

KARST RESEARCH INSTITUTE at ZRC SAZU

**Speleological Association of Slovenia
Slovenian National Commission for UNESCO
IGU Commission CO4.22 Karst
International Union of Speleology UIS
Region of Istra
Natura Histrica**



**18th INTERNATIONAL KARSTOLOGICAL SCHOOL
“CLASSICAL KARST”**

DINARIC KARST



GENERAL INFORMATION, PROGRAMME, FIELD TRIPS, ABSTRACTS

Postojna, 2010

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PLACES OF VENUE

- **Cultural Centre, Prešernova Ulica 1, Postojna** (No. 2 on the Map) and
- **Karst Research Institute ZRC SAZU, Titov trg 2, Postojna** (No. 1 on the Map).

LECTURES

- PowerPoint presentations should be given to organisers 15 minutes before the start of your session.
- The time slot for a regular talk can be seen from the programme. Please consider about 2-3 minutes for the discussion (i.e. 12+3).

LUNCH

- Lunches are not organized during Monday, Tuesday and Wednesday, but 90 minutes lunch breaks are in the schedule (see the places to eat on the Map).
- Simple lunch will be organised for the excursions on Thursday and Friday. These two lunches are included into the registration (no additional payment is provided). One non-alcoholic beverage is included in the price.
- During sessions, 15 min free coffee breaks are planned.

PLACES TO EAT

- **Minutka (No. 4 on the map):** Nice restaurant with pizza, pasta, excellent Balkan food and daily menu.
- **Čuk (No. 5 on the map):** Restaurant in the Sport park with plenty of space. Although known as pizzeria, they also serve good pasta, Balkan food, traditional local and “global” food, incl. salad bar and daily menu.
- **Bar Bor (No. 6 on the map)** For those of you who will wonder where is Jadran.... They serve their food in Bar Bor, 50 m down the street from the old location.
- **Šport hotel (No. 7 on the map)** also serves daily meals.
- **Špajza (No. 8 on the map)** for those looking for fine ambient and food.

