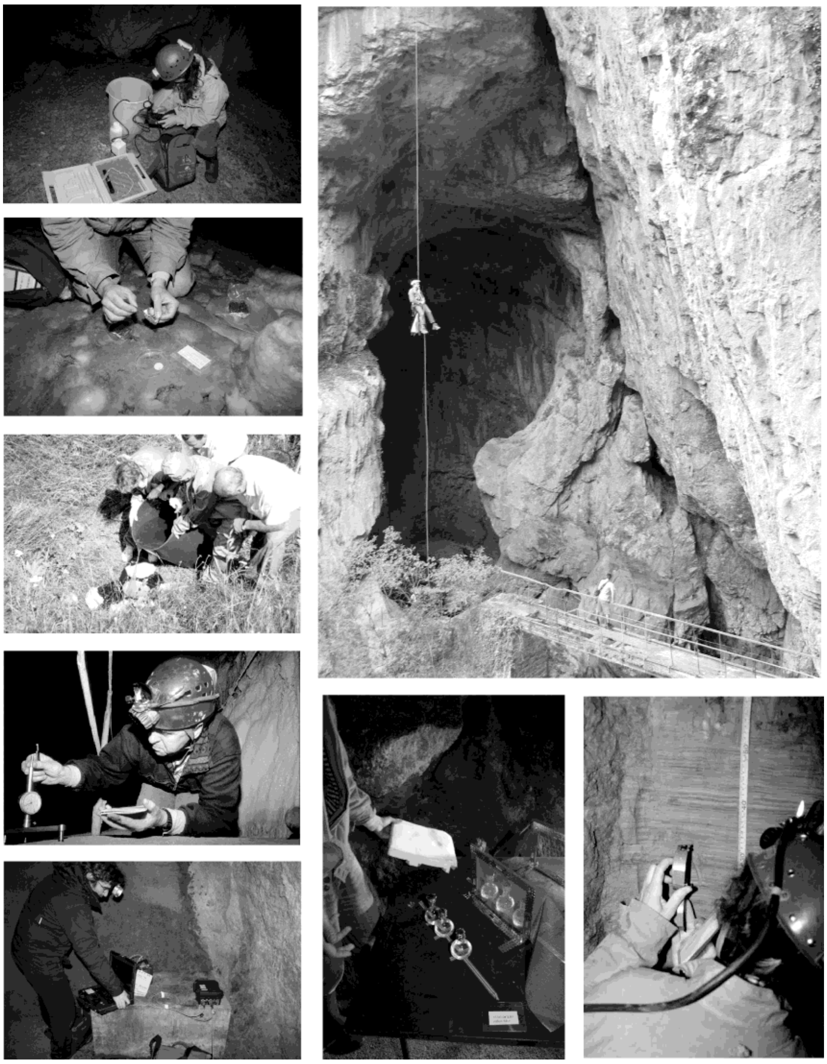
Park Škocjanske jame, Grotta Gigante S.A.G./Velika jama v Briščikih, Karst Research Institute ZRC SAZU and Università degli studi di Trieste

INTERNATIONAL CONGRESS on "SCIENTIFIC RESEARCH IN SHOW CAVES"

13th to 15th September 2012



Škocjan – Borgo Grotta Gigante/Briščiki – Postojna, September 2012

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GUIDE BOOK AND ABSTRACTS

Škocjan – Borgo Grotta Gigante/Briščiki – Postojna, September 2012

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Borut Peric
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Karst Research Institute ZRC SAZU
Università degli studi di Trieste, Dipartimento di Matematica e Geoscienze

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INTERNATIONAL CONGRESS on
"SCIENTIFIC RESEARCH IN SHOW CAVES"

From 13th to 15th September 2012

PROGRAMME

13. 9. 2012

Keynote speakers: *Andrej Kranjc, Chris Groves*

9:00 – 9:30 Registration
9:30 – 9:45 Welcome speeches
Gordana Beltram – *director of the Škocjan Caves Park*
Alessio Fabbricatore – *director of the Grotta Gigante*
Tadej Slabe – *director of Karst Research Institute ZRC SAZU*
Drago Božac – *mayor of the Municipality of Divača*

9.45 – 10:10 Andrej Kranjc: *Researches done in Show Caves - historical Overview*
10:10 – 10:35 Chris Groves: *Karst Hydrology Research in Show Caves of the Mammoth Cave International Biosphere Reserve, Kentucky USA*

10:35 – 11:00 coffee break

11:00 – 11:15 Giuseppe Camero: *Ground Penetrating Radar survey at Santa Croce Cave (Bisceglie – Italy)*
11:15 – 11:30 **Mitja Prelovšek:** *Use of MEM for protection of karst caves – example* ***from Križna Jama, Slovenia***
11:30 – 11:45 Christophe Gauchon: *Scientific research in show caves: a French overview*
11:45 – 12:00 Tatyana Kalinina: *The structural, textural and mineralogical rocks characteristic in the Kungur Ice Cave and their transformation at karstification*
12:00 – 12:15 Roberto Colucci: *The Karst Meteo-Climatological Observatory, a scientific facility within the Grotta Gigante show cave centre (Italy)*
12:15 – 12:30 **Matej Kržič:** *The solutions to prevent damages to the active part of* ***Križna Jama show cave, Slovenia***

12:30 – 13:00 discussion

13:00 – 14:00 – lunch

14:00 – 14:15 Rosana Cerkvenik: ***Impacts of Visitors on Cave's Physical Environment***
14:15 – 14:30 Carla Braitenberg: *Recording the music generated by the Earth with the Grotta Gigante pendulums*
14:30 – 14:45 Heros Lobo: *Non-linear response of cave temperature subjected to tourist visitation (Cave of Santana, Petar – Brazil): implications for carrying capacity of show caves*

14:45 – 15:30 discussion

16:00 – 18:30 VISIT TO **GROTTA GIGANTE/VELIKA JAMA V BRIŠČKIH**

19:30 – dinner

14. 9. 2012

Keynote speakers: ***Franci Gabrovšek, Franco Coren***

9:00 – 9:25 **Franci Gabrovšek:** *Relevance and measurements of selected physical quantities representing cave environment: examples from Postojna cave and Škocjan cave (Slovenia)*
9:25 – 9:50 Franco Coren: *Integrated geophysical and remote sensing studies on Grotta Gigante show cave (Trieste Italy)*
9:50 – 10:05 Massimo Sbarbaro: *WI-FI in the show caves*
10:05 – 10:20 **Vanja Debevec Gerjevič:** *Environmental monitoring and radiation protection in Škocjan caves, Slovenia*
10:20 – 10:35 Stefano Furlani: *MEM and TMEM measurements inside and close to the Giant Cave (Grotta Gigante, Italy)*
10:35 – 11:00 coffee break

11:00 – 11:15 Janez Mulec: *Microbiological parameters assist in evaluating human impact in show caves*
11:15 – 11:30 Olga Kadebskaya: *Scientific research in Orda and Kungur Ice Caves*
11:30 – 11:45 Slavko Polak: *Terrestrial fauna monitoring in the Postojnska Jama, Jama Pod Predjamskim Gradom and Škocjanske Jame – first results*
11:45 – 12:00 Stephan Jaillet: *3D laserscanning and geomorphological studies in Orgnac cave (Ardèche, France)*
12:00 – 12:15 **Marija Zlata Božnar:** *"E-learning" lectures for setting up a modern DTN communications based cave micrometeorological stations, example of Postojna Cave, Slovenia*

12:15– 13:00 discussion

13:00 – 14:00 lunch

14:00 – 15:00 poster session: Giuseppe Camero, Tadej Slabe/Martin Knez/Mitja **Prelovšek, Borut Peric, Giovanni Costa/Peter Suhadolc/Stanka Šebela/Ml**aden **Živčić, Asta Gregorič, Franco Cucchi/Luca Zini, Barbara Wielander, Miris Castello, Alfonso Pura, Ezechiele Villavecchia/Guido Peano/Rosa Rita Gili, Nataša Ravbar/Jure Košutnik, Carol Nehme, Janja Kogovšek**

15:00 – 18:00 **VISIT TO ŠKOCJAN CAVES**

18:30 – dinner

20:30 – 22:30 **participation at »JAMNARKULT« festival of scientific and** documentary films, Matavun

15. 9. 2012

9:30 – 10:30 visit to Notranjska Museum in Postojna

11:00 – 13:00 VISIT TO POSTOJNA CAVE

13.00 – 14:00 – lunch

14:00 – end of congress and departure

ŠKOCJANSKE JAME

Andrej Mihevc
ZRC SAZU Karst Research Institute, Postojna, Slovenia

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 (Fig. 1). 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 64 known 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 (Fig. 2). They were formed by the sinking river Reka that after sinking flows towards Kačna jama, Labodnica and then to springs of Timavo in Italy.

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. 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 (Mihevc 2001, Mihevc & Gabrovšek 2012).

