
The Ponikva cave/tunnel is one of five caves worldwide that is used as a road tunnel. A few months ago the road through the tunnel was fully surfaced with asphalt. The Ponikva has an active channel in which the eponymous brook sinks when the water table is low. When the water table is high, the swallowhole is unable to take all the water, some of which is evacuated through an artificial channel laid alongside the road in the cave itself. Fossil channels extend the full length of the cave.
The remains of pottery vessels dating from prehistoric times have been found in the cave above the entrance (part of the oldest fossil channel). Evidence of occupation by Palaeolithic man (flint artefacts and a bone harpoon) has been found in one of the side channels at the other end of the cave.
Speleologists have launched a campaign to halt all works in the Stijene quarry and to place both the quarry and Ponikva cave under some form of statutory protection.

Salt karst: A GIS model to assess the dynamic and risk phenomena under natural and anthropogenic conditions

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The dynamic of salt karst (halo-karst) become lately one of the most current research topics in Romania. In Romania, salt mineral is widely distributed natural resource, covering the main surface of Sub Carpathians, as well as the eastern and southern hills bordering the Transylvanian depression.
This study is comparing two salt deposit areas in Romania: the salt deposits of the Meledic Plateau (natural salt karst area, with minimal human impact) and Ocnele Mari salt mine (anthropogenic salt karst area). Both areas belong to the same geomorphological unit (Sub Carpathians) and have the same geological age. Though, the studied areas differ in their structural geology and tectonics, as well as in the human pressure, e.g. conditions affecting the rate of karstification.
Meledic Plateau salt is mixed with non-karstic layers (clays and breccias). Through the salt deposit tectonics, these layers were included in its geological structure. Such impure salt deposits are economically unrewarding, so the area remained untouched, with a very rich endo- and exokarst features.
Ocnele Mari settlement, in the Vâlcea County, Romania, is an important salt exploitation site from 1970 to 1991, using dissolution technology. Back in 60's, the salt exploitation technologies (partially invented in Romania) followed basically the karst processes – dissolution of salt was used to produce high concentrated brine. The brine was then sent by pipelines to adjoining chemical platform for further use. Yet, the high productivity of this technology brought a dramatic impact on the landscape. While the fast subterranean salt karstification was poorly monitored, the over dense network of wells on the mine field created underground voids of enormous proportions. By means of echo measurements taken in 1993 and 1995 by SOCON (Sonar Control Kavernenvermessung, Germany), a gigantic cavern of 4 million m3, filled with brine, with a diameter of approximately 350 m was detected. This cavern - one of the largest in the world - was linked with the acceleration of karst processes by human impact.
Soon after, two collapse sinkholes were formed (first in 2001, enlarged in 2004 and 2007; second in 2009), covering more than 20 hectares, with destroying the nearby settlement.
In order to map areas with high and very high susceptibility for karst processes and to include them in vulnerability maps, I have built a GIS model using ArcGIS Desktop 9.3.1 software. The model was applied separately on both study areas, using the same parameters. The proposed GIS model is based on two series of three parameters (raster maps with geology, hydrographical density, DEM, aspect, slope, and land-use), and their combination is conceived as a cube diagram. The combination of these parameters indicates areas of conflict among these parameters and areas of no conflict. The conflict occurs i) if three raster cells sharing the same spatial location have equal collapsed preference values (major conflict), or ii) if two raster cells have equal collapsed preference values and the third cell has a lower collapsed preference (moderate conflict). The conflict area is associated with the high susceptibility for karstification.
The model predicts two types of salt karstification: small and disparate areas (natural salt karst area) and wide and continue areas (anthropogenic salt karst area). Also, the model has accurately predicted the last collapse sinkhole produced in Ocnele Mari area (2009).
The proposed model could be very helpful on other areas containing evaporites where an accelerated karstification could produce similar dramatic events.

Late Pleistocene evolution of Antelias valley (Lebanon): speleogenic approach applied on Kassarat cave system with implication of U/Th datations records.

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Lebanon landscape is characterized by tow karstic mountain chains with a variety of surface karstic forms as well as endokarstic network systems.
A research project on Lebanon's karst geomorphology was conducted recently by EDYTEM laboratory CNRS-UMR 5204, France and Saint-Joseph University of Beirut and aims at reconstituting: i) speleogenic evolution based on geomorphologic indicators, ii) karstogenesis evolution related with the downcutting of the Mediterranean hydrographic network (Antelias river), iii) palaeogeographical stages of these valleys.
Antelias valley is chosen as one of the main karst study sites. Located 10 km north of Beirut city, Antelias river has 20.4 km2 of catchment area and drains directly to the Mediterranean sea. Tow caves were selected downstream of the valley: Kanaan cave (fossil cavern at 100 meters a.s.l.) and Kessarat active network with 4.6 km of multiphase canyon galleries, located between 57 and 96 meters altitude.
A morphogenic analysis has been completed in each cave with a geomorphologic approach, using detailed cartography, cross sections surveys as well as deposits analysis.
The study completed in both Kanaan and Kessarat caves determined a paleo-phreatic zone at 95-98 meters a.s.l. This first erosional level is attributed to paragenetic forms such as tubular galleries, semi tubular channel and anastomosis ceiling, clay deposits notches and dissolution pockets. The water level migration downstream of the valley has disconnected Kanaan cave from the drainage network while Kassarat underground river entrenched a meander passage below the initial phreatic level. The base of Kassarat Vadose canyon at 65 meters is characterized by a semi-phreatic tube, while down cutted clay deposits are located at 70-75 meters, revealing a probable second erosional level with a long term stabilization of the water table level around these altitudes.
The major siphon of Kessarat river is located actually at 57 meters and connected to Fouar resurgence spring. Antelias river if fed by Fouar spring, located at 33 meters a.s.l. between the Jurassic limestone and the cretaceous impermeable Aptien/Albien stratas. This contact constitutes the water table level of the karst drainage as well as the Antelias river hydrographic network. The actual stage of the cave genesis and the valley'drainage system is attributed to a transitory erosional phase.
The karstic levels revealed by the speleogenic study, the first around 100 meters and the second at 65-70 meters are controlled by a local base level. Scallops direction in Kanaan cave showed a dominant NNO paleo-flow direction closest to the river location rather than the Mediterranean sea. We conclude that Antelias river thalweg was the base level of Kanaan and Kassarat cave at the time when the karstic active level of the valley was at 100 meters and Antelias valley was less downcutted. Local base levels such as Antelias thalweg and Fouar spring existed and affected the valley drainage system even with a close Mediterranean sea level (1.8 km from the valley to the shoreline).
However, slight differences between water table level (Fouar spring and rver thalweg) and sea base level (Mediterranean Sea) are to be taken into consideration. The Aptien-Albien hydrogeological barrier could explain this altitudinal shifts due to time that Antelias drainage system would take to erode impermeable strata's and then to join the sea base level.
To complete the geomorphological evolution of the valley, prospective studies and analysis was completed (Sanlaville P, 1977) on nearby uplifted sea erosion levels in Dbayeh area. Marine abrasion surfaces and deposits were recorded at 10-12 m., 20-22 m., 40-60 m., 85-90 m. and 100-130 m. A first geomorphologic correlation between uplifted marine levels and karst water table level lead us to suggest four karst genesis phases for Antelias valley:
i) The first stage is the development of a phreatic zone nearby the water table base level set at 100 meters altitude. We suggest a sea level at 85-90 meters controlling the water table level stationed around 100 meters with a paragenetic rise in the karstic system.
ii) The migration of the water base level (Fouar spring) downstream of the valley has initiated the Vadose entrenchment of Kassarat cave system and Antelias drainage system. iii) The third stage in characterized by a stable water table level (Fouar Spring) around 70-75 meters while we suggest a sea level around 40 to 60 meters altitude.
iv) The actual stage is a continuous downcutting of the karst drainage as well as Antelias hydrographic network to a transitory water base level located at 33 meters a.s.l.
Considering Lebanese restraining bend as an active tectonic margin, Mount-Lebanon uplift might explain a fast down cutting of the karst drainage and the hydrographic system. Recent studies revealed evidence on continuous tectonic pulsation of Mount-Lebanon range. The LFS shortening began in mid-Miocene period (18-15 My) along the Lebanese restraining bend. A continuous shortening from late Miocene (7.5-5 My) to Quaternary