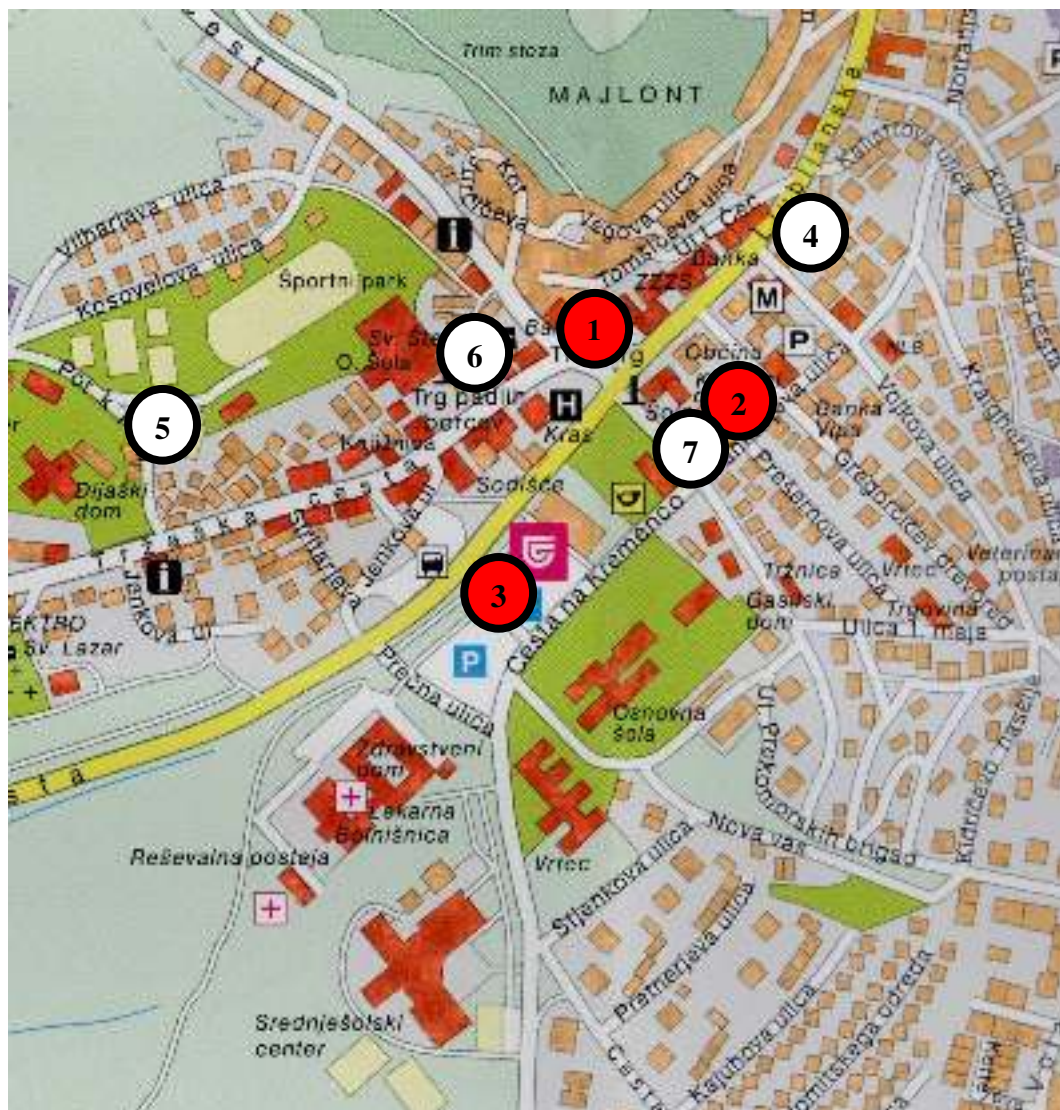
EXCURSIONS

- **Register for each excursion at registration desk in Monday morning.**
- All buses depart from the public parking in front of PTC Primorka (Novi trg 6, Postojna; No. 3 on the Map) exactly on fixed time.
- Head light are recommended, walking shoes and field clothes are necessary.
- Insect repellents are recommended (we will be walking in the areas populated with ticks (*Ixodes ricinus*) that transfer mainly lyme disease and tick-borne meningitis.
- Take care for additional information and changes regarding the bus departures.
- Water will be available on all busses.
- **Participation on the excursions is at your own risk.**

POSTERS

- Leave posters at registration desk on Monday before the lunch break.
- Posters will be divided according to their contents in different groups.
- Max. format of poster: 70 cm x 100 cm (width x height) portrait layout.
- 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 Cultural Centre of Postojna (Kulturni dom, Prešernova ulica 1)
- 3 Parking place in front PTC Primorka, Novi trg 6
- 4-7 Places to eat.

PROGRAMME

Monday, 14th June 2010

7.30-13.00	REGISTRATION	Cultural Centre
8.30-9.00	OPENING SESSION	
	SESSION 1: Dinaric Karst	
9.00-9.30	Dinaric Karst – general overview	
9.30-9.45	The age of Karst – some examples from Slovene Dinaric and Alpine Karst	
9.45-10.15	Short History of Dinaric Karst Research	
10.15-11.30	<i>Coffee Break</i>	
11.30-12.00	Geological evolution of Dinaric Karst region	
12.00-12.30	Hydrologic characteristics of Dinaric Karst	
12.30-13.00	Subterranean biodiversity in Dinaric karst, distribution patterns of its species and some paleogeographic implications	
13.00-13.30	Speleology of the Dinaric Karst	
13.30-15.00	<i>Lunch Break</i>	
15.00-17.00	Poster Session	Karst Research Institute
18.00-21.00	Postojnska jama cave – speleogenesis and history of use	Evening Field Trip

Tuesday, 15th June 2010

	SESSION 2: Karst Areas of the World	Cultural Centre
8.10-8.40	South China Karst world natural heritage	
8.40-9.00	Karst in arid settings	
9.00-9.20	Karst of the mountains	
9.20-9.40	Karst morphology of the Northern Calcareous Alps	
9.40-10.00	Karst in Gypsum	
10.00-10.20	"Karst" in rocks of limited solubility	
10.20-10.40	Alpine and coastal karst in Sardinia and along the Italian coasts	
10.40-11.00	<i>Coffee Break</i>	
	SESSION 3: Karst Geomorphology	
11.00-11.20	Polje, dolina and collapse dolina	Cultural Centre
11.20-11.40	Karst planation processes and karst plains	
11.40-12.00	Aspects of time in karst	
12.00-13.30	<i>Lunch Break</i>	
13.30-20.00	High Plateaus and Levelled Surfaces of Dinaric Karst (Hotenjka stream,	Afternoon Field Trip

	ponors, karst on dolostone, karst levelled surface, Hrušica high plateau)	
20.30-21.30	IGU Karst Commission meeting	Karst Research Institute

Wednesday, 16th June 2010

8.30-10.00	SESSION 4: Karst Land Protection		Cultural Centre
8.30-9.15	Towards a transnational serial Dinaric Karst World Heritage Park: what needs to be done	Paul Williams	
9.15-9.40	PROGEO	Ljerka Marjanac	
9.40-10.00			
10.00-11.00	Preparation time for afternoon field trip		
11.00-19.00	Contact karst – allogenic impact (blind valleys of Matarsko podolje, caves and unroofed caves)	Afternoon Field Trip	
20.00-21.00	Unresolved Mysteries of the Karst	Philipp Häuselmann	Karst Research Institute
afternoon	UNESCO meeting	Karst Research Institute	