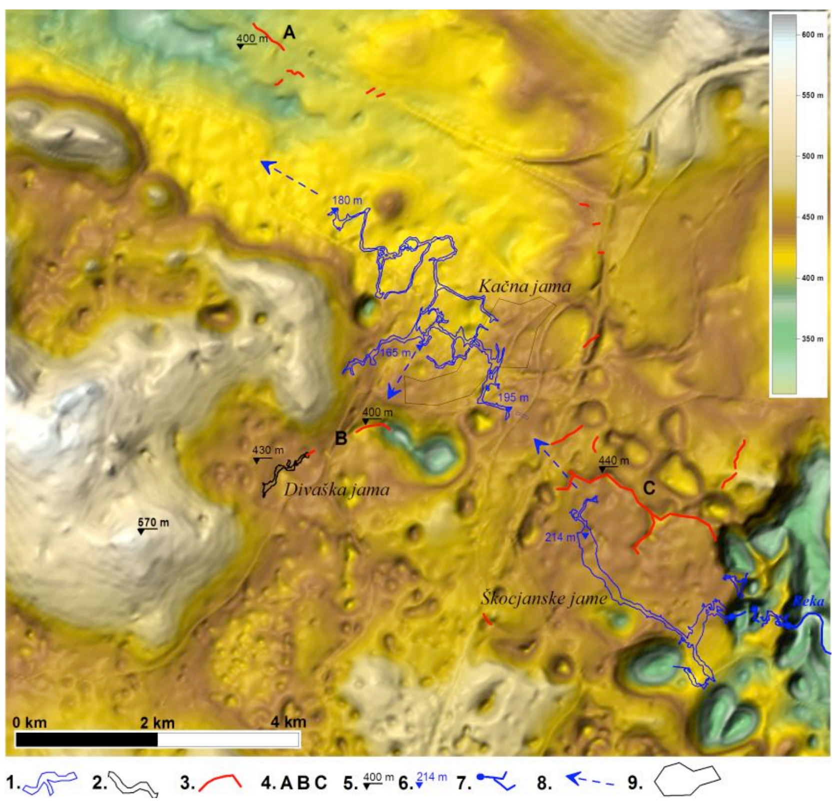


Fig.1. The map of the Divača karst. On the levelled surface the large collapse dolines are dominating features, solution dolines are frequent, but they represent only small

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.A: Unroofed cave near Povir, 4B: Unroofed cave in doline Radvanj, continuation of Divaška jama, 4C: 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.

Kačna jama is the longest cave system of Reka River in the continuation of Škocjanske jame. The entrance lies west from Divača at 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.

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 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 in Italy about 35 NW from Škocjanske jame. Three main springs with mean discharge 30.2 m^3/s on the coast are connected by a network of passages that reaches a depth of about 80 m below the sea level.

The Škocjanske jame 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 jame 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. The large water quantities 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 jame, 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 in the cave 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.

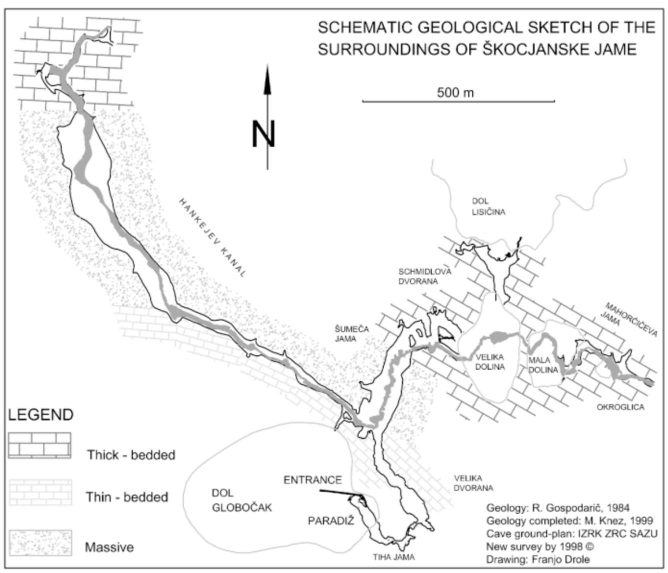


Fig. 2. Map and stratigraphy of Škocjanske jame.

Mihevc, A., 2001. Speleogeneza Divaškega krasa (The speleogenesis of the Divača karst). ZRC Publishing 27, 180 pp., Ljubljana.

Mihevc, A. & Gabrovšek, F. (editors) 2012. Karst forms and processes, 20th international Karstological School “ Classical Karst”, Guide book & abstracts, Postojna, 18 – 21 June 2012, 80 pp.

POSTOJNA CAVE SYSTEM

Stanka Šebela
ZRC SAZU Karst Research Institute, Postojna, Slovenia

The Postojna Cave System is the second in length (20,570 m long; 115 m deep) between the known caves in Slovenia. The cave is connected to the Planina Cave (6.656 km long; 65 m deep) by unknown passages. There remains about 2,000 m unexplored separation, although an underground water connection has been known since the explorations of Gruber in 1781. The train for visitors was installed in Postojna Cave System in 1872 and from 1884 the cave had electricity. The first printed guidebook was written by Agapito in 1823 but the oldest inscriptions on the cave walls date from the 13th and 14th centuries. In 1818 Luka Čeč discovered new parts of the cave and this is the official year of discovery of the tourist section of the Postojna Cave System. 34 million tourists had visited the Postojna Cave since 1819. The cave system is the cradle of speleobiology.

The Pivka River flows on impermeable Eocene flysch and sinks into the underground system of Postojna Cave System at an elevation of 511 m on the contact with Cretaceous limestones (Fig. 1). Several km downstream, the underground Pivka joins the Rak River passage in the Planina Cave System and emerges from the cave entrance to form the Unica River at an elevation of 453 m. At Postojna the average annual precipitation is 1,565 mm (1982-2000). Dye-tracing experiments in 1988 provided evidence for the bifurcation of the Pivka, for the surficial river also drains toward the sources of the Vipava River and thus forms part of both the Adriatic and the Black Sea drainage basins. The portion of the Pivka that enters the Postojna Cave System belongs to the Black Sea drainage basin.

In geotectonic sense Slovenia is situated at the border between Adria microplate and Eurasia plate and characterized by complex and neotectonically active geological conditions. Since the late Miocene to Pliocene paleomagnetic data had indicated about 30° counterclockwise rotation of Adria microplate. During Miocene to recent the thrust belts along the Adria margin include Dinaric thrust system, South-Alpine thrust system and Dinaric faults. Dinaric faults cut and displace both Dinaric and South-Alpine fold-and-thrust structures. Most of them are characterized by moderate historic and recent seismicity.

The area is part of the Javorniki-Snežnik thrust unit, which has been overthrust over the Eocene flysch. The Hrušica thrust unit, which is upper Triassic dolomite, overthrusts the Javorniki-Snežnik thrust unit. Overthrusting took place after the deposition of the Eocene flysch. During the Miocene and Pliocene, the overthrusting was accompanied by folding. The principal folding deformation in Postojna Cave is the Postojna Anticline (Fig. 1).

It is important to distinguish older overthrusting and folding deformations from younger faulting deformations. The Postojna Cave System is situated between two regionally important faults with the NW-SE Dinaric orientation. These are the Idrija Fault on the north and the Predjama Fault on the south. The tectonic structure of the area between those two faults has all the characteristics of the intermediate zone between two dextral strike-slip faults. The cave passages of Postojna Cave System follow strike and dip of the bedding planes, especially those with interbedded slips. They are developed in both flanks of the Postojna Anticline. They also follow Dinaric and cross-Dinaric (NE-SW) oriented fault zones and mostly north-south oriented fissured zones (Šebela 1998).

During the development stages of Postojna Cave System some of the geological structures were reactivated and appear to be connected with the formation of collapse chambers. The geological structural elements were used as pathways for cave development. Along the same fault zone in the cave up to four different reactivations can be detected. The fault zone that runs from Pisani Rov and through Velika Gora shows sinistral horizontal movement in Pisani Rov, reverse fault movement at Velika Gora and dextral horizontal movement and normal fault movement in Lepe Jame. The same Dinaric oriented fault zone is monitored at two places with TM 71 extensometers. The same fault zone is cut by the cross-Dinaric oriented fault zone in Lepe Jame. This neotectonic fault zone was active post cave development because it cuts older cave sediments, which are at least 0.78-0.99 Ma in age.

On the SW flank of Postojna Anticline Dinaric oriented fault zones prevail, while on the northeastern flank the cross-Dinaric oriented fault zones prevail. Underground River Pivka passage follows the strike direction of bedding planes in the southern part and bedding strike dip direction in the northwestern part.

The Postojna Cave System is developed in Cretaceous carbonate rocks. The passages of Postojna Cave are developed in upper Cretaceous (Cenomanian, Turonian and Senonian) mostly bedded and thick bedded limestones. The Cenomanian and Turonian limestones are more thin-bedded and can include chert lenses. The Senonian limestones are thick bedded to massive. The cave passages are developed in about an 800 m thick lithological column.

Recent micro-tectonic deformations have been monitored continuously in 3D in Postojna Cave with TM 71 extensometers since 2004. Two instruments, 260 m apart, were installed on the Dinaric oriented (NW-SE) fault zone that is situated about 1,000 m north of the inner zone of the regionally important Predjama Fault. Monitoring on both instruments has shown small tectonic movements *i.e.* a general dextral horizontal movement of 0.05 mm in 4 years (Velika Gora) and extension of 0.03 mm in 4 years (Lepe Jame). Between the longer or shorter calm periods, eleven extremes have been recorded regarding characteristic changes in displacement (Šebela et al. 2010).

All karst caves in Slovenia are natural worths that belong to the state property. Postojna cave system is 3/4 managed by private company and ¼ by Comune of Postojna, both need to accomplish expert control and recommendations for management of cave system and climatic and biologic monitoring of cave system.

The systematical study of underground meteorological conditions in Postojna Cave with the purpose to determin human impact on natural worth started in 2009. Beside four meteorological stations (air temperature, water temperature, humidity, wind direction, wind speed, CO_2) other 15-20 places are selected in the cave as monitoring sites where air temperature, air pressure, humidity and wind are continuously measured. The cave is well ventilated deep inside. The average air temperature (2009-2010) on the top of Velika Gora is 11.10 °C and 10.66 °C for Lepe Jame. For the same period the average air temperature on the surface outside Otoška Jama is 9.20 °C.

Šebela, S. (1998). Tectonic Structure of Postojnska jama cave system. ZRC Publishing, vol. 18, 112 pp. Ljubljana.
Šebela, S., Vaupotič, J., Košťák, B. and Stemberk, J. (2010). Recent measurement of present-day tectonic movement and associated radon flux in Postojna cave, Slovenia. *Journal of Cave and Karst Studies* 72/1, 21-34.