period (Elias et al, 2006; Gomez et al, 2006) is believed to uplifted Mount-Lebanon range with a 1 to 4 mm/a slip rate (Daeron et al., 2005; Mahmoud et al., 2005) along the Lebanese fault system.
On the other hand, sea level oscillations should be taken also into consideration when marine terraces are dated and integrated in the geomorphologic model. To confirm the evolution model we proposed, datations are required to correlate karstic level with uplifted marine terraces. However, continuous urban extensions of coastal cities to nearby mountains slopes are deteriorating marine surfaces and deposits actually more difficult to find. Consequently, the speleogenic approach could contribute in defining an approximate age to a karstic level controlled by a nearby sea level.
U/Th datations on stalgimite K2-2010 in Kanaan cave, attributed to the first karst stage, showed an age around 194 ka ± 0.98, while K1-2010, a stalagmite developed on collapsed block after a vertical drawdown stage, revealed an age around 127 ka ± 0.74. We conclude that Kanaan cave was in place clearly before 200 000 years. Consequently, we suggest late Pleistocene period to Antelias valley at the time when the river thalweg and the karstic level was around 95-100 meters a.s.l. A continuous entrenchment of the valley from late Pleistocene till Holocene period is proposed with a probable intermediate river thalweg and karstic level stationed around 70-75 meters.
Unfortunately, no datations were conducted on marine deposits located on elevated sea levels to complete the geology age model we proposed. Only few C14 and U/Th datations on low uplifted marine terraces (0.8-1.2 meters) revealed late Holocene ages (Morhange et al., 2006) and late Pleistocene ages (20-25 meters). Correlations between high elevated lebanese terraces with marine terraces in other Levant region are too soon to be completed, due to the few results we obtained as well as differences in slip rates between lebanese restraining bend and other active margins.
Therefore, further observations and U-Th datations on calcite will be completed in Jeita cave, in Kelb valley to correlate the geomorphologic model in Antelias valley to Kelb valley. Cosmogenic datations on quartz will be also conducted in the near future, as the deposits analysis in Kessarat network revealed cave infillings rich in quartz and attributed to the first karst genesis stage. Quartz datations will better insert high karstic level age in the geology history of Lebanon.

Ikaite in the Scărisoara Ice Cave (Romania): origin and significance

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Ikaite, $CaCO3 \cdot 6H2O$, is a rare, metastable carbonate mineral first identified in submarine reef-like columns growing from the bottom of Ikka Fjord (SW Greenland) at temperatures between -1.9 and 7ºC. Inactive tufa towers found along the shore of Mono and Pyramid lakes in western US are believed to represent former ikaite structures that were converted to calcite. These sites, along with two others in Japan and Patagonia are so far the only terrestrial occurrences of ikaite. Notes reporting its presence in ice accumulations and icicles around some saline springs from Shiowakka (Japan), prompted us to search for ikaite in the perennial ice deposit of the Scărisoara Ice Cave.
A reconnaissance mineralogical study undertaken between 1996 and 2000 pointed out the presence in the glacial and periglacial sectors of the cave of large surfaces covered with thousands of micro-pearls (<400 μm), pearl conglomerates, fibrous efflorescent calcite (var. lublinite) as well as monohydrocalcite. Except for monohydrocalcite, the deposition of all the other mineral phases are triggered by freezing of dripping and seeping water. In addition, phosphate minerals and abundant organic material (leaves, branches, logs) are common in many parts of the cave.
Two types of ikaite were positively identified by XRD and environmental scanning electron microscope studies: 1) various crystal shapes (< 670 μm across) forming white-light cream patchy accumulations within certain ice layers and at the surface of ice stalagmites/domes, and 2) glendonite (calcite pseudomorphs after ikaite), typically shaped as rosettes (up to 4.7 cm). Glendonite samples were found protruding out from the ice tongue in the Great Reservation. Considering the particular cave settings and microclimate (temperature is always below 2ºC) in which the two types of ikaite occur, it appears that they were cryogenically precipitated. This preliminary conclusion is largely based on similarities between the stable isotope signature in cryogenic calcites and two glendonite samples recovered from the Great Reservation in Scărisoara Ice Cave.
The high $\delta 13C$ (0 to 10‰) and $\delta 18O$ (-1 to -10‰) values, typical for cryogenic carbonates in Scărisoara Ice Cave, are due to rapid water freezing that is accompanied by swift kinetic $CO2$ degassing. In comparison to the cryogenic calcite samples, the very low $\delta 13C$ values (-14‰) found for the ikaite precursor of glendonite, implicate biogenic $CO2$, as the main carbon source for its precipitation. Therefore, glendonites may be considered useful indicators of warm/wet conditions outside the cave, time when biogenic-derived $CO2$-rich waters seeped into the cave.

Future work on these carbonate precipitates may shed light on the relationship between the oxygen isotope values in the ice layers and ikaite's temperature-restricted field of formation. The aim of this study is 1) to infer the δ18O from hydration water of ikaite and cross-calibrate it against the δ18O obtained from ice layers that contain ikaite and 2) better understand the precipitation of ikaite and its transformation into anhydrous carbonate. The results can serve as basis to further explore other paleoclimatic and paleoenvironmental implications the presence of ikaite in perennial ice cave accumulations might have.