Thursday, 17th June 2010

8.00-19.30	Geomorphology and hydrogeology of Kras plateau (Škocjanske jame, collapsed dolines, unroofed caves, karst leveled surface, dry valleys, springs of Timava)	Whole-day Excursion
20.00-	Reception at Karst Research Institute	

Friday, 18th June 2010

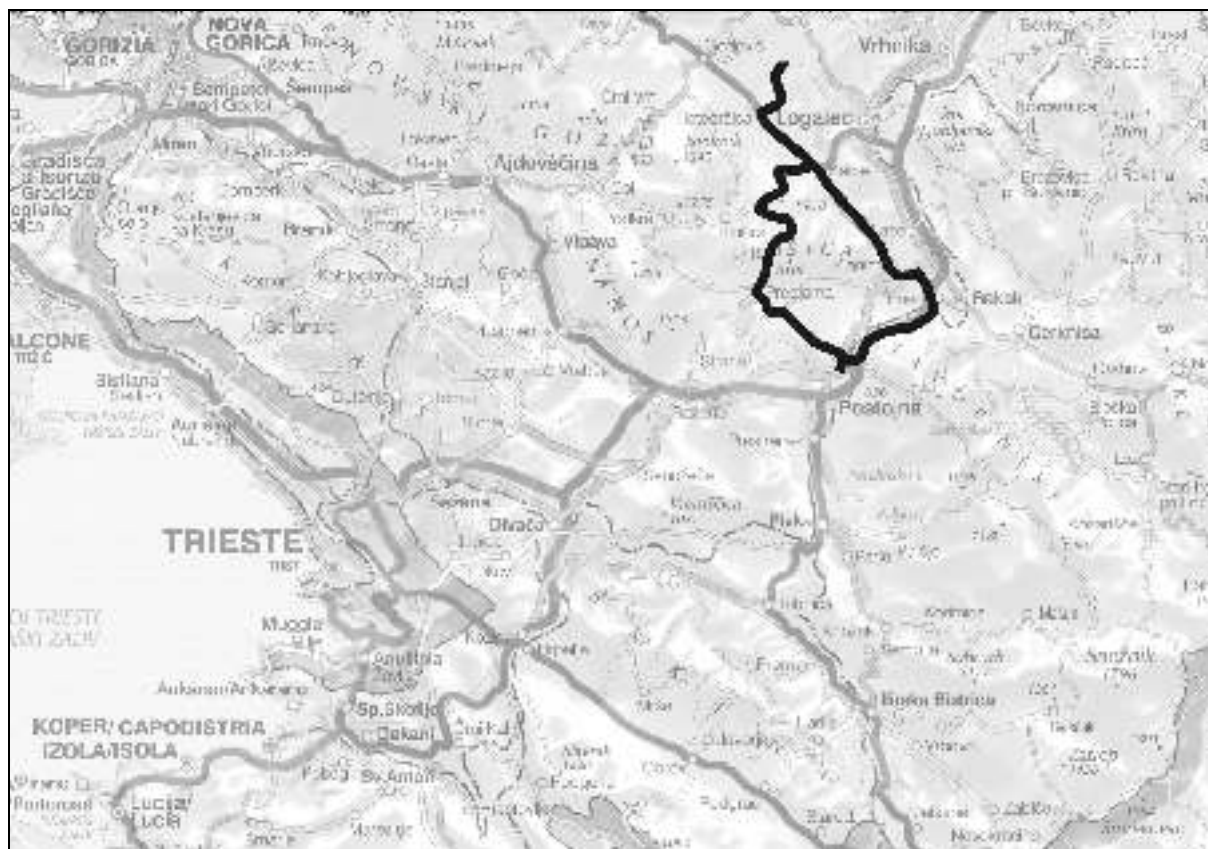
8.00-17.00	Geomorphology and hydrogeology of Ljubljana karst river (Loško, Cerkljansko and Planinsko polje, Rakov škocjan, springs of Ljubljana)	Whole-day Excursion
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Saturday, 19th June 2010

9.00-12.00	Optional tourist trip to the Proteus Vivarium (Speleobiological Station of Postojnska jama) and to Otoška jama	
13.00	Optional tourist trip to Jama pod Predjamskim gradom (1.5 hours tour; transport from Postojna is not provided!)	
13.00 or 15.00 or 17.00	Optional tourist trip to Križna jama (2 hours tour; transport from Postojna is not provided!)	