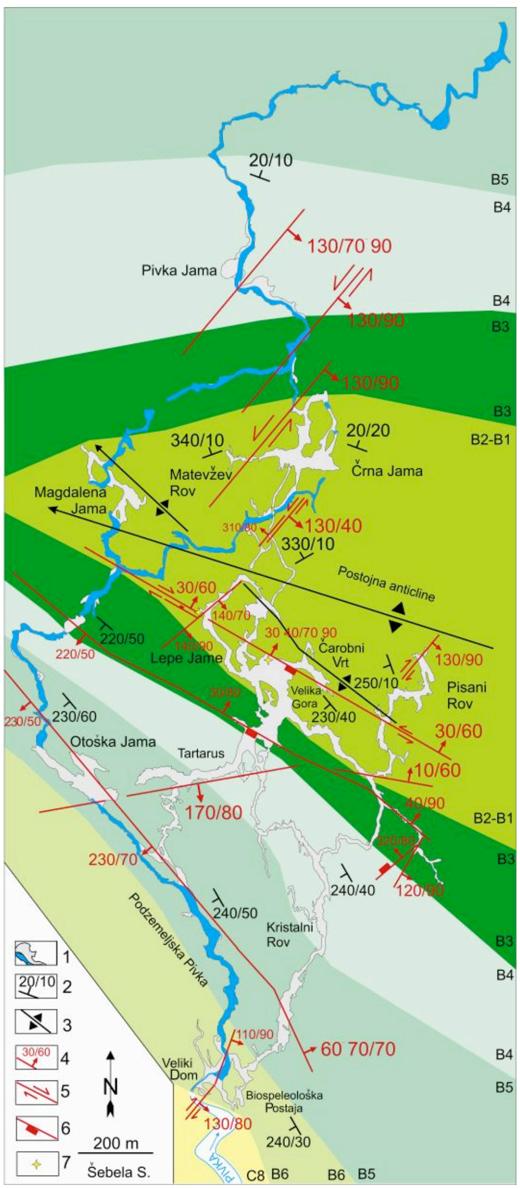


Fig 1. Geology of Postojna Cave System. 1-cave passage with underground River Pivka, 2-strike and dip direction of bedding plane, 3-anticline, 4-strike and dip direction of fault, 5-dextral horizontal movement, 6-vertical movement, subsidence of SW block.
B1 – thin-bedded Cretaceous limestone (165 m), B2 – thick-bedded Cretaceous limestone (50 m), B3 - very thick-bedded Cretaceous limestone with *Chondrodonta* horizon (up to 110 m), B4 - thick-bedded Cretaceous limestone with rudists (290 m), B5 - very thick-bedded Cretaceous limestone with rudists (420 m), B6 – thick-bedded Cretaceous limestone (130 m), C8 – Eocene flysch.

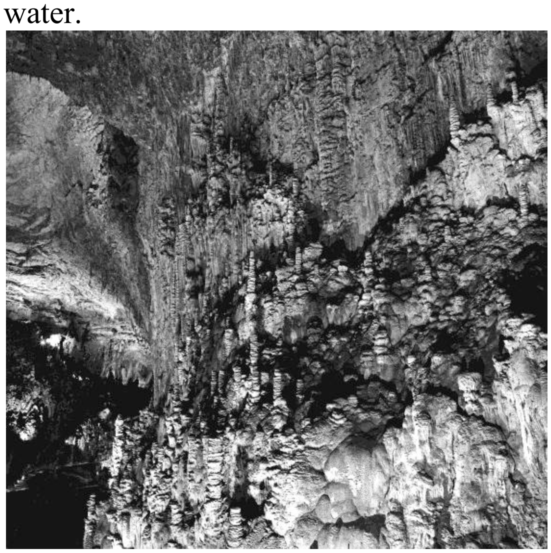
THE *GROTTA GIGANTE* (ITALY) AS A TOURIST AND SCIENTIFIC CENTRE

Alessio Fabbricatore & Donatella Cergna
Grotta Gigante S.A.G./Velika jama v Briščikih, Italy

The *Grotta Gigante*, located in the heart of the Karst area, the cradle of world-wide sports and scientific speleology, is the only show cave in the province of Trieste and with its 75,000 annual visitors, is the second tourist centre in the province of Trieste and one of the first ones in the Friuli Venezia Giulia region.

The access to the cave is inside the modern *Visitors Reception Centre*, inaugurated in 2005, where you can also find rooms hosting natural history exhibitions. Impressive staircases lead visitors inside a natural gallery down to 101 m under the surface to discover a huge cave, which is 98.50 m in height, 167.60 m in length and 76.30 m in width. The beauty of the path is enhanced by the presence of magnificent concretions (the best-known are the *Colonna Ruggero*, 12 m high and with a diameter at the base of 4 m, and the *Palma*) and charming colours (white and grey tones due to calcite and ample reddish nuances due to iron oxides).

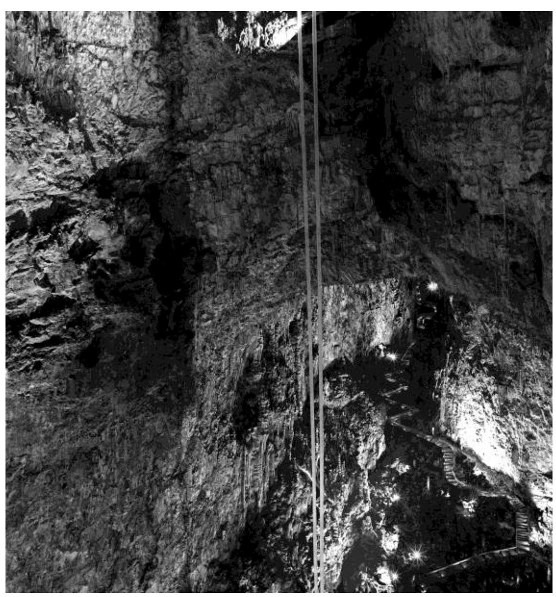
The cave, formed by the ancient work of extinct underground rivers, was explored in 1840 by Alfred Friedrich Lindner, who was searching for the underground water of the Trieste Karst for the water supply of the town, whose population had greatly increased under the Habsburg Empire. Here, the Austrians started the first important studies on Karstification on an international level: that is why the science that studies the interaction between water and limestone rocks is known as *Karst* all over the world, since it began on the Trieste Karst during the search for underground water.



The *Grotta Gigante* was opened to the public in 1908 and is now run by the *Società Alpina delle Giulie - sezione di Trieste del Club Alpino Italiano* (Julian Alpine Association – section of Trieste of the Italian Alpine Club). In the last few years a lot of effort has gone into leading the cave's offer to a level of excellence: in 1997 a path was built enabling the use of the original, natural entrance (used by the first explorers in 1840) as the exit; in 2005 works for the construction of the above-mentioned visitors centre (where the museum, multimedia room, educational and laboratory space and ticket office can be found) were completed and at the end of 2009 the new lighting system was inaugurated, which was carried out following rigorous eco-friendly, energysaving standards. In the *Visitors Reception Centre* you can visit for free a museum hosting natural, archaeological and palaeontological finds and documentation concerning current scientific research conducted in the *Grotta Gigante.*

School groups visiting the *Grotta Gigante* are offered both a traditional guided tour and workshops on specific themes concerning Karst cave: a specialised guide will accompany the groups on the tour, introducing school children and students to the underground world of Karst cave, of which the Grotta Gigante is a magnificent example. Students will therefore have the chance to discover how the Karst massif and its complex system of caves were formed, how stalactites and stalagmites grow, how scientists use *the Grotta Gigante* to study the movements of the Earth's crust, how speleologists look for and discover new caves, etc. Information is adapted according to the level of the students, from pre-school up to University. Almost half of the 75,000 annual visitors consist of students from schools of all kinds and levels, from preschool to university, for whom special educational programmes have been conceived in order to make the most of their visit to the *Grotta Gigante*.

The *Grotta Gigante* is a very important centre of scientific research. Inside the cave, *pendulums,* i.e. sensitive instruments able to detect the movements of the earth's crust, were installed. The *pendulums* provide a unique historical series of continuous measurements of the deformation of the Earth's crust. These measurements are carried out by *Department of Mathematics and Geosciences of the University of Trieste* and the *National Institute of Geophysics and Volcanology*. Inside the cave you can also find the digital, broad band *Seismographic Station* run by the *National Institute of Oceanography and Experimental Geophysics* and the *Department of Mathematics and Geosciences of the University of Trieste*, thanks to a cooperation agreement. The Geophysics Station is also equipped with two clinometers, which monitor the rotation movements of the cave on the horizontal plane.



Outside *Grotta Gigante,* in the surrounding green area, you can find:
a) the *Climatological Observatory of the Karst*, which has been operating since 1966, is part of the regional meteorological network of Friuli Venezia Giulia and the Trans-European network.