Mravljetovo brezno v Gošarjevih rupah cave: dissolution of dedolomite

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The Cave MravljetovoBrezno v GošarjevihRupah (length = 400m; depth = 74m; altitude of the entrances = 613m and 618m) is located at the eastern flank of the Sora Valley some 100 m above the river on the lower part of elongated mountain ridge VrhSvetihTrehKraljev in RovtarskoHribovje, the pre-alpine region in the western part of central Slovenia.
The mountain comprises a few hundred meters thick sequence of Middle Permian to Middle Triassic carbonate and siliciclastic rocks with intercalations of evaporates. In sixties, during the drilling course in the area of nearby Rovte Village up to 270 m thick evaporate horizon that forms up to 59% thickness of the Upper Permian and over 29% of Lower Scythian dolostone succession has been found in the subsurface. There, up to metre thick lenses of gypsum and anhydrite alternate with dolostone that comprises veins and geodes of gypsum. The outflow from 500 m deep well is still rather constant, a few litres per second with the water comprises over 300 mg/l of SO_4^{2-}.
The cave is developed in bedded fine to middle grained Middle Triassic dolostone. The cave channels exhibit ramiform and maze like orientation guided by faults and joints. The wall rock morphology show some features characteristic for dissolution with slowly flowing rising water (i.e. feeders, rising channels, cupolas, lack of fast flow scallops…) while some are characteristic also for descending percolating waters (i.e. shafts, down cutting vadose meanders, fluvial sediments of sandy and gravel size particles…). Locally wall rock surface is highly irregular and jagged.
One of the most distinguished characteristics of the cave is particular yellowish to reddish brown rock that looks at first sight as an eroded infilling deposit. However, gradual transition from this type of rock to the host rock, its highly calcareous mineralogy, and preserved echinoderm bioclasts parallel to those in the host rock suggest different origin. Commonly, the cave floor is covered almost exclusively with cobles and blocks of this material. XRD analyses reveal that unaltered greyish host rock is built mainly of dolomite while yellowish brown altered rock of calcite with traces of dolomite in some samples. Between these two end members pale dolostone with gradually higher content of calcite occur. Yellowish to reddish brown colour of the samples is associated with small amount of Fe hydroxides (i.e. goethite and ferrihydrite). Among other minerals in yellowish brown deposit small amounts of kaolinite, illite, sericite and quartz have been detected. Locally, cave walls are coated with white up to a few mm thick crust predominantly comprises hydromagnesite while some ledges are covered by earthy light rusty-coloured siltymaterial built of gypsum with traces of goethite and ferrihydrite andsandy particles of calcite.
On the basis of known general geological data, basic morphology of the cave channels, cave rocky relief, field and mineralogical evidences of the host rock alternation, and the limited geochemical data form the well we suggest that the major part of the cave has been primarily partly or mainly developed in deep seated phreatic condition initially by the dissolution of previously dedolomitized portion of the host dolostone. Later, the cave has been modified above the phreatic zone. High content of SO_4^{2-}in the water that arising from the well suggests continuous dissolution of evaporates and possible dedolomitization and/or in different location also dissolution of dolostone and limestone.
The research leading to these results has received funding from the [European Community's] Seventh Framework Programme [FP7/2007-2013] under grant agreement n°247616.

What we know about the longest Croatian cave?

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Intensive speleological research on Mt. Crnopac in last decades resulted in 2004. with the discovery of the longest Croatian cave, Cave system Kita Gaćešina – Draženova puhaljka. The length of the cave is 22 519 m and the depth 665 m. The main morphological characteristic of the cave is a network of multiphase cave passages, some of them with very large cross-section dimensions. Estimated cave volume is 1.3 million m3. The exploration of the cave was conducted by the members of The Speleological Committee of the Croatian Mountaineering Association. From 2004 to 2012 there were 70 explorations with 181 cavers from 27 clubs from Croatia and Slovenia, France and Serbia. Cave map has 3106 survey stations with average distance of 8.5 m, average cross section 7.6 m and average inclination 30.6 degrees. Furthest Station is 2470 m form the entrance.
Crnopac massif is the most southern part of the Velebit mountain range (part of Dinaric coastal mountainous karst, SW Croatia). The massif is built of thick carbonate deposits of upper Triassic, Jurassic and Cretaceous age. Speleogenesis of the caves in the Crnopac massif probably have lasted continuously from the beginning of the massif uplift (upper Miocene ?). The massif is situated between higher terrain of Gračac polje on the north and Zrmanja River valley on the south and east. In such conditions polygenetic multilevel caves have developed inside the carbonate massif. Presently known caves are the remnants of various levels of paleodrainage systems that conducted waters from the higher terrain on the north to the base level springs on the south and south-east. Older phreatic and epiphreatic channels are frequently crossed by younger invasion vadose shafts, which provide entrances to the most of explored caves and also connections between different levels inside the caves. Mechanical properties of the Oligocene to Lower Miocene carbonate breccias have significant role in the cave morphology. Low frequency of cracks and joints in these massive breccias enables preservation of underground passages and chambers of very large dimensions. Moreover, cave channels developed in breccias generally have well preserved phreatic and epiphreatic morphology, while collapsing processes are more expressed in channels developed in older carbonate rocks. Fluvial sediments are present in the majority of paeleophreatic channels, and sediment exploration in the future would greatly contribute to the understanding of cave genesis.
Complex speleogenesis produced a polygenetic multilevel system that has a key influence to present cave microclimate and hydrology. The measurements of the cave microclimate, radon concentration and water quality parameters will help to understand important processes in the cave.

Cave surveys, the representation of underground karst landforms, and their possible use and misuse

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One of the main goals of caving activity is to draw maps and sections of the explored caves, thus producing a valuable documentation that is of crucial importance to all those people that, for several reasons, will never visit the cave. Cave maps greatly vary, depending upon many reasons, including but not limited to ability of surveying team, graphic skills, availability of software, etc. Apart from these issues, reliability of the instruments used during the survey is of extreme importance, too. From identification of the cave entrance, to measurements of distance, angle, and azymuth, each survey may be affected by significant errors, that rarely can be appreciated or assessed only by looking at the cave map and sections. Especially when dealing with old surveys (given the rapid evolution of tools and instruments in the last years, we consider in the present article "old" also surveys of some 20 years ago), reliability can be very low.
Nowadays, the use of modern technologies such as Global Positioning System (GPS) and tools (laser distance meter), combined with availability of software specifically dedicated to cave mapping has brought to a much higher level of precision, and reliability of the cartographic products delivered by many caving organizations. However, there is still an high number of "old" maps, and these are often used even by people and professionals outside the karst and caving world.
Ideally, one should re-map with the today available tools all the known caves, or at least check the quality of the old maps. This is not possible in the short time, which brings to some interesting questions: how should the information contained in cave maps be read? Is there the possibility of mis-reading what is actually shown, and use it in wrong ways?

We feel that transferring information about a cave from cavers to other people is not a simple matter, that too often is underestimated, which results in misuse of the information produced by cavers. To discuss this matter, we will present the following examples from Apulia, coming out from the experience of a project the Apulian Speleological Federation is leading in these years:
- a comparison of cave maps, produced with the old traditional methods and the newly available methodologies;
- data on reliability of the location of cave entrances;
- mapping of underground karst landforms;
- identification and interpretation of cave levels;
- considerations about the overall reliability of cave maps.