High Plateaus and Levelled Surfaces of Dinaric Karst

Tuesday, 15th June 2010, 13.30-20.00



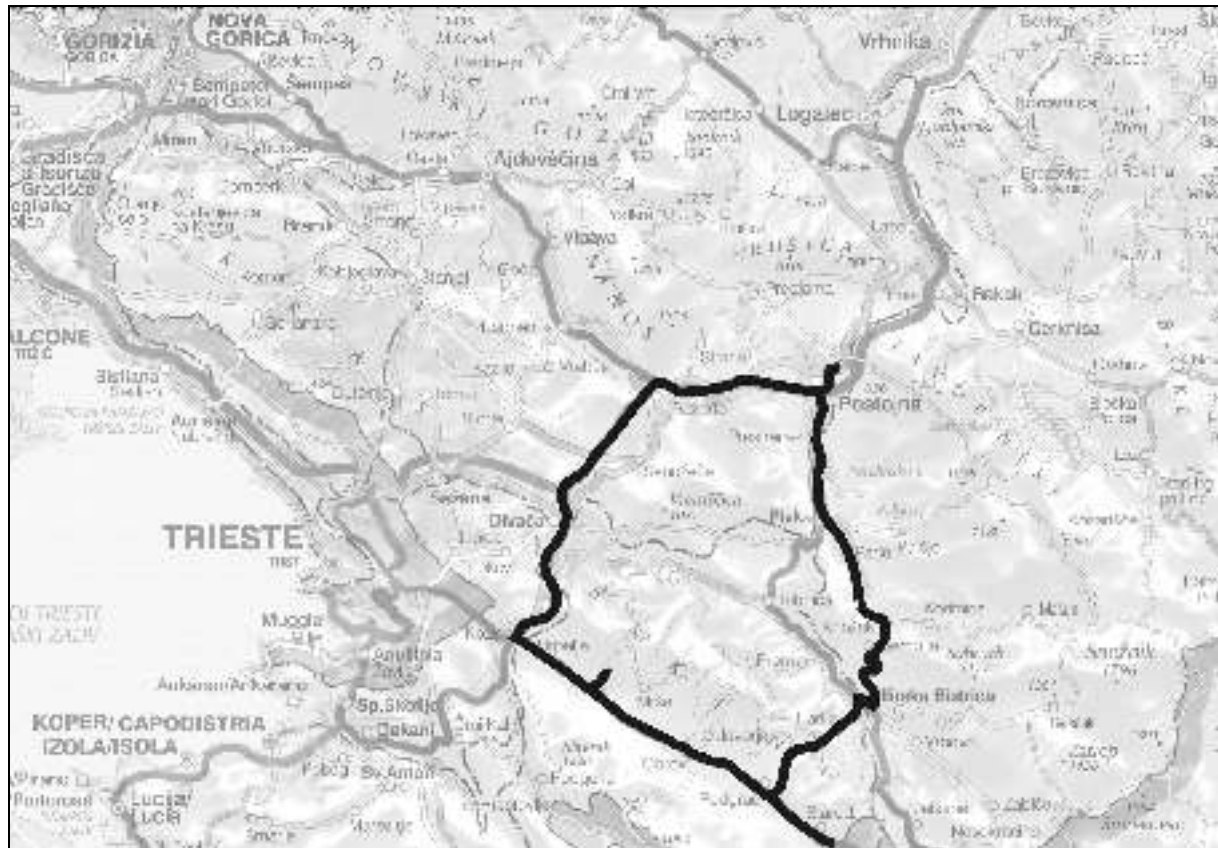
Short description

We will visit dolomite karst landscapes at village Hotedrška. On dolomite surfaces with dolines or fluviokarst dry or blind valleys and sinking streams developed. We will walk on dolomitic plateau Ravnik and in blind valley Žejna dolina to the sinking point of a stream. Then will cross corrosional plain or ravnik at Hotedrška to the ponor of Hotenjska brook into a shaft with a mill. In continuation we will cross the levelled surface with many dolines on Hotenjski ravnik and Novi svet. After will leave low levelled surface and drive with bus on across Hrušica high karst plateau. Here we will walk into some larger dolines in limestone and dolomite and enjoy the view from the edge of the plateau above levelled surfaces above Postojnska jama.

There will be about 70 km by bus and some short walks. Walking boots are recommended.