The traditional mechanical instruments have been complemented by a new-generation, electronic meteorological station equipped with GPRS data transmission and real time data display on the Web and on the maxi screen in the waiting room of the *Visitors reception centre*.

b) the *Epigean station for the measurement of karstic dissolution*, which has been operating since 1979, investigates the extent of the lowering of limestone rock surfaces due to meteoric water. Measurements are taken in accordance with the *Department of Mathematics and Geosciences of the University of Trieste.*

It is also worth mentioning:

- the studies concerning the radiography, by means of cosmic rays, for the *Chooz experiment,* which enabled to carry out a *Muon radiography* of the *Grotta Gigante,* i.e. the reconstruction of the shape of the cave's vault from the measurements of the flow of cosmic rays coming from various directions, which were compared with available geological data. The radiography was carried out thanks to the collaboration between the *National Institute of Oceanography and Experimental Geophysics* (OGS) and the *National Institute of Nuclear Physics*.
- the archaeological studies, carried out by the *Regional Direction for Cultural Heritage and Landscape of Friuli Venezia Giulia, Superintendence for Archaeological Heritage Friuli Venezia Giulia* and by the *Department of Humanities - University of Trieste*, which show that the cave was used from the Neolithic Age to the Early or Middle Bronze Age;
- the palaeontological studies carried out by the *Natural History Museum* of Trieste;
- the biology stations: underground fauna and flora, i.e. *Lampenflora*. The presence of the *Lampenflora*, which represents an alteration in the fragile underground environment, is continuously studied and monitored thanks to the collaboration with Department *of Life Science* of the *University of Trieste*;
- the laser scanner survey carried out in 2011, which enabled to obtain the actual measures of the cave, with a very high degree of precision, and to carry out a virtual, interactive video, which can be watched on a computer, for those who are physically unable to walk down the many steps of the tourist path. The video is also used during educational activities;
- the monitoring of radon. The *Regional agency for the protection of the environment*, with reference to the measurements of radon in the *Grotta Gigante*, in compliance with legislative decree no. 241/00, drew up the final technical report, which includes the results of the measurements taken on the tourist path. According to this report "the action level does not exceed the limits fixed by the above-mentioned decree";

The important combination of tourism and scientific research made it possible for the *Grotta Gigante* to be constantly monitored in order to ensure eco-compatibility between the flow of tourists and the delicate underground environment of the cave. The Grotta Gigante is therefore the ideal place both for families and schools and for all those who wish to learn and have fun, while visiting an unusual and fascinating environment.

Access and timetable:

The cave is open all year round. The tour of the cave, which lasts one hour, is on foot and accompanied by specialised guides.

Location: the cave is only 20 minutes away from the town of Trieste and 5 minutes away from the *Sgonico* motorway exit (for those coming from Venice/Udine) and the *Prosecco* motorway exit (for those coming from Trieste/Ljubljana/Croatia).

More information on the website: www.grottagigante.it or write to info@grottagigante.it

ABSTRACTS

Scientific research in show caves: a French overview

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Ca. 100 caves and shafts in France are visited by tourists: some of them have a long past of tourism activity, other are more recently arranged, but many karst scientists have worked and still work in these caves. International Congress in Škocjan will give a good opportunity to deliver an overview of scientific research in French show caves.

These caves are opened in various karstic places: low plateaux of west France, mountain plateaux of Grands Causses and Jura, Alpine and Pyrenean karsts even if high altitude shows caves are not current. Consequently, researches leaded in caves are various, and deal with prehistoric archaeology, hydrogeology, speleogenesis, speleothems studies, underground climatology and so on… Some of the observations are one-shot, other take part in research programmes during several years, and sometimes more. Some of researches are directly linked with tourism activity (for example, atmospheric monitoring or studies about safety for visitors exposed to flood) others use facilities furnished by the show cave (electricity power, accessibility, help by tourist staff…) even when researches are made beyond the touristic galleries.

This contribution will be based on an exhaustive investigation among cave managers and among French (or working in France) karst scientists. The aim is to offer a wide overview on the past ten-year research in show caves, focusing on interests and limits of such a science activity.

"E-learning" lectures for setting up a modern DTN communications based cave micrometeorological stations, example of Postojna Cave, Slovenia

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Under the frame of Slovene national applicative project L6-2156 (C) "Measurements and analysis of selected climate parameters in karst caves – Postojna cave example" managed by prof. Tadej Slabe MEIS researchers in cooperation with Karst Research Institute ZRC SAZU from Postojna have installed a modern cave environmental information system. The system consists of 4 micrometeorological stations with basic meteorological measurements and measurements of CO_2. All the stations are automatic, operating 24/365, two of them are mobile and autonomous. Data transfer can be done manually or using DTN (Delay and disruption tolerant networking) Internet protocol. Data are elaborated in test bed environment based on SQL connectivity data base.

Within the framework of European Leonardo life-long learning project » eLearning-DTN« MEIS researchers prepared a set of lectures (Video, PPT, documents, ...) – an eLearning course, that presented to interested audience the whole process of setting up and maintenance of a modern DTN based cave micrometeorological station. The course will be publicly available.

Recording the music generated by the Earth with the Grotta Gigante pendulums

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The Grotta Gigante houses a geodetic station since 1959, which has the goal to observe deformation of the cave. The instrumentation consists of two ultra-broad-band pendulum type tiltmeters, and two medium-to-long period tiltmeters, next to environmental parameters as temperature and atmospheric pressure. The exceptionally long and continuous time-series of the tiltmeters allow us to demonstrate the existence of several astonishing phenomena that cause the cave to change continuously shape, also if only to a small amount, which can be recorded only with sophisticated instruments, as are the ones installed. The movements due to the different causes sum up to produce the complete observed signal and our goal is to separate and identify the different phenomena. The work we do in identifying the different agents can be compared to a music lover listening to a symphony-concert, and amusing himself by identifying the melody of the first violin, flute, triangle, the violoncello and the double base, and then identifying the corresponding musicians and instruments on stage. As the music has high and low tones, the deformation of the cave is composed of slow and fast movements, continuous movements, or abrupt, sudden events that repeat very rarely. In this work we will start with showing the observation sequence of tilt for the time interval 1966-2012, and identify the deformation due to the following causes: temperature, underground water-level, sea level of the Adriatic sea, position of sun and moon and vibration of the Earth due to three of the 5 greatest mega-earthquakes ever recorded (Sumatra-Andaman Islands, Chile, Japan). The results show an excellent example of scientifically sound and important instrumentation installed in a show-cave visited regularly by the public.

Ground Penetrating Radar survey at Santa Croce Cave (Bisceglie – Italy)

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We show the results of a Ground Penetrating Radar (GPR) survey carried out above Santa Croce Cave, aiming at locating other cavities in the area near the main extant cave. The cave is a large karst cavity (more than 100 m long and 6-7 m wide and high) and is remarkable from both a speleological and archaeological point of view. Here a femur of Neanderthal Man (more than 50,000 years B.P.) and an imprint of a Neolithic mat (6,560±50 years B.P.) were found. The GPR investigation was performed through profiles, for a total length of 2,000 m, on an area of 7,000 m^2, located on either side of the known cave. Since the ceiling of the cave is deep about 15-20 m from ground level, which is a lot for radar methods, we used a low frequency system with 50

MHz antennas and an advanced data processing system. As a matter of fact, the collected data were processed with both 2D and 3D analysis. The main processing of the radar sections, able to detect reflections from any cavity, was performed by frequency and F-K filtering, background subtraction and migration. For a 3D visualization, the amplitude of the radar signals was analyzed by time slice maps. Some high amplitude radar reflections came out around the cave, at a different level. We think these could turn out to be cavities. One of the cavity is connected to a karst tunnel, filled with red clays and branching out from the cave. It was successfully excavated for 50 m and is a new tourist's attraction now.

Bryophytes and ferns of lampenflora in Grotta Gigante (NE Italy)

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Lampenflora consists of phototrophic organisms, which grow near artificial light sources in show caves; these communities represent an alteration of the underground environment and may cause damages both to speleothems and cave fauna. A floristic research on the bryophytes and ferns (land plant) of lampenflora of Grotta Gigante ("Giant Cave", Trieste, NE Italy) was carried out in 2012. 26 sites near artificial lights of different kinds were sampled in the show cave, for a total of 50 floristic releves. 16 moss species and 2 ferns were found; no liverworts were observed. The most common and widespread mosses are *Eucladium verticillatum, Fissidens bryoides, Oxyrrhynchium schleicheri* and *Rhynchostegiella tenella;* 7 moss species were found only in one to two sampling sites. The fern *Asplenium trichomanes* is common, with well-developed individuals growing in highly illuminated sites with dripping water; *Asplenium scolopendrium* in development in one site is a new record for the lampenflora of the cave. Some moss species belong to the flora of natural cave entrances of the Italian Karst, while others are typical of disturbed and open habitats. The main stalagmites of the cave are colonized by *Eucladium verticillatum*. Small, scattered individuals of 4 moss species and *Asplenium trichomanes* were observed growing around some LED lamps installed in 2009 along the cave's pathways. In the artificial tunnel opened to public in 1996 lampenflora is colonizing the walls around the fluorescent lamps fitted in 2009, with 7 species of mosses and small plants of *Asplenium trichomanes.*

Thanks to the long history as a show cave, the absence of chemical treatments to control lampenflora growth and the possibility to date new installation of several lamps, Grotta Gigante represents an interesting case-study of lampenflora.

Impacts of Visitors on Cave's Physical Environment

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Studies of impacts on caves usually cover the topics of water pollution, microclimate, lampenflora and cave biota. On the other hand there is a much more important influence on the

morphology of the cave directly from visitors, such as footprints, soiled and broken formations, graffiti, etc. They accumulate in caves and reduce their scientific (i.e. they “erase” important information on the development of caves and the surface above) and aesthetic values.
The most significant impacts are off-trail footprints – trodden fine sediments, destroyed gours and cave pearls; graffiti and broken formations. In show caves, infrastructure causes the most significant and visible impacts, followed by the impacts of cave maintenance (off-trail footprints, broken formations, etc.). Infrastructure for mass visits of caves must comply with regulations on the safety of visitors, but these regulations often require interventions in caves that cause harm on their inventory.