Breakdown deposits: characteristics and their significance in the evolution of karst systems

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Breakdown deposits in caves are originated because of the effects of gravity-driven processes on rock masses affected by karst. Even though breakdown processes may occur during several stages of cave development, they are mostly active in the enlargement phase, as well as once water has left the cave, moving downward toward the phreatic base level. This results in removing the buoyant support, thus leaving unsupported the cave walls and ceiling.
When the rock mass is heavily fractured, and/or interested by weathering processes, the usual evolution consists of rock failures (that can be discriminated into different typologies) and production of breakdown deposits. Occurrence of breakdown may result in enlargement of the cave, exposition of larger rock surfaces to dissolution, upward stoping that creates large chambers or shafts, eventually reaching the ground surface and leading to formation of sinkholes.
Breakdown pavements litter the floors of many caves, often masking the real base of the karst system. They often characterize the largest chambers or caverns within karst systems, and are related to those areas where different discontinuity systems or karst galleries and conduits controlled by structures meet. Closing any possibility of exploration, breakdown deposits may create an impassable physical barrier, not allowing further passages to cavers; on the other hand, sometimes it is exactly through the presence of breakdown deposits that a gallery comes in direct communication with a nearby chamber.
Recognition of breakdown deposits in karst systems is therefore very important for several reasons, since they: i) characterize zones of weakness in the rock mass, likely more prone to karst processes; ii) can indicate possible direction of cave continuation; iii) are a crucial element to be considered in terms of instability processes within karst systems; and iv) are among the most common and largest deposits found in caves.
This contribution intends to describe breakdown deposits, and highlight the relevance of their detailed analysis and mapping, combined to that of the rock failures producing them, aimed at reconstructing the different stages of evolution of karst systems.

Some considerations on depressions, dolines, and similar karst landforms

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Karst landscape is characterized by a limited number of distinctive features and landforms, which are originated through the process of solution of carbonate rocks. When rocks other than carbonates are present, such landforms are often combined to others of different origin. Even in entirely karst territories, further processes (gravity-related, fluvial or marine activity, etc.) beside karst may be active.
Among the most peculiar landforms of karst, dolines have a preminent role. The term doline, of Slavonic origin, means literally valley but actually it has been used since a long time to indicate more or less well defined topographically depressed areas related to karst. Apart from the long diatribe in preferring the term doline or sinkhole, it is without any doubt that doline is used in very different situations to indicate significantly different forms. As a matter of fact, to precisely designate what one actually means it is necessary to add another word before it: thus, solution dolines, collapse dolines, and so on.
However, it is important to note that the use of a correct terminology is of primary importance when producing maps and/or documents that are addressed to people other than karst scientists. As regards land planning and management, for instance, dealing with a solution doline (that is, a very slight depression, with likely slow to extremely slow evolution) is very different than dealing with a collapse sinkhole (generally characterized by abrupt walls, presence of underground voids, and possible instability problems).

Starting from the above considerations, the present contribute intends to describe some situations in karst areas of southern Italy in order to highlight the need to better discriminate among different types of depressions and dolines, and to provide some insights on the processes that produced such landforms, and their likely future evolution as well. To reach these aims, examples of karst geomorphological maps will be described, covering different sectors of southern Italy, and namely:
1 – instability phenomena, from collapse dolines to slope movements s.s.;
2 – collapse versus solution dolines;
3 – distinction between dolines and depressions;
4 – karst lakes, originated in different morphological settings, and used as hydric supply.

Water quality of coal mine cave

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Several underground coal mines is in operation at Korba city (22° 21′ 0″ N, 82° 40′ 48″ E), central India. This groundwater is draining out as runoff water and being a major culprit to pollute the surface water. A huge amount (> 10000 MT per year) of coal is mined out to create artificial cave. They may tend to occur catastrophic hazards i.e. land slide, earth quake, fire, etc. in this region. The water quality i.e. pH, conductivity, TDS, hardness, alkalinity and chemical content of fluoride, chloride, sulfate, nitrate, sodium, potassium, magnesium, calcium, etc. of the coal mine caves is discussed to understand the potential hazard.

Frost weathering – the main factor for the development of shelter caves?

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Compared to karstic caves originating from the chemical dissolution of water, there are only a few studies on the genesis of shelter caves. These are by far smaller but can host important archaeological or paleontological findings. Some shelter caves can reach 100 m in length and they can make up a significant number of caves in an area. They occur in different kinds of rock but mainly in carbonates. Shelter caves are often described as a result of frost shattering processes in literature. However, the exact development of the caves in accordance to the weathering rates of frost shattering over time has not been determined yet. A precondition for the process to be effective is a well developed joint system as well as the availability of water. If frost shattering is assumed to be responsible for shelter cave genesis two questions arise: (1) Which process removes the material from the caves? (2) Can the effectiveness of the process be measured and what amount of time is needed for a cave to develop?
In Lower Austria 34 % of all caves are shelter caves, occuring in different types of rocks and in various altitudes. Two of those caves, located in Lower Triassic dolomitic limestone at about 600 m a.s.l., were chosen as study sites. One is exposed to the north, having a length of 12 m and one to the south (10 m length) which allows for observing the influence of the local climate. For one winter-spring-season rock temperatures are being recorded in different depths, as well as air temperatures at the ceiling and at the ground of the caves on an hourly basis. To evaluate the amount of accumulating debris from ceiling and walls, a fine meshed net (4 mm) was installed and is unloaded monthly. These measurements will be continued until the end of May 2012. To evaluate the thickness of the sediment in the cave and at the slope downhill of the cave, trenches were dug and electrical resistivity tomography was measured.
At the moment measurements are still in progress and only first results can be reported. Electric resistivity tomography revealed that the sediment is up to 2 m thick. Diverse debris collected form the nets indicate that the process is still active. Future analyses of the temperature data will help to determine the reaction time of the rock to varying air temperatures and to estimate how long the rock was frozen. The results will be compared with the amount of debris collected in the net in order to identify periods of higher activity. Knowledge about the sediment thickness in the cave serves as a basis for estimating the retreat rates for frost shattering of carbonate rock in shelter caves.

Passage shape evolution in epiphreatic zone

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The cross-section of vadose passages is often interpreted to deduce some of the processes and conditions during their evolution. We present a model of evolution of vadose passages derived from basic principles of flow, dissolution and transport. Storm Water Management Model (EPA SWMM) is used to numerically calculate flow through solving Saint-Venant equations. Dissolution of soluble walls and transport of dissolved species are coupled to the calculated flow. Starting from an initial geometry, the model determines the rates of rock removal at each point in the channel and propagates the solution in time to obtain the evolution of channel cross-section. We present the evolution of initially phreatic conduit which evolves to vadose stage and discuss the resulting shapes of the passage under different hydrological conditions.

From speleothems to glaciers: disentangling between karstic and glaciologic processes in caves

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Karst of the Yucatan peninsula (Mexico)

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There is an ongoing research in the region of the Yucatan Peninsula focused on water caves and cenotes. In the last years, many researchers from the Slovak and Czech Speleological Societies also work there. The whole karst area is developed in the Neogene coral and mussel limestones, which formed more than 1300 m heavy strata. The relief is plain with maximum altitude differences between 10-30 m; only in the south part of the peninsula we can find heights. There are no rivers or flows in this area, all the water flows through underground karst water channels to the edge of the plateau (sea shoreline) and here mixed the fresh water with salt water. These karst water channels are almost horizontal with large cross-sections. There were found sinter forms and fossils of extinct species, so at least one evolution phase was probably under terrestrial conditions. Many cenotes are formed on the karst surface (similar to collapsed dolines in the Central European karst areas), these originate by collapsing of very thin cave roofs. They have round perimeter and many present entrances to huge caves.
The cavers from Czech and Slovak Speleological Societies organized many expeditions to map and discover new cave passages in the last years. In December 2011, they connected two long cave systems Tux Kupaxa Cave and K´oox Baal Cave, so the 4th longest underwater cave system in the world was created and the total length is now 56 591 m.
During the expedition in February 2012, we mapped and investigated 3 caves (with total length of about 2,5 km), which are interesting not only from speleological and carsological point of view, but also from the archeological point of view. We have also found relicts after the Maya culture there (walls, altar…).
The future research opens possibilities and conditions for more detailed geomorphological research in this karst area.