Contact karst – allogenic impact

Wednesday, 16th June 2010, 11.00-19.00



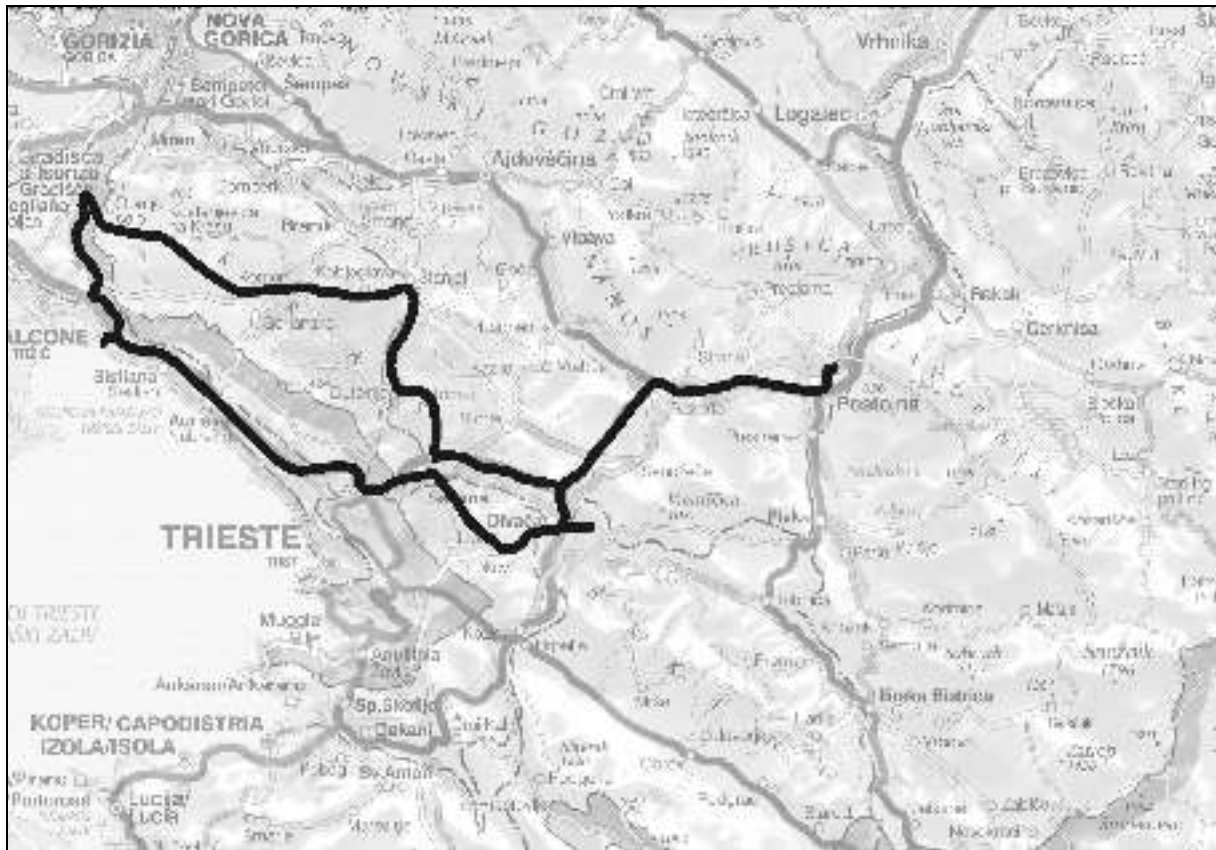
Short description

Field trip to contact karst on the edge of flysch Brkini hills, where several small rivers are sinking and shaping the karst surface close to ponors. These features of allogenic impact developed in interaction of surface and underground drainage and well reflect evolution of karst drainage system. We shall stop at the blind valley of Brezovica, Odolina, Jezerina and Račiška dana. At these four blind valleys some differences in evolution can be attributed to different tectonic uplift. After we will walk to the unroofed caves Ulica and Ulica pečina cave, to see the remnants of old caves with allogenic sediments and to the hill above village Starod with a good view above the contact karst area and above corrosion levelled surfaces.

There will be about 150 km by bus and several short walks. Hand lamp and walking boots are recommended.