The Karst Meteo-Climatological Observatory, a scientific facility within the Grotta Gigante show cave centre (Italy)

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The Karst Meteo-Climatological Observatory is situated in the same place as the historic headquarters of the Borgo Grotta Gigante Meteorological Office, which was set up in 1966 and started operating on January 1st, 1967. The meteorological facilities and the weather office are located on the premises of the Grotta Gigante visitors centre. In 2008 an Automatic Weather Station (AWS) was set up in order to work in parallel with the traditional-analogical instrumentation. In 2010, in the lower part of the main cavern (Grande Sala), a temperature probe was installed to monitor the microclimatic condition in this sector of the cave every 5 minutes. All the AWS data are available to the public both in the waiting room near the cave entrance and on the web. One of the main characteristics of the Observatory, mainly for educational reasons, is that of having both the traditional, mechanical-analogical part of the data collection carried out by observers and electronic sensors. This factor is essential to ensure continuity and homogeneity of the historical data series collected to date and distinguishes the observatory from a normal weather station. The data collected are published in *Osservazioni Meteoriche* (*Meteoric Observations*), a magazine edited by Grotta Gigante as a supplement to scientific journal *Atti e memorie* (*Acts and Memoirs*) of the *E. Boegan Cave Commission*. The synergistic cooperation of various scientific organisations involved in climatic research made it possible to carry out this project. The organisations involved are: the *Società Alpina delle Giulie*, the *E.Boegan Cave Commission*, as well as the *Friuli Venezia-Giulia Regional Meteorological Observatory*, part of the *Regional Agency for Environmental Protection* (ARPA), the *Institute of Marine Sciences* of Trieste (ISMAR), part of the *National Research Council of Italy* (CNR), the *Friuli Venezia Giulia Meteorological Union* (UMFVG), the *Environmental and Public Works Section* and the *Water Service* of the Friuli Venezia Giulia Region. After 46 years of continuous and homogeneous measurements, the Borgo Grotta Gigante dataset provides the longest and most continuous climatological record of the Italian Karst area.

Seismic noise and temporary seismological measurements in the Postojna Cave System

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In Grotta Gigante and Grotta di Villanova caves in Northeast Italy seismological measurements have been regularly performed since a number of years. Karst caves are suitable places for such studies because they are situated under the surface where generally seismic noise is lower than at locations on the surface. The idea to establish the first underground seismological station in Slovenia has thus led us to make preliminary seismic noise measurements in Črna Jama (northern part of the Postojna Cave System) in 2007. In search for further suitable stable places within the cave, we next performed seismic noise measurements, followed by a temporary accelerograph installation, near the highest point of the Velika Gora chamber in the first half of 2010. Since May 7, 2010, the seismic station is located inside an about 9 m long artificial tunnel that was built for geophysical measurement purposes in Tartarus passage in 1931. Horizontal pendulums with photographic registration for detection of minimal variations of the vertical direction were installed in the tunnel in 1932 and removed before the 2nd World War.

From January 27 to February 12, 2010, the seismological station in Postojna Cave System (VGPJ) recorded 79 earthquakes with epicenters near Postojna. Data were especially important to determine the seismological characteristics of the $M_{LV}=3.7$ Postojna earthquake (15 January 2010) swarm sequence. The station in the tunnel (TTPJ) operated till the end of 2010 and recorded more than hundred earthquakes of the sequence near Ilirska Bistrica that started on September 15, 2010, with two $M_{LV}=3.5$ earthquakes and lasted till the end of the year 2010.

The final aim of this study is the installation of a permanent seismic station inside the Postojna Cave System and its future integration, with real-time seismological data acquisition, into the Slovenian and Italian seismological networks.

Grotta Gigante: a multidisciplinary underground laboratory for the Earth Science studies

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The Grotta Gigante (Italy) is one of the most interesting and important tourist caves in Italy open to the public since 1908. It is located in the Classical Karst and it was discovered in 1840 by Antonio Federico Lindner, a mining engineer who in the early XIX century became involved in the research of the underground course of the river Timavo. The cave consists of a large room 167 meters long, 76 meters wide and 98 meters high with a total volume of over 365.000 cubic meters.

The morphology, the central location within the Classical Karst and the possibility to access it with ease, have encouraged the use of the cavity also as a scientific laboratory and a point of reference in Earth Science studies. Today the cave hosts two horizontal geodetic pendulums, two clinometers, an I.N.O.G.S. seismology station, some stations that measure the intensity of karst leaching and dissolution through TMEM, some continuous sensors for Radon.

Recent explorations have discovered a series of wells, which allow the cave to reach an altitude of 18 meters above sea level, for a total depth of 252 meters. Thanks to the efforts of the CGEB - S.A.G. Trieste cavers during several years of excavation, a new frontier of study has opened for Grotta Gigante and all the Classic Karst. The new bottom consists of a wide well intercepting a tunnel near the base level, along which there are visible signs of rising groundwater. In order to quantify these hydrological signals, at the end of December 2009 the Department of Mathematics and Geosciences of the University of Trieste has installed a Diver - CTD for the continuous measuring of the water level, conductivity and temperature. This new station integrates the extensive Karst groundwater monitoring network managed by the University of Trieste and will permit to implement the knowledge of the Classical Karst hydrodynamic circuits.

Proposal for the "Heaven's cave" (Phong Nha-Ke Bang national park, Vietnam) adaptation for tourist purposes

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Heaven's cave is located in the centre of the Phong Nha-Ke Bang national park. National park is protected also as a UNESCO world heritage site. Due to economic situation in this region as a result of lack of natural resources, karst tourism represents an important opportunity for raising the quality of living in the province. A proposal to adapt non touristic Heaven's cave for tourism was presented to Karst Research Institute at ZRC SAZU.

The first task was to measure the cave in order to establish its ground plan, longitudinal profile and significant cross-sections. At the same time a speleological evaluation of the cave is being carried out, in other words a description of the current state as regards geology, geomorphology, hydrology, meteorology, speleobiology, archaeology and paleontology. The description of the current state includes a photographic inventory of significant elements of the cave. On the basis of characteristics of the cave, the risks to and vulnerability of the cave is defined and fundamental nature protection guidelines highlighted. The second part of the research presents a range of identified tourist attractions with a proposal of access to them (type and route of path for tourists) and a proposal of illumination. Use of the cave as a show cave must correspond of sustainable nature protection guidelines, since only in this way can we maintain the cave in its-natural equilibrium. Access to the cave is very important. This is based on the proposed use of the cave as a show cave (number and type of visitors), the carrying capacity of the external environment and UNESCO guidelines.

Environmental monitoring and radiation protection in Škocjan caves, Slovenia

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Škocjan Caves were listed as UNESCO World Heritage Sites in 1986, due to their exceptional significance for cultural and natural heritage.

Park Škocjan Caves is located in South Western part of Slovenia. It was established with the aim of conserving and protecting exceptional geomorphological, geological and hydrological outstanding features, rare and endangered plant and animal species, paleontological and archaeological sites, ethnological and architectural characteristics and cultural landscape and for the purpose of ensuring opportunities for suitable development, by the National Assembly of the Republic of Slovenia in 1996.

Park Škocjan Caves established monitoring that includes cave microclimate parameters: humidity, CO_2, wind flow and radon concentration and daughter products. Some results will be present in order to establish carrying capacity and to present microclimatic conditions of the caves. Quality of air measurements will be presented as well.

Monitoring of Radon has been functioning for more than ten years now. Presentation will show the dynamics observed in the different parts of the caves, related to radon daughter products and other microclimatic data. Relation of background radiation to carrying capacity will be explained.

Implementing the Slovene legislation in the field of radiation protection, we are obligated to perform special measurements in the caves and also having our guides and workers in the caves regularly examined according to established procedure. The medical exams are performed at Institution of Occupational Safety, Ljubljana in order to monitor the influence of Radon to the workers in the cave. The equivalent dose for each employed person is also established on regular basis and it is part of medical survey of workers in the caves. A system of education of the staff working in the caves in the field of radiation protection will be presented as well.

Integrated geophysical and remote sensing studies on Grotta Gigante show cave (Trieste Italy)

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The Grotta Gigante show cave (Trieste, Italy) has been intensively used not only for touristic purposes but also for scientific research and applications. In this paper we illustrate the most recent integrated studies that have been conducted on this site and in the particular results from a series of remote sensing and geophysical campaigns. This project has been developed in a strong integration between the SAG (Società Apina delle Giulie) owner and manager body of this tourist attraction and OGS (National Institute for Oceanography and Applied Geophysics). Therefore in this paper we will describe the results of airborne and terrestrial laser scanning integration surveys, which have allowed to reconstruct dimensionally the cave and its surroundings with a very high detail; the results of an extensive 3D photographic survey that enable us to integrate the laser scanning measurement with the radiometric (colour) information of the measured points, this information will form the be the base of a future data integration that will allow to generate a full 3D virtual reality model of the entire cave itself. In addition to these we will describe the results of very high resolution gravity survey that enable us to define potentiality and limits of this methodology in cave “spotting”. Grotta Gigante again has been demonstrated to be optimal ground for geophysical methods calibration and exploitation. We believe that what has been focussed on Grotta Gigante can be repeated on different show cave sites to better increase the knowledge of such interest sites.

MEM and TMEM measurements inside and close to the Grotta Gigante (Italy)

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It has been suggested that MEM and TMEM are very useful to study limestone erosion and surface change rates. In the Classical Karst around the city of Trieste and near the Grotta Gigante, a number of micro erosion meter stations have been set in 1979. Erosion rates have been regularly collected since that date in correspondence of limestone surfaces located close to the entrance of the cave. Beside stations located outside the cave, other stations have been set inside it, in order to measure the rising of stalagmites. Moreover, at the mid of the eighties, 20 limestone, dolostone and gypsum samples have been collected all over Italy. They have been located outside the cave, in order to compare different weathering degrees and observe their erosion rates in the same climatic setting. Nowadays, the Grotta Gigante MEM dataset is the longest in the world.

During the last decade, a number of more stations have been set in particular environmental settings or to investigate lichens weathering. In particular, 3 stations have been set to study limestone erosion rates on vertical walls inside the cave, while 9 stations concern the study of lichens erosion. The latter are part of a network of more than a hundred of stations all over Italy, while more than 500 stations are widespread all over the Mediterranean area.