Karst and Cave Evolution in the Alps

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Present-day dissolution rates in stream caves of Slovenia.

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Dissolution is a process that is responsible for cave formation and one of the most important during later speleogenesis. Although we know this, we have only few field data that show its actual rates. Taking into account this conclusion, we start to measure present-day dissolution rates in 2004 to find out (a) magnitude of present-day dissolution rates, (b) spatial and (c) temporal variability and (d) to highlight those factors that are influencing dissolution rates the most. Our research was carried out in stream caves of Dinaric karst usually in epiphreatic zone. The majority of measurements were done by using limestone tablets but at some locations also

micro(erosion)meter was used to compare results of different methodology. The biggest advantage of measurements with limestone tablets is their high precision (up to ±0.05 μm) and accuracy (on average ±0.2 μm; maximum observed error was ±0.4 μm).
Generally, dissolution or flowstone deposition rates in epiphreatic zone are low, which corresponds to long-term evolution of caves. Along main underground streams in the epiphreatic zone, rates of several μm/a are common. Such rates are characteristic for caves influenced by concentrated autogenic recharge, diffuse autogenic recharge, even allogenic recharge, where the catchment area is composed of carbonate rocks, and for composed diffuse/concentrated autogenic-allogenic recharge. Caves with dissolution or flowstone deposition rates higher than 0.1 mm/a are extremely rare.
One of the biggest surprise was detection of prevailing low flowstone deposition rates in some regionally important caves (Postojna Cave, Planina Cave, Škocjan Cave, Tkalca jama Cave, Križna jama 2 Cave, but high flowstone deposition rates in Križna jama Cave), which can not explain actual dissolutional morphology of the caves. Discrepancy between morphology and present-day processes is definitely not related to low discharges since we were lucky to measure processes also during the very high discharges with high-recurrence interval. It points out that the direction (dissolution-flowstone deposition) and rates of processes can change in tens of thousands of years according to change of hydrological situation in the aquifer or due to climate.

Human alteration of karst landscape: the examples from Slovene karst

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This contribution examines the national legislative framework on spatial planning in karst regions, and presents some cases of inappropriate management and human alteration of karst landscape in Slovenia. Unfortunately, in the current legislation, the standards and conditions for the protection of karst landscape characteristics (e.g. dolines) are loose and not fully elaborated. Principally, there are no uniform mechanisms to protect specific relief forms or for the adequate protection of karst. To a large extent, the preservation of the characteristic karst landscape is left to local communities that most often lack the necessary financial and professional resources to appropriately direct land use, and those dealing with spatial planning and land use have insufficient knowledge regarding the complexity of karst and its vulnerability. In a selected area settlements Hrpelje-Kozina and Divača (Kras) changes in land use and its effect to deterioration of karst landscape has been analyzed and evaluated. These areas have been subjected to intensive urban, traffic and business development since the motorway had been brought to their vicinity fifteen years ago. Consequently, new residential areas, industrial zones and business parks have been set up in karst landscape, originally covered with numerous dolines. The unique karst relief with various types, shapes and dimensions of surface features is usually considered only as an obstacle for faster local spatial development (e.g. building of industrial zones, traffic infrastructure, settlements, etc.) by decision makers, planners and construction engineers. Therefore, karst landscapes are extremely susceptible to human impact, which has to be considered in spatial planning in order to preserve its natural value.

Baseline physicochemical investigations on waters from three blue holes, San Salvador Island, Bahamas

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Measuring the physical and geochemical parameters in the water column of blue holes has the potential to help our understanding on various hydrological issues, geochemical processes, weathering of minerals within the host rock, biota, groundwater quality, and contamination. Physicochemical parameters have been studied in the water column of Inkwell, Church, and Watling's Blue Holes (San Salvador Island, Bahamas). Cations, anions, and field parameters were collected from multiple depths at the three blue holes and compared to the average ocean concentrations of these parameters in order to assess the freshwater versus saline groundwater responses to evapotranspiration, tidal influences, and freshwater spring input. The salinity concentrations were found to vary at the surface of each blue hole; however, salinity concentrations became similar with respect to depth at each location. This indicates that processes are occurring at the surface at each location causing variation in salinity, chlorine (Cl-), potassium (K+), electric conductivity (EC), and total dissolved solids (TDS) concentrations. These variations are likely a result of the blue holes connectivity to seawater, seasonality, and evaporation processes.

The effect of different weather events on the water quality of some karstic lakes on the Aggtelek and Slovak Karst region (Hungary-Slovakia)

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According to the monitoring results of some karstic lakes on the area of the Aggtelek and Slovak karst (Hungary-Slovakia) was proven that these shallow lakes are quite influenced by anthropogenic activity and the climate extremities. The aim of the study is to show the effects of the weather events on the water quality and quantity.
Water quality and changes in the state of the karstic lakes was monitored between 2008-2010. We searched answer on the intensified eutrophication process which took part in the last decades in these lakes. In this process play role the various contamination sources but also the climate which shows bigger frequency in the extremities in the last few years. The aim of our study is to determine the effect of the climate on the water quality and quantity of the lakes with the use of drought indices.
The amount of precipitation decreased after 1980 compared to the previous years, and the number of drought periods was also higher than the number of wet periods.
A strong, significant correlation was found between the water quality parameters and the different drought indices, which, depending on the lake's state and position, affect them in different ways. The most connections occurred with weather events ruling during 6-12 months, these events affect the processes of all lakes.
Since most water chemistry parameters are affected by extreme weather events, their increasing frequency could cause sudden extreme changes in water quality and quantity, which in the case of these shallow and unstable lakes may trigger irreversible changes.

Lakes on the Aggtelek and Slovak karst - some aspects of the changes in their state

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According to the monitoring results of some karstic lakes and springs on the area of the Aggtelek and Slovak karst (Hungary-Slovakia) was proven that these waters are quite influenced by anthropogenic activity and the climate extremities.
The reasons of the typically higher nutrient content and advanced trophic stages are the specific point and diffuse pollution sources typical for the narrow environment. The quality of habitats was changed by the variety of human use, and in some cases, by the rehabilitation works. This, together with the climate effects cause significant instability in the water quality and threaten the cave ecosystems which are associated with some of the lakes. Currently, as a number of protected species is linked to these habitats, or in some cases complex hydrology systems are concerned, the Slovak and Hungarian authorities also seek to ensure greater protection to the catchment area. In addition, some rehabilitation projects were completed and are also in progress for lakes' rescue – their effects and their possible outcomes are reviewed. This paper aims also at presenting the characteristics of the patterns in the water quality of the lakes between 2008-2010, wetland condition assessment according to the macro-vegetation, and several approaches to assess the impact of the weather events on the water quality.