Geomorphology and hydrogeology of Kras plateau

Thursday, 17th June 2010, 8.00-19.30



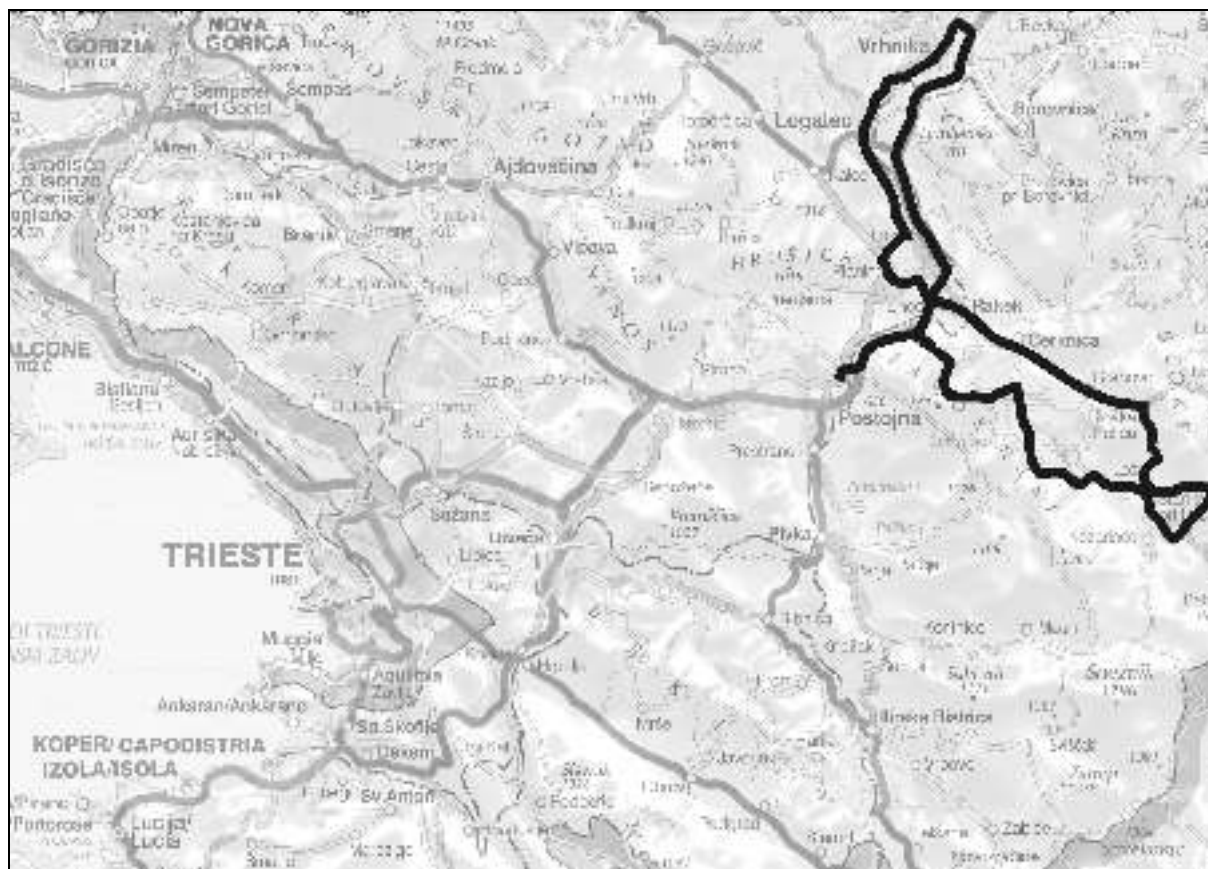
Short description

Field trip will take us along and across the Kras plateau from the sink of Reka in Škocjanske jame to the springs of Timavo. We shall stop at the surface above Škocjanske jame to see large unroofed cave, former sink of Reka, than Škocjanske jame. After lunch break at Škocjanske jame we shall continue across the plateau, a stop at caves at Kanjduce and main springs of Timavo river on the Adriatic coast. We shall continue towards dry valley of Doberdob and on the plateau passing Kostanjevica, Štanjel and Sežana.

There will be about 150 km by bus and some short walks. Walking boots are recommended.