Data indicate mean erosion rates ranging from 0.01 mm/yr to 0.05 mm/yr for limestone and up to 1 mm/yr for gypsum. Erosion rates vary depending on the type of rock and the location. Stations located on lichens show a marked variability probably related to the occurrence of rainfalls and to night and day variation in humidity.

Relevance and measurements of selected physical quantities representing cave environment: examples from Postojna cave and Škocjan cave (Slovenia)

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Caves are unique and vulnerable environment. Show caves are among those with the highest exposure to human influence. In this work we focus on a physical environment of caves and present monitoring and role of some of its basic quantities. Neglecting darkness and (once enlightened) visual factors, it is the cave atmosphere, which we feel most intensely. Its state is indicative of cave's environment. Air temperature is the most commonly measured quantity. It is nowadays measured by the platinum resistance thermometers (e.g. Pt100) with data loggers. The accuracy in cave monitoring should be 0.15 K or higher. Precise and long term temperature records in caves have demonstrated that cave atmosphere is much more dynamic than previously considered. Movement of air in caves is important process for the advection of heat and mass. Ultrasonic anemometers have proven to be most useful for its measurement. They have become widely available and affordable. They are robust with no moving parts and can be readily connected to data loggers. They measure wind speed and direction in 2D or 3D. Caves are humid environment. In moderate climate the relative humidity of cave air is usually close equilibrium. Measurement of humidity in potentially condensing environment is a difficult task. Due to large hysteresis, regular humidity sensors are mostly useless in caves. Child mirror hygrometers are most precise, but expensive and probably not robust enough for the use in caves. Warmed probe technology is a compromise. CO_2 plays important role in dissolution/precipitation processes. Presence or absence of different sources and advective transport makes CO_2 in caves one of the most variable parameter. Tourist potentially present important additional source of CO_2, however, their presence is mostly unlikely to influence the natural precipitation and dissolution processes. CO_2 in cave atmosphere is now measured by Nondispersive Infrared CO_2 sensors, which measure absorption of infrared light by the CO_2. In Postojna cave a meteorological monitoring of the above parameters has been established. We present some of the results and discuss their importance. Many caves are part of the main water pathways through the karst aquifers. In Slovenia, two most important show caves are ponors of the regional rivers with extreme and vigorous variations of discharge. Extreme floods present risk to the infrastructure in both. Continuous monitoring of water levels has enabled us to understand the mechanisms of flood propagation in Postojna cave and Škocjan cave and determine the reasons for flooding in these caves.

Natural radioactivity study in Bossea cave system (Italy): radon exchange dynamics between bedrock, waters and atmosphere in underground environment

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The Underground Karst Laboratory of Bossea Cave from 1994 carries out a research on natural radioactivity in underground environment, which implies the study of radioisotope concentration in the rocks bounding Bossea cave system and emission and diffusion process of radon gas in the cave.

In year 2010 started an avant-garde study on radon exchange dynamics between bedrock, waters and atmosphere inside cave system, founded on innovative instrumentation for radon continuous measurement in water, supplied as prototype from producing firm. The new interesting knowledge about radon transfer from emitting rocks to collector’s running waters in submerged zone of cave system was achieved, following radon exchange from collector waters to cave atmosphere.

Similar process has been established in smaller drainage deriving from percolating waters. In both cases clear correlations between the flow increases of cave system collector and the increases of radon transfer from emitting rocks to waters was checked.

Radon as a tracer of cave ventilation and health hazard – the case of the Postojna Cave

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Research of radon (^{222}Rn, $t_{1/2}$=3.82 days) in karst caves has two main aspects. The first is the aspect of radiation protection connected to high radon levels. Due to high relative humidity and low air circulation, the cave air is characterised by very low particle concentration, which plays an important role in radon dosimetry. The second aspect is connected to cave climate studies, in which radon has often been used as an excellent tracer for air circulation, since it is a noble gas and highly abundant in caves.

During the last two years, radon concentration was measured continuously at four locations in the Postojna Cave in order to determine spatial and temporal variations of radon concentration and thus its ventilation characteristic. Parallel monitoring of radioactive aerosols of radon decay products (RnDP) and general (non-radioactive) aerosols in the particle size range of 10–1100 nm was performed in the air of Postojna Cave at the lowest point of the tourist path in order to improve the methodology for dose assessment, focusing on the unattached fraction of RnDP (f^{un}). Results of calculated dose conversion factors (DCF), taking into account f^{un} (using Porstendörfer approach), are much higher than recommended values, and differ significantly for summer and winter period.

Karst Hydrology Research in Show Caves of the Mammoth Cave International Biosphere Reserve, Kentucky USA

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The lower Carboniferous limestones of south-central Kentucky contain one of the world's great karst regions with over 1,000 kilometers of explored and surveyed cave passages in a four county area including the Mammoth Cave System (630+ km), the world's longest known cave. The area has been designated as a US national park, and by UNESCO as both a World Heritage Site and International Biosphere Reserve. Many public and privately managed show caves are here, providing excellent sites for cave related hydrologic, biological, and resource management research activities. For several decades karst hydrology research has been conducted by scientists and students from Western Kentucky University in collaboration with several area tour caves. In Mammoth Cave projects have studied hydrology, geochemistry and water quality in the Logsdon River through a set of 145 m deep wells the bottoms of which can be reached in the cave for instrumentation, at Edna's Dome along the cave's "Wild Cave Tour," and in the Historic Section of the cave. Epikarst hydrology and impacts of agriculture have been the focus at Crumps Cave (Cave Spring Caverns), and we are now developing a reference site at Lost River Cave for a global monitoring network to study landscape/atmosphere CO_2 interactions.

3D laserscanning and geomorphological studies in Orgnac cave **(Ardèche, France)**

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Recent laserscanning techniques can revisit the geomorphological analysis methods traditionally used in caves. Indeed, laser scanning offers very high resolution topography. Very large point clouds are acquired and after consolidation, meshing and processing, analyzes on the 3D models can be performed. This type of approach is particularly interesting in cavities where size or conservation issues are important. This is the case of Orgnac, a major French tourist cavity, the only cave ranked "Grand Site de France".

Three examples of 3D geomorphology studies illustrate here the relevance of this approach. (1) The gigantic underground volumes did not allow direct observation of all parietal morphologies. A 3D reconstruction of the «Salles rouges» chamber permits the identification of bench-marks on the 3D model. These works give us a reconstitution of the sedimentary aggradations during Pliocene. (2) A forest of stalagmites tilted was protected for conservation reasons and access restrictions. Again the construction of a 3D model and some informatics developments gave us automatic mapping to study in their environment the geometrical characteristics of 140 stalagmites. Finally (3), a detrital fan is currently being excavated for archaeological studies. This excavation destroys irreparably a side of this unique underground archive. Site supervision by LIDAR offers at each stage of the search, a topography, which is a very fine memory of the deposit. In addition, 3D reconstruction and analysis of sedimentary structures provides information about its genesis.

Through the diversity of these three examples, we measure the value of this type of analysis on 3D model to better understand underground morphologies. The implementation of this approach in tourist cave also offers an additional opportunity: the scientific mediation to the public, eager for this type of 3D production with many possibilities of representation.

Scientific researchs in Orda and Kungur Ice Caves

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The Kungur Ice Cave drew attention of numerous researchers from XVII century. In 1948 the karst and speleological station was organized. Researchers started to observe the cave systematically as well as study karst processes in the Ural territory. 100-year anniversary of scientific and excursion activity in the Kungur Ice Cave will be in May, 2014. Today the Kungur Ice Cave is one of the few caves in the world and unique in Russia in which for 60 years complex scientific supervisions are carried out.

Studying of the Orda Cave began in March of 1994 after opening of its underwater part. Today it is the most extended underwater cave of the world in sulphate deposits. Research team together with speleodivers developed a special technique of underwater karst researches. Studying of the Orda Cave included a complex of researches under water and on an earth surface. Under water it was groundwater flow observation, photography, camera shooting and also water, rocks and bottom sediments sampling. Studying of karst forms, hydrochemical sampling of surface water etc. was carried out at the surface. Further the Orda Cave at the organization of continuous supervision in an underwater part can become the interesting range for further karst processes studying.

The structural, textural and mineralogical rocks characteristic in the Kungur Ice Cave and their transformation at karstification

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The Kungur Ice Cave is created in the interlaid karst carbonate and sulphate rock mass of Ledyanaya Gora upland. Section studying in the grottoes allowed to reveal two stages defining structural and textural rock features, they are sedimentary and diagenetic and also hypergene ones. The rhythmic interlayering of carbonate and sulphate deposits testifies to alternation of period interchange of increase and decrease of water mineralization in evaporate basin. There was dolomite precipitation at decrease of a water mineralization and inversely – sulphate deposits. The main hypergene processes were anhydrite hydration and subsequent gypsum dissolution. These processes were followed by the carbonate rock changing such as a desalination, recrystallization and reprecipitation of material. Freedom from impurities in carbonate minerals, fluorite and manganese oxy hydroxides presence testifies their formation in low temperature and oxidizing conditions at the expense of a hypergene reaggregation of initial carbonate rock elements.

It is supposed that the calcareous components desalination from dolomite layers and gypsum dissolution along intergranular boundaries on sites of a high fracturing of carbonate-sulphate layers led to organ pipes formation and filling of subjacent cavities by collapse-breccia. Such nature is supposed for dolomite and gypsum breccias in the Morskoe Dno Grotto and transition from the Ruins Grotto to the Corallovy Grotto. Possibly such rocks mark cavities position of the Great-Kungur Cave.