Micrometeorology of Covadura cave (SE Spain) as global change proxy

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It is well known that human activities have negative effects on the natural environment, such as the current warming of the climate that, from a physical point of view, is characterized by two key parameters, temperature and precipitation. The study of these variables over time may help to predict the evolution and causes of global warming and to develop a protocol that minimizes its effects as far as possible.
The use of karst cavities as "laboratories" for studying underground environmental parameters (temperature, relative humidity, CO_2 concentration, etc.) is increasingly common in researches on climate change. This is due to the high thermal inertia of karst systems that eliminates the high frequency meteorological signals ("background noise") that often distort the original records when making measurements at the surface.

In this sense, one of the main topics of the GLOCHARID Project is to focus on Covadura Cave System, a cave complex in the gypsum karst of Sorbas (Almeria, South-East Spain). This network of underground passages is developed within gypsum strata of Messinian age, with up to 7 levels of galleries connected by shafts, reaching a maximum depth of 120 metres. This cave system has several entrances that connect underground and external atmospheres, thus enabling a strong air flow.
Temperature and relative humidity in the cave have been monitored from September 2011 by 25 dataloggers distributed in all cave levels at different depths and distances from the entrances. Data acquisition has hour-frequency. Furthermore, there are similar sensors at the surface, in order to compare the underground record with the external one.
The preliminary results have shown that the relative humidity and air temperature recorded at each cave microclimatic station vary considerably both in time and space. The trend in the relative humidity reveals an increase with the depth and the distance from the main entrances of the system. Furthermore, it was found that the uppermost cave conduits (Level 1, 2 and 3) have less inertia to changes respect to the deeper levels and are more subject to external weather variations with only a slight delay. Even daily cycles have been observed. As expected, the atmosphere of the deepest part of the cave system has been more stable and remains saturated in water vapour (relative humidity of 100%), except when external relative humidity drastically decreases and temperature drops. This effect propagates from the surface across the galleries within hours.
The air temperature spatial pattern is characterized by a decreasing trend from the entrance to the deepest parts of the cavity, with some exceptions. The behaviour of the climatic series obtained in Level 5 is worth to note (only recorded during 3 months), which has a temperature lower than the deeper levels, behaving as a "cold air trap" capable of keeping inside for a long period of time, masses of cold, dense air flowing through the other galleries. Furthermore, the temperature in the deepest level (Level 7) is largely unaffected by external climatic variables and remains almost unchanged, with values close to the average annual of Sorbas (15 °C). This level, where the high frequency fluctuations are minimized, is the ideal place to install a microclimatic monitoring system to conduct a long-term study on major shifts in the global climate system. Both Level 7 and 5 show thermal inversion phenomena (cave air warmer than outside in winter), which occurred since mid-November at the deepest level and since mid-December at Level 5. Finally, the areas where the cave temperature varies more quickly are located at the interconnections among the various levels, particularly in correspondence of the vertical shafts. Clear evidence is represented by the Level 6 where, despite its depth, cave atmosphere shows the influence of the strong airflow caused by differences between cave and surface temperature.
According to these preliminary results, it seems evident that the effects of Global Warming will affect irreversibly the stability of the deepest part of the cave system, where microclimatic variables have a high inertia and are altered only in exceptional circumstances, generally arid. Taking into account that the general observations point to a high frequency of extreme events, including the continued droughts and the progressive increase in the average temperature in south-eastern Iberia up to +5.8 °C in 2080 (IPCC, 1999), cave micrometeorology may play a key role in monitoring and controlling the effects of climate change in semiarid environments.

The landforms of the karst mountains in the middle latitudes: reflections, trends and problems of the research.

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Some characteristics of groundwater dynamics in the upstream parts of the karst systems.

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Karst aquifers are generally highly heterogeneous and anisotropic medium composed of conduits, fractures and rock matrix. These hydraulically contrast components of the aquifer are in constant interaction and unsteady state. Continuous unsteady state of the aquifer prevents forming of common water table, which is representative for all aquifer components. Simultaneous groundwater monitoring in active conduits and surrounding fractured rocks provide probably the best possible insight of hydrogeological processes in karst system. Water level and temperature loggers were installed in a few caves and adjacent boreholes in the sinking zone of Lika and Gacka lost rivers, situated in Croatian Dinaric karst area. Obtained data provide general characteristics of groundwater dynamics in the upstream part of the karst massif, which separate Lika and Gacka karst poljes from the Adriatic coast. Temperature data proves to be a good indicator of a water origin during variable hydrologic conditions, while water level dynamics data serve as an indicator of hydraulic properties of conduit and surrounding rocks, vertical distribution of high permeability horizons and water flow directions. Very pronounced heterogeneity of

water level, as well as high level gradients was designated. High water level gradients in conduit systems are probably enabled by prevailing influence of vadose flows, especially during the low water conditions. Water levels in the caves during dry periods are fixed by downstream overflow position in the conduit systems. Overflow occurrences result in creation of numerous hydraulic discontinuities in the conduit network. During high water conditions, conduit flow often transfers from vadose to phreatic, causing better hydraulic integration of the system. Therefore function of the hydraulic discontinuities is time-variant and dependant on hydrologic conditions. Described phenomena result in a great variability of underground water flow characteristics, not only considering different components of aquifer (i.e. conduits, fractures, matrix), but also in adjacent parts of conduit systems.

Unified Database of Speleological Objects as part of Nature Conservancy Information System of the Czech republic

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Karren or not: rock surface textures in coastal karst

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Limestone surface textures in coastal areas tend to exhibit a gradation of forms that are often morphologically similar but genetically contrastive. They include dissolutional sculpturing, haloclastic and biocorrosional features, physical scars of bioabrasion, and other textures. Often, all of these are subsumed under the general name of karren. This is problematic because the genetic origin of many small-scale facets of coastal limestone may have little or nothing in common with classical karren, which is traditionally limited to features made by dissolution and should exclude products of other processes. This distinction may be difficult to make because of often extraordinary morphological similarity between polygenetic features, but is important for correct paleoenvironmental interpretation.

We have examined hundreds of limestone textures found in coastal karsts worldwide and attempted to identify those that are most likely to have multiple origins and cause uncertainty among field workers. We recognized several recurring morphotypes that include both karren and non-karren variants. Textures of irregular pits and residual points and ridges between them are characteristic of eogenetic karren that forms through biochemical corrosion of diagenetically-immature rocks in supratidal zone; however, they also commonly arise from bioabrasional attack by limpets, whose round homing scars overprint each other and leave behind mechanically produced microtopography in intertidal zone of various substrates, including many telogenetic rocks. Exceptionally intricate honeycomb-textures can be a result of salt-weathering in wave-splash areas; similar morphologies can also be produced in subtidal rocks by endolithic sponges. Systems of small-scale interconnected cavities and tunnels permeating rock surface layers are typical products of mixing corrosion in coastal springs and caves; matching labyrinths can also be made in live coralgal rock by certain chitons. Flat-floored coastal pans are quintessential products of biochemical dissolution by microbially-modified wave splash; nevertheless, they can also develop by mechanical erosion of grazing echinoderms. Assemblages of round-floored pits are the most common coastal karren at higher latitudes; comparable textures also form at most lower-latitude coasts as remnants of boreholes produced by bivalves.