Geomorphology and hydrogeology of Ljubljana karst river

Friday, 18th June 2010, 8.00-17.00



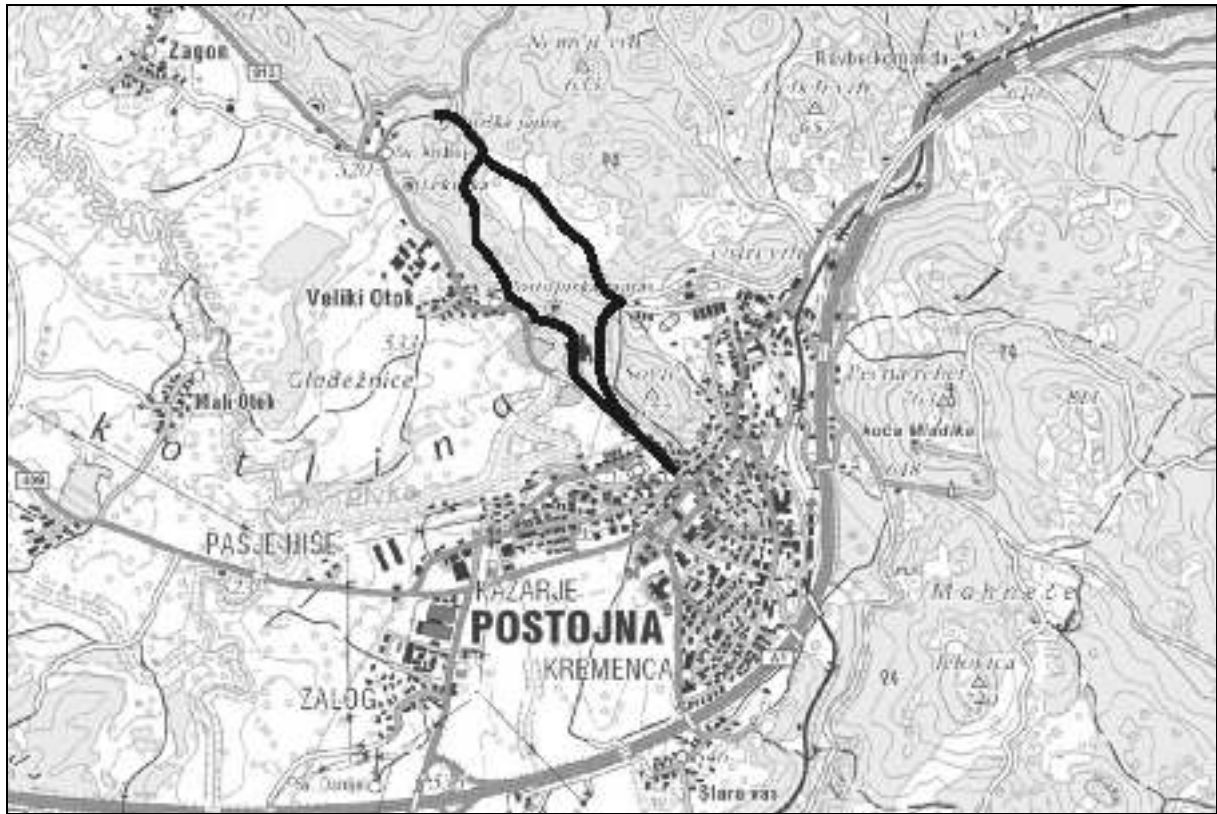
Short description

Field trip will cross the great deal of Ljubljana river catchment area. First we will visit Loško polje, one of high poljes in the Ljubljana basin. We shall see the springs of springs of Obrh at Vrhnika and sinks at Dane village. Next, lower polje is Cerkljansko polje. We shall cross it from springs to the sinks, depending also on water level, since it is flooded in this time of year. Next stop is karst valley Rakov Škocjan. We shall see the springs and ponors of river Rak and also the two natural bridges, remnants of the cave passage. After lunch we continue to Planinsko polje and stop there at Planinska jama, spring of Unica river and some ponors on the other edge of the polje. Then we continue across the surface to Vrhnika, where are final springs of Ljubljana.

There will be about 100 km by bus and short walks. Walking boots are recommended.

Optional tourist trip to the Proteus Vivarium (Speleobiological Station of Postojnska jama) and to Otoška jama

Saturday, 19th June 2010, 9.00-12.00



Optional tourist trip to the Jama pod Predjamskim gradom

Saturday, 19th June 2010, 13.00 (transport from Postojna is not provided)

Optional tourist trip to the Križna jama

Saturday, 19th June 2010, 13.00 or 15.00 or 17.00 (transport from Postojna is not provided)

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MONITORING OF WATER LEVEL, TEMPERATURE AND ELECTRIC CONDUCTIVITY IN RELATION TO WATER HYDRODYNAMICS IN CAVE “NEVIDNA VODA” (ODŽAK, BOSNIA & HERZEGOVINA)

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The response of cave hydrodynamics to a rainfall event can provide various informations of the catchment that recharges the cave. The studied cave “Nevidna voda” is located in the Dinaric karst, southwest Bosnia and Herzegovina. It is a 653 m deep cave and the measurements were obtained at the depth of 395 m in a time step of 10 h. Rainfall events were associated to a signal from a data logger in order to study the hydrodynamics of the water flowing through the cave. The decrease of water temperature in summer months suggests the infiltration of cold water due to the snowmelt of snow stored in the karst fissures and fractures near the surface. The increase of water temperature does not necessarily coincide with the increase of electric conductivity which indicates the mixing of rainfall and snowmelt waters. The complexity of the studied karst system and its physics can not be completely clarified, yet with integral information about catchment, cave geometry and measured chemo physical properties of inflowing water, it is possible to obtain a better understanding of its dynamics.

Keywords: cave, hydrology, karst

SPELEOLOGICAL EXPLORATION OF MT. CRNOPAC (CROATIA)

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Mt. Crnopac is the SE part of the Velebit Mountain range. This area is a subject of intensive speleological research in last decades. The most important caves of Crnopac massif are Munižaba (5993 m, -437 m), Kita Gaćešina-Draženova puhaljka (11560 m, -530 m), Burinka (325 m, -290 m), Gornja (Upper cave) (2682 m, -42 m) and Donja (Lower cave) Cerovačka pećina (1295 m, -22 m). The main morphological characteristic of those caves is a network of multiphase cave passages, some of them with very large cross-section dimensions. The biggest estimated volumes of the caves are about

1.8 million m³ (Munižaba), 1.1 million m³ (Burinka) and 0.8 million m³ (Kita Gaćešina). The possibilities of further scientific research in those caves are discussed.