Significance of water research in show caves

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In karst caves water drips from the cave ceiling and in the majority of cases deposits calcium carbonate, which builds calcite decorations. Continuous measurements of precipitation on the surface, which then flows through the cave ceiling (vadose zone), and measurements of physical parameters of dripping in the cave provide us with the dynamics of flow through the vadose zone. In Postojna Cave, Slovenia, 100 metres below the surface, continuous measurements of flows, temperature and electrical conductivity have been taking place for 10 years, along with monitoring of the transfer of aftificial tracer which we injected on the surface in June 2002. Monitoring has also taken place of the calcium, magnesium and carbonates content of the dripping water and of the presence of selected contaminants (chlorides, nitrates, sulphates and phosphates). The measurements have provided the dynamics of flow in relation to precipitation and conditions in the soil and the vadose zone, which has significant storage effects. They have also shown that the transfer of contaminants are directly linked to flow dynamics. Watercourses drain into ponor caves from inhabited karst or non-karst areas and thus result in the introduction of pollution to the underground. Detailed monitoring of two flood pulses of the Reka upstream of the ponor has provided the basic characteristics of the transport of contaminants through the Škocjan Caves.

Researches done in Show Caves - historical Overview

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A cursory examination of some important show caves of the World confirms that the research and the success of the show cave, meaning the number of tourists, presentation of a cave, conservation and preservation, are tightly connected. By research is meant the exploration (penetration into the cave, cave survey), the scientific research (natural properties as well as anthropogenic features and history), and monitoring. The first and the last are not “scientific research” in a proper sense, but they precede them (without basic data scientific research is impossible) or are the result of them. Monitoring, which is not based on data of scientific research is merely monitoring for itself. Scientific research may instigate other activities (education for example), which in turn can give an impulse to new or to deepened scientific work. It must not be forgotten that a support of show caves administration towards the scientific research is of great importance and can result in spectacular discoveries. In the presentation, each of these statements is illustrated by the examples of different well known show caves.

The solutions to prevent damages to the active part of Križna Jama show cave, Slovenia

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Detailed study of the limestone deposition of the cave stream in the Križna jama revealed that the growth of rimstone dams increases in the winter time when the air temperature at the surface is very low. Due to shorter and less severe winters in the last 10 years and increasing tourist visit to the cave, the damages to the rimstone dams made during the visit of the active part of the cave do not regenerate as successfully as they did in the past. Limited visit of the active part of the cave will help to preserve natural processes of deposition. Cave administrators are testing variety of protective materials to minimize damage to the most vulnerable sections of rimstone dams.

Microbiological parameters assist in evaluating human impact in show caves

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Today many caves are open for public display, but their opening often brings reversible and/or irreversible effects on the cave environment and cave-dwelling organisms. Different microbial indicators were used to evaluate human impact and some possible approaches were tested to remediate affected sites in Postojna Cave and Škocjan Caves, Slovenia. Human impacts related to tourist use in the underground include light eutrophication and lampenflora around lamps, microclimatic changes, and high organic load on various surfaces. As a response to lampenflora in caves and in order to reduce electricity consumption, cave management in many places have begun to install LED lamps; however, different emission spectra of LEDs do not have a major impact in lowering the biomass production of lampenflora. Lampenflora algae change the ratio of photosynthetic pigments, chlorophyll *a* : chlorophyll *b* : carotenoids as a response to altered emission spectra of LED lamps. Pigment composition reflects the macroscopic aspect of lampenflora as seen by human eyes.

Concentration of chlorophyll *a* in lampenflora alga *Chlorella vulgaris* was lower when a cool white LED was used as a light source (~1.7 mg/l), higher at yellow green and blue LEDs (2.6 mg/l), and the highest at a halogen lamp (4.3 mg/l). Lights change cave temperature and humidity, and depending on their position and the nature of illuminated objects, the objects can radiate heat and consequently elevate the temperature of the surrounding atmosphere even when lights are turned off. Surfaces with actively growing lampenflora and dead lampenflora incrusted with calcite were successfully remediated with a buffered solution of hydrogen peroxide. During visits, tourists introduce many culturable microorganisms, especially bacteria. A thousand tourists cumulatively elevated the basal bacterial counts from ~20 bacteria in a cubic metre of cave air up to several thousands (>2,500 bacterial colony-forming units/m^3). Tourists also introduce and spread microorganisms through footprints (>15,000 bacterial and fungal culturable counts per 100 cm^2). Touching of speleothems by tourists is another problem which is reflected in detection of culturable microorganisms of up to 1,500 per 100 cm^2. Show caves with mass tourism have a high input of human-related microorganisms on various surfaces and in the atmosphere. Presentation of delicate underground features to tourists, especially those prone to biodeterioration, such as paintings and inscriptions, should be carefully considered.

Geomorphology research in Jeita Cave, Lebanon: speleogenesis study for a scientific valorization of a touristic cave

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Jeita grotto is one of the longest caves in the Near-East region with more than 10,000 meters of underground network gallery. Situated 18 km north of Beirut, it holds the record of the longest stalactite in the world with 8.2 meters long. In 2011, Jeita cave was one of the 28st finalists for the selection of the new seven natural wonders of the world competition. It was the only cave site represented in this final short list. Adding to these points, the touristic value of this site that makes Jeita cave the first visited site in Lebanon: explored totally by Lebanese cavers in 1950's, it was opened to the public in 1958 and later on in 1969, after the discovery of the upper galleries. Jeita cave receives, in average, more than 280,000 visitors per year (Source: les sommets du tourisme, Chamonix, 2009). With all these natural and historical characteristics, most visitors do not know the scientific value of this site. Lack of visual and material information in the touristic path encourage the visitors to ask speleologists about the cave, when they are on site. One of these questions was about the genesis of the grotto: how this big underground canyon of 75 meters deep was formed? These informational requests encourage us to put up new challenges throughout our study on the cave geomorphology and speleogenesis.

Therefore, a research project on Lebanon's karst geomorphology was carry out since 2009, by Saint Joseph University of Beirut in collaboration with EDYTEM laboratory UMR 5204-CNRS, France. These studies aims at reconstruct: *i)* speleogenic evolution of caves based on geomorphologic indicators, *ii)* karstogenesis reconstitution related with the down-cutting of the Mediterranean hydrographic network (Antelias and Kelb river), *iii)* palaeogeographical reconstitution of these tow valleys. One of these caves was Jeita grotto located on the north side of Kelb river. We wanted to expose these results to the public concerning Jeita site, once the cave history uncovered.

Our work consists at reconstituting the downcutting stages of Jeita underground canyon according to the karst base level, which is the Kelb River. The methods used to our study were based on completing a high-resolution geomorphology map of the cave combined with detailed cross-sections of the canyon and retrace paleohydrological records from sediments sequence.

On one hand, six specific sites were selected and surveyed in the upper and lower galleries. The detailed map led us to complete an inventory of erosion processes (dissolution, fluvial, collapse) that participated in the cave formation. Adding to this method, 26 detailed cross-sections were completed and showed us the cave original morphology assigned to fluvial erosion of the underground river. While geomorphology map helped to understand the spatial distribution of deposits, cross-sections illustrated the erosion processes succession in the canyon and revealed common shapes and aspects on different sites. Combining these two methods has lead to reconstruct four stages of the Jeita canyon history based on a relative chronology approach.

On the other hand, two in-fillings sequences in both upper and lower galleries were completed. A grain-size analysis has revealed the deposit dynamics and the palaeoflows of the underground river such as velocity variations and flow directions. The paleohydrological records contributed at the comprehension of Jeita Underground River.

As these scientific results helped us to uncover the cave history, our suggestion is to respond on tourist's scientific curiosity by implementing educational boards in different locations, outside and inside Jeita cave. These backboards consist on showing specific cross-sections and exposing cave dimensions and its different genesis stages. A general scheme on Jeita canyon down-cutting compared to Kelb valley could be added next to one of the cave entrances.

Our duty as cavers and karst scientists is not only to gather data (through photos, maps and description…) on caves and publish them in our bulletins, but also to inform and instruct the public on the scientific value of Lebanon's underground natural heritage. Communicating science can be one of the best mean to preserve natural sites, such as Jeita cave.

Karst water course tracing between ponor and springs: the Reka river example, Kras/Carso, SW Slovenia-NE Italy

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The Reka River subterranean flow is about 35 kilometers long. The river sinks in the Kras aquifer in Škocjan Caves and reappears in the springs on the other side of Kras plateau in Italy. The subsurface flow of Reka River can be reached in five caves, three in Slovenia (Kačna jama Cave – Brezno 3G abyss system, Jama 1 v Kanjaducah Cave and Brezno v Stršinkni dolini abyss) and two in Italy (Labodnica/Grotta di Trebiciano and Čudovita jama Lazarja Jerka/Grotta meravigliosa di Lazzaro Jerko). Two of them, namely Škocjan Caves and Labodnica/Grotta di Trebiciano are also show caves.

The aim of this study was to prove a connection between some of above mentioned caves and to analyse the dynamics of water transport between the ponor and the springs of Reka River. For the tracing experiment uranine was used. It was injected in superficial stream of the Reka River close to Gornje Vreme, at the contact between flysch and carbonate rocks, about seven kilometers before Škocjan Caves at the altitude of about 330 m. At this point a solution of 5 kg of uranine in 15 l of water was injected on the 4th September 2006 at 10 a.m. The samples were taken in four caves and three springs - places where we expected tracer.

The weather in the autumn 2006 was relatively dry. During the tracing experiment two rain events occured (68.7 l/m^2 all together).

The tracer first arrival in Škocjan Caves is recorded about ten hours after the injection. Several peaks of uranine concentration curve in Škocjan Caves followed the rain events. In Kanjaduce Cave the fluorimeter was out of water due to severe drop of water level. The tracer concentration rose two days after the first rain event and after the second peak in Škocjan Caves, however the rise was small and only qualitative and speculative interpretation of Tracer Breakthrough Curve (TBC) was possible. Similar was the situation in Labodnica Cave where the tracer appeared at the same day as in Kanjaduce Cave. A small peak in the TBC could represent the arrival of the unranine few days after the rain event, however, the rise was small again and therefore questionable. Clear TBC at springs of Timava River revealed appearance of the tracer after a month, on 6th October. Aparent speed between the injection point by Gornje Vreme and the Timava spring was 51 m/h. The slowest known speed until this tracer experiment was 80 m/h (Kranjc, 1999).