Karst field workers should be aware of the manifold origins of similar rock textures. Comparing and contrasting pairs or sets of comparable morphologies should help with correct identification of genetic origin and allow more accurate interpretation of field observations.

The caves from Dealul Popii (Rodnei Mountains, N Romania): mineralogy, morphology and speleogenetic implications

GEOLOGICAL SETTINGS OF THE MAŁA W MUŁOWEJ CAVE, TATRA MTS (POLAND)

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Mała w Mułowej Cave is located in the West Tatra Mts. in the Czerwone Wierchy Massif. Entrance is situated 1757 m asl in the Middle Triassic limestone and dolomites belong to Ździary Unit, part of Czerwone Wierchy Nappe. Mała w Mułowej Cave is 555m depth and 3863m length. The cave has two main conduit which separate at a depth 60m. First conduit is a vertical type and contain the biggest chamber in Tatra Mts. with dimensions 85x35x90.m. Second conduit is a aven type too, but only to 300m depth, further corridors run 800m in a straight line towards the WNW to a depth of 555m.
Since 2002 new discoveries have been made in the Mala w Miłowej Cave. Bac-Moszaszwili & Nowicki (2006) described geology of the Cave relied on other explorers verbal informations. Later measurmets done by Recielski were interpreted by Grodzicki (2008).
Fieldworks, included measurements of the geological structures (fracture, bedding and fault planes, tectoglyphs) and morphological observations enable to the fine genetic classification of individual corridors. Also Rock samples were collected for stratygraphy recognition. All collected data are display as structural plans of caves and geological cross-sections. Furthermore the structural analysis has been made.
The Mała w Mułowej Cave up to 300m depth developed in the Middle Triassic banding limestone and dolomites. Corridors system at vertical part of the cave, was determined by inverted, horizontal brachysyncline. Large cubature parts as the Fakro Chamber, the Geriawitów Pitch, the Czesanka Pitch were formed in the hinge zone which was under the biggest stress and thus was the most susceptible to karstification. The Collaps character of the Fakro Chamber can be explained by the fact that near the core was the biggest compression results of which must have been a number of discontinuities and minor folds. The Czesanka Pitch developed near the crest where was the biggest tension which explain why it were formed on loosened bedding planes.
About 300m under the cave entrance passages were formed mainly at the contact between the autochtonous High Tatric sedimentary cover and the Ździary unit. First represents marly shale of the Zabijak formation and limestones of the Wysoka Turnia formation, second The Middle Triassic limestone and dolomites and the Early Triassic limestone with shale interbeds. Below, the main factor determining the course of the cave is the tectonic contact and related fractures. The corridors were developed in carbonates ensued karstification and also in the shale. Flowing water is easier to mechanically erode fragile shale than rinse out carbonates. Some parts of passages recede of the contact between carbonates and shale i.e. Meander Ebola, Meander TPKC, Meander Dwudziestolecia. Probably it is a result of related fault transverse to contact.
Research have shown that the Mała w Mułowej Cave developed in the syncline of the Middle Triassic rocks, not in the inverted rocks series from the Triassic to the Cretaceous as in Bac-Moszaszwili & Nowicki (2006). Besides, research indicated that the cave corridors do not pass to Organy unit, but whole of them are in the Ździary unit and its contact with the autochtonous High Tatric sedimentary cover.

The caves from Dealul Popii (Rodnei Mountains, N Romania): mineralogy, morphology and speleogenetic implications

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Dealul Popii is a small isolated karst area situated in the southern part of the Rodnei Mountains (Eastern Carpathians), which hosts nine cavities developed in Devonian - Lower Carboniferous crystalline limestones and dolomites with quartz and mica intercalations. A detailed mineralogical study was carried out on samples from these caves, revealing an association consiting of carbonates (calcite, aragonite, smithsonite), sulfates (jarosite, gypsum), oxides (goethite, hematite, rancieite, todorokite) and quartz.
Baia lui Schneider (Schneider's Mine, 800 m long, 38 m deep), the longest cave in the area, is renowned in Romania for its aragonite speleothems, whereas Speranţei (Hope) Cave, 74 m long, was supposed to represent its upper level. Previous studies on Baia lui Schneider (as well as its name, and local legends) suggest that some of its passages have been mined at least since the XVIIIth century; due to its large entrance and main passage, vandalism of the XXth century is also evident. Speranţei Cave is a small labyrinthic cavity with passages rarely passing 1 m in width or height. It was initially considered to have been formed by infiltration water, but its morphology and archeological findings raised questions concerning its true genesis.
Chemical analyzes on samples from both cavities confirm the local legends concerning mining works in these cavities. Their mineralogy, as well as other morphological and archeological findings indicate that the some of the cavities from Dealul Popii were initially hydrothermal karst voids, partly or completely filled, and the mining works followed closely the karst passage directions.

Map of karst rock outcrops in Macedonia

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Extension of karst rock outcrops in Macedonia is given by Andonovski (1981) as 2440 km2, which is 9.5% of Macedonia's total area, or by Kolčakovski & Boškovska (2007) as 2724 km2 (10.6%). This data is usually accompanied with a large scale map of general extension of karst rock outcrops (Kolčakovski, 2001), which is highly generalized and inaccurate. Different map, but with similar quality is also given by Kekić (1980). Both of the values about karst rock outcrops in Macedonia are based upon the basic geological map of Macedonia, published in 1 : 100 000 scale. The low precision of the karst rock extension maps, demanded creation of a new accurate digital map and data using GIS methods. We present the methodology used to produce the data and the map, as well as the results which can be easily combined with other data (such as faults, caves, karst springs etc.) and can serve as a base for further analyses of karst terrains in Macedonia.

Cover-collapse sinkholes in the Franconian Alb - Germany – selected examples and conditions of formation

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Recent events of cover-collapse sinkhole formation, the geomorphological, geological and hydrological conditions of selected sinkholes and the spatial and temporal occurrences of such landforms were studied in the Franconian Alb, a karst area located in southeastern Germany. The study area consists of karstified limestones and dolomites of Jurassic Age. It is partly covered by Cretaceous and Miocene deposits and a clayey to loamy overburden. The thickness of the loamy cover ranges from a few decimetres up to ten meters. Sinkholes are widely distributed in the area, to some extent they were formed by cover-collapse processes.

In order to prepare a geohazard map, historical records from different archives (public and governmental archives, municipalities, counties, water management agencies, newspapers, local population) were used for a compilation of sinkholes which resulted from collapses. The frequency of cover-collapse sinkhole events differs in areas with agricultural or forestal use. Farmers often backfill these surficial cavities immediately after their formation, before these objects can be registered officially. Therefore a documentation of such collapse events may be restricted in terms of detailed statistical analyses. Nevertheless seasonal clusters of collapses can be observed with a distinct focus on the first months each year.

Recent collapses show close relations to climatic conditions. During winter or spring the majority of collapse events are associated with snow melt or heavy rainfall resulting in an increase of the soil moisture and a decrease of shear strength within the loamy cover. Consequently, loose material overlaying cavities can be washed down, or the sediment itself moves downward. For single events, the antecedent climatic development (precipitation, thickness of snow cover, air temperature, soil temperature) was analysed for identification of the triggering factors.