The fluorimeter in Kačna jama did not record any data. During the tracing experiment we faced several problems, which diminished the quality of data. Observation stations with field flurometers were in remote parts of caves up to 340 m deep. Therefore the inspection and the maintainance were impossible during the experiment. We expected large fluctuations of water levels. Nevertheless we did not expect a substantional drop of level after fixing the fluorimeters. Yet the period appeared to be exceptionally dry and fluorimeters were part time out of the water, recording no data on tracer concentration.

Terrestrial fauna monitoring in the Postojnska Jama, Jama Pod Predjamskim Gradom and Škocjanske Jame – first results

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Postojnska Jama, Jama Pod Predjamskim Gradom and Škocjanske Jame are amongst the first touristic Show caves in the world. Besides by the tourists, these caves were visited by numerous naturalists and speleobiologists and are therefore faunistically relatively well investigated. Many subterranean taxa have type localities in these caves. Surprisingly enough, even today new cave animal species are occasionally found and described from these caves. Since they have been accessible to the visitors for a century, their impact on these cave fauna is to be expected. Postojnska Jama d.d. company and Park Škocjanske Jame started monitoring tourists' impacts on subterranean terrestrial fauna in Postojnska Jama and Jama Pod Predjamskim Gradom in 2009, as well as in Škocjanske Jame in 2011. In the paper we present the monitoring methodology and the first results obtained. The so far discovered terrestrial fauna in these caves is listed and an evaluation of the various human impacts to the fauna is presented.

Use of MEM for protection of karst caves – example from Križna Jama, Slovenia

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Križna Jama (Križna Cave) is well known show cave in Slovenia due to underground water flow and more than 44 underground lakes. Lakes are separated by sinter dams and the latter are the reason why the lakes have been formed most probably during Holocene. During long tourist visit, 10 sinter dams are crossed both ways and touristic use of cave, even with great caution, leads inevitably to the abrasion of sinter dams.

This is one of the reason that Mihevc started microerosion measurements (MEM) in 1994 downstream of the 1st lake. Nevertheless, this measurement places are away from touristic pathway and give only information on natural background (sinter deposition rate). Since 2006 we are aware that growth of sinter dams can be significantly lower upstream and therefore damage due to touristic use can be much higher. We still did not have any information what the abrasion rate is. This is the reason that we extended measurement places to the sinter dams between 3rd and 4th lake, 7th and 8th lake, and 9th and 10th lake. In addition to Mihevc's way of measurements, we established measurement places on touristic pathway and away from it, which allows comparison of natural sinter deposition with anthropogenic abrasion. Results confirmed

high vulnerability of sinter dams upstream of 4^{th} lake due to low sinter deposition rates. At distant measurement places (e.g., between 9^{th} and 10^{th} lake), abrasion rate on touristic pathway can be some tens of µm/a higher than natural growth rate. Especially vulnerable are sinter dams that are partly flooded – in such cases the natural growth rate is lower and erosion due to softer dam higher. Differences between individual years can be significant since annual sinter deposition rate highly depends on extremely low daily winter temperatures, when practically all sinter is deposited and hydrological situation during summer, when sinter dams are normally partly dissolved by flowing water.

Results of MEM measurements are useful and taken into account by the society that manages the cave (DLKJ). The society incorporates results into the strategy of cave visit and such relationship presents an outstanding example of very good cooperation between cave science and cave management. Similar cooperation is possible in caves where speleogenetic processes (sinter deposition or dissolution) are similarly low and therefore caves highly vulnerable.

Monitoring of touristic caves: Market analysis

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The present work is part of the European project Undersafe. The goal of this project is to develop a technical system specifically tailored for safety in Touristic Underground activities. In order to develop the project adequately to the needs of end-users, it was highly recommendable to conduct a market analysis. A survey was sent by mail and, so far, answered by more than fifty entities, from a total of about 380 tourist caves in the European Union. The survey was designed to be filled by means of short and quick answers. It consisted of several parts: Identification of contact details, activity data, describing their physical characteristics as well as visitors, Undersafe Project evaluation and a free space box for additional information that respondents could consider necessary. The survey was send by a Google Docs spreadsheet. This online application provided an easy way to answer the questions through an Internet link. This application allows repeated sendings of the email survey. The survey results have enabled us to gain a better understanding of the characteristics of the caves to monitor and take into account new factors to be monitored, and that had not previously been considered in the project, such as the control of radon levels in the caves.

Monitoring and analysis of cave **air temperature variations in Županova Jama show cave,** Central Slovenia

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On the basis of long term high resolution monitoring of the cave air temperature basic statistics and time series analysis have been employed to evaluate thermal states of the cave atmosphere variations. Since 2009 a network of six locations has been established in a show cave Županova Jama (Mayor's cave) in Central Slovenia and outside the cave. Continuous measurements with a resolution of 30 and 60 min respectively have been made using BaroDiver (Eijkelkamp) and T-buttons 22L. Temporal and spatial variations of cave air temperature have been compared to external air, amount of precipitation and tourist visits using cross-correlation analysis of hourly data sets. The results of seasonal patterns analysis show very good correlation between external – cave air and demonstrate that air convection is a driving force for the heat exchange between the cave and the surrounding environment. However, occasional irregular variations in daily patterns are caused by human impact. The temperature rises for a few tenths of ºC right immediately after the visit decrease back to their initial values within a few hours. The effect of visitors has therefore been considered to be insignificant for the cave microclimate and not to affect cave environmental processes (e.g., condensation, evaporation) and habitat. The study shows the usefulness of the cross-correlation analysis of microclimatic data sets.

Non-linear response of cave temperature subjected to tourist visitation (Cave of Santana, Petar – Brazil): implications for carrying capacity of show caves

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The monitoring of the cave atmosphere is frequently used to provide support for the evaluation of changes caused by the tourist visitation. Such measurements are generally taken at specific points along the routes established for visitation and reflect the effect of the time spent by visitors. A program for monitoring the levels of temperature, humidity and carbon dioxide in the cave of Santana, one of the most important show caves in Brazil, was undertaken for this purpose, thus providing support for the evaluation of the carrying capacity established for tourism in that cave. The studies were conducted during regular visitation of the cave, so that the impacts of this visitation on the air temperature at two specific points could be evaluated. The increase was identified to be up to 1.1 °C in the Cristo room monitoring station and up to 1.3 °C in Encontro room monitoring station, both localized in a dry and upper gallery of the cave, above the lower

gallery of the river. The investigation of the variation of temperature, in the present study, showed that the interval of time spent at a specific point in the cave is more critical than the absolute variation of the temperature, which is an important contribution in the process of definition of the tourist carrying capacity of a cave, mainly in the days with a more intensive tourist visitation (weekends and holidays).

WI-FI in the show caves

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The WI-FI (wireless) within the caves – used in daily visits, but also in case of special needs (such as rescue procedures) – may, in our opinion, lead to useful results that sometimes have not even been imagined.

We first tested in wide cavities (such as the main hall of the Grotta Gigante, Italy), in tunnels, and wells how the signal transmitted by a WI-FI Access Point is amplified and how the radio waves do not dissolve (as assumed first) in the various collisions with the wall. Placing WI-FI transmitter on the bottom of the Grotta Gigante we were able to cover the entire cavity.

What are the purposes of the WI-FI coverage in a cave? In the experiments we have found so far that we can get some quite specific results; first of all for security scopes. With the technology, which is now available, WI-FI cameras can send via internet images from the cave, what already happens with city-cameras for traffic information or live weather information.

On the other hand, the WI-FI cameras can be used in case of an accident. The WI-FI webcams previously placed in strategic locations along the path can be removed in case of need and used in the cave. The cameras will send the images to an internet web page, for example to a site first aid; the medical staff outside the cave will be able to see in real time what is happening in the cave, deciding and communicating the best solutions to be adopted. This solution will provide adequate and quick answers, allowing the rescue staff to manage the emergency, to alert if necessary, a helicopter or an ambulance.

At the same time the WI-FI coverage allows us to work inside the cave as if it were outside. Nowadays, in many countries e have the possibility to scroll on smartphones geotagged images of a town or village. But how can we georeference something that is not covered by satellites such as the interior of a cave? We suppose we could do it through the WI-FI network and associating it with QR codes (Quick Read Code). Depending on where you are in the cave are QR codes that, through the WI-FI connection, connect our smartphones to the image relative.

Bat-population in Hermannshöhle (Kirchberg am Wechsel, Lower Austria) from 1965-2012

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The entrance of Hermannshöhle has been known for a long time by locals; the cave was thoroughly explored and documented for the first time by Hermann Steiger von Amstein in 1843. Soon afterwards the cave was opened to the public and guided tours were organized. Hermannshöhle is Austria's oldest showcave. Today its length is 4277 m, its depth is 73 m. Already in 1931 the cave was declared a Natural Monument and was thus protected, until today Hermannshöhle is considered a Protected Cave. Since 1942 investigations in the cave's bat-population have been made. Bats have been marked and so it was confirmed that they migrate up to 30 km to reach their wintering grounds in Hermannshöhle. Since 1965 the cave's bat-population is counted twice a year (in November and in March). The Lesser Horseshoe Bat (*Rhinolophus hipposideros)* is the most frequently found bat-species in this cave but 13 other bat-species could also be determined. The bat-population in the seventies and eighties consisted of approx. 200 exemplars; it has increased to approx. 700 exemplars in 2010.