Also saisonal or episodic flooding of dry valleys create new collapse structures acting later as ponors. In this context, small-scale surficial karst depressions without outlet (underlain by thick loamy deposits) show an efficient drainage via a few temporary active ponors and connected subsurface pipes. These ponors are affected by frequent morphological changes due to the power of the inflowing water, but mostly they are blocked by loamy material.

Besides the climatic or hydrologic relations, the formation of cover-collapse sinkholes is influenced by human activities. Collapses within soils are often caused by the mechanical stress following/during farming activities or they are located near motorways, roads and close to buildings where the infiltration was disturbed.

Selected cover-collapse sinkholes were studied in detail with respect to their geomorphological and geological characteristics in order to document cavities and the subsurface structure of the sinkholes. Additionally, the physical properties (grain size, moisture content, shear strength) of the collapsed sediments were analysed within the accessible parts of the collapse sinkholes. Different sediments could be separated: Only little differences were indicated for still slow-sliding sediments (high water content and low shear strength) and accumulated older collapse material (slightly increased shear strength). In contrast lower moisture contents and an increased shear strength were observed for cover deposits resting above karstified limestones or older fillings observed within cracks which were not affected by the collapse processes. The deviant water contents and shear strength data of the slide mass point to the conditions before the collapse event happened.

Recent karst of Natural Park "Lena Pillars" (Yakutiya, Russia)

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Natural Park "Lena Pillars" is located in the latitudinal part of the valley of great Siberian River Lena. Orographically region explored belongs to Prilensko'e Plateau raised at 300-600 m a.s.l., dissected by the valleys of Lena and Boutama Rivers. Climate of the territory is Sub-arctic extreme continental and dry: average annual temperature of the air is –9,8°C at the annual temperature amplitudes to 98°C. Average annual precipitations doesn't exceed 249 mm. There is the area of continuous permafrost up to 300 -500 m thickness. Lower Cambrian limestones and dolomites with a thickness 400-500 m outcrop represent the karst rocks.
In spite of the insignificant quantity of the precipitations, falling on the territory of NP Lena Pillars, recent karst is widespread here. Generally, the permafrost blocks the quick infiltration of precipitations, that is the reason of the accumulation of the water is realized on the surface of karst massifs. Moreover, on the one hand, the additional receipt of the water is supplied by the processes of condensation, occurred both from the air because of considerable amplitudes of daily fluctuations of air temperatures, reaching 12,8°C, and in consequence of the big gradients (to 7,8°C per 1 m) between earth temperature and lower situated perennially cryotic rocks (Fig. 3). By the observations on the condensermeter, average value of condensating water reaches 80 mm for the warm season on the territory of Central Yakutiya.On the other hand, according to L. Jakucs (1977), the solubility of CO2 in the water decreases with the increase of temperature of the solution: at temperature 0°C the coefficient of absorbing of CO2 is 1,713, at temperature 10°C – 1,194, at temperature 20°C – 0,878, at temperature 30°C – only 0,665. Thus, the cold waters of permafrost's regions, saturated by CO2, are characterized by the considerable aggressivity in respect to karstifying rocks.
More than that, the infiltration of summer precipitations along the deep fissures of carbonate rocks, the condensation, as well as the considerable snow accumulation, have the warming impact on the cryolithozone, increasing her temperature till 3-4°C and condition the formation of supra- and intra-permafrost taliks.
Therefore the development of karst relief in the regions with permafrost is in need of in some times less of precipitations as compared with the ones where the permafrost is absent.
The manifestations of recent karst are represented by the following formes: karren, sinkholes, disappearances of the rivers, karst springs, dry valleys, small caves, niches, etc.
Type of the karst, developing in conditions of permafrost, has the specific scientific name: ground frozen karst. Karst of Natural Park "Lena Pillars" is the obvious example of such type of the karst.

Hypogenic caves in Sicily: a preliminary study of morphological and depositional features

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A preliminary study was carried out in two hypogenic cave systems in Sicily in order to define their morphological and depositional features, and to understand the speleogenetic mechanisms responsible for their origin and evolution. These are the Monte Inici karst system and the Acqua Fitusa cave.
The first is located in northwestern Sicily, along the southeastern side of Mt. Inici. It is composed of two caves, the Eremita cave and the Cocci Abyss, formed in Lower Jurassic limestones and dolomitic limestones (Inici Fm.), and Middle-Upper Jurassic reddish-gray limestones with ammonites (Buccheri Fm.). The caves are 3D phreatic systems, reaching a total length of over 2 km, and a depth of about 300 m. These caves are characterized by large galleries connected by deep shafts, and morphologies linked to condensation-corrosion processes, such as mega-scallops and big cupolas. Different types of chemical deposits, among which gypsum, have been observed, whereas alluvial deposits are lacking. The air temperature, measured in December 2011, is 15.5-18.0 °C in the Cocci Abyss and 17.6-21.0°C in the Eremita cave. The Monte Inici karst system appears to be linked to the thermal water forming the Gorga (T = 49 °C) and the Terme Segestane (T = 45 °C) hot springs, located eastward and at lower altitude in respect to the cave systems. An important role in the evolution and widening of the subterranean voids is played by air flow.
The Acqua Fitusa cave is located in central Sicily, along the northeastern side of Mt. La Montagnola. It is a subhorizontal cave, about 700 m long and 25 m deep, formed in Upper Cretaceous calcareous breccia with shallow water fragments (Rudist breccias member of Crisanti Fm.). The cave represents a good example of inactive sulfuric acid cave formed close to the piezometric surface level. Actually the H2S-rich spring, with a temperature of ~25°C, lies northward and at lower altitude respect to the cave. Condensation-corrosion processes are responsible for the origin of different small and large size morphologies, i.e., condensation tables, wall niches, ceiling cupolas, megascallops, weathered walls, boxwork, replacement pockets, etc. Gypsum crystals and crusts have been surveyed at different heights.

Antalya, Karstic Area, Water Resurces, Sinkholes, Protection

Mustafa Yıldırım &
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Sustainable management of karst areas

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The Indonesian archipelago contains approximately 15.5 million hectares of karst topography ranging from Sumatra to Papua. The distribution is close to 20% of the total territory of Indonesia.
Karst region is a unique area. The area has a landscape of steep slopes, basins, caves, irregular protruding limestone rocks, an interconnected system of underground streams, forest soil and composition of different species at each height. Karst area is a natural resource that is not renewable and it is a highly sensitive area for all forms of environmental change. The region is dominated by karst limestone (dissolution of carbonate rocks) which has a dynamic ecosystem and important reservation of water.
Along with the rapid development, the various interested parties utilize this area in order to improve economic welfare. To date in Indonesia, karst areas are still considered by most people and even by miners and geologist only as a natural resource that has economic value. Karst is mined for cement, building materials, tiles (marble), jewelry and various other industries. Dolomite and calcite ($CaCO_3$ which has undergone a process of crystallization) are also mined for various industries. In addition, the phosphate contained in sediments in some caves inhabited by bats and swiftlets are also mined for production of organic fertilizer.
The impact of conflicts of interest in utilizing today's karst region is linked to an increased demand for cement by industrial activities. It is feared that the management and utilizations that are not based on the knowledge of the dynamic system in karst areas can affect the sustainability of resources especially water resources