Keywords: Dinaric karst, Mt. Crnopac, Croatia, speleology

COMPARISON OF THE OUTER AND INNER DINARIDE'S CAVES: THE CASE OF VRDOVO (DINARA MT.) AND ŽUMBERAK MTS., CROATIA

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Caving Club Samobor has explored different parts of the Dinaric karst during ten years of its activity. Here is given a comparison between caves in the Vrdovalo vicinity (Dinara Mt.) as part of the Outer Dinaric high karst and at the Žumberak Mts. as a part of the Inner Dinaric shallow karst in Croatia. Dinara Mountain represents natural and historical border between Croatia and Bosnia and Herzegovina. The whole karstic region from Italy to Albania was named after it. It is a part of the Outer high karst Dinarides and belongs to the Dinaric carbonate platform (Dinaricum) structural unit. Speleological researches of southeastern parts of Dinara Mt. were carried out from 2007 at the karstic plateaus Vrdovalo and Podi, and around Bitelić, Rumin, Priorice and Malin. We have explored thirty-two caves there among which dominate pits (73%). All caves were formed in limestones, mainly Cretaceous age, what is in accordance to the rest of the Croatian karst. According to the morphological type simple caves dominate (73%), followed by the knee formed caves (15%). The longest explored is a cave system Crvenkuša and Tamnica (caves) and Suhi Rumin (pit) with a total length of 430 m. With the 140 m explored depth Jama u Konjikuši Gornjoj pit is the deepest at the moment, although one can expect much deeper pits like adjacent Nevidna voda (-653 m, Dinara Mt., Bosnia and Herzegovina). The most of the caves are dry, and all the types of cave sediments are present within them. By the richness of speleothems stands out Bila Lipotica cave and its final hall. This research also found intensive pollution of the karst underground by the various waste including mines and explosives (e.g. Smrduša Gornja, Smrduša Donja, Buljanov Ponor, Tumbas, Krstačka). Žumberak and Samoborsko gorje Mts., or Gorjanci in Slovenia, is a mountain range bordered by the rivers Krka, Sava and Kupa. Its biggest part belongs to the Nappe of the Supradinaricum structural unit upon the Dinaricum structural unit that is exposed only at the westernmost part of the researched area. Žumberak and Samoborsko gorje Mts. belong to the Inner Dinaric shallow karst. The Croatian part of the terrain was explored in detail from 1975. by the Speleological Section „Japetić“ Samobor whose tradition continued the Caving Club Samobor. A hundred-eighty-two caves and pits were explored to date of which 55% caves. The most of them were formed in Upper Cretaceous carbonates, what is in accordance to the rest of the Croatian karst. According to the morphological type simple caves prevail (76%) and the knee formed caves (10%). They are followed by branching (9%) and level caves (4%). The complex caves are the least numerous (1%), and no system was found to date. The longest is Provala cave (1862 m long and 57 m deep) and the deepest is Bedara cave

(1019 m long and 113 m deep) at the moment. There is more groundwater at this area, so 11 caves are permanent springs, and 8 are periodical springs. All types of caves sediments could be found in explored caves, but by the richness of speleothems stand out Jamina and Pušina caves. The waste insertion is a big problem here also and some caves are completely buried with it (e.g. Dubičeva znetva, Mesaruša...). Caving Club Samobor continues its researches at the both of the terrains, where is expected the discovery and exploration of deeper pits in the peak part of Vrdovo. The most noticeable difference between caves of the Outer and Inner Dinarides is in the relationship of pits and caves what is in accordance to the knowledge of the Dinaric karst.

Keywords: Dinaric karst, Croatia, Dinara Mt., Žumberak Mts., caves

HYDRO-ACCUMULATION OF THE HYDROELECTRIC POWER PLANT LEŠĆE (CROATIA): THE EXAMPLE OF THE EXTENSIVE DEVASTATION OF CAVE KARST HABITATS AND CAVE FAUNA

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The construction of the Hydroelectric Power Plant Lešće, which is the second power plant on the river Dobra, after the Power Plant Gojak, is in its final phase. For this purpose, the dam was built in the canyon of the river Dobra which will create a 13 km long reservoir between the village Gorenci and the Power Plant Gojak. Parts of the tributaries Bistrac and Ribnjak are also going to be submerged. In 2008 and 2009 Croatian Biospeleological Society conducted biospeleological research in the wider area of the canyon in order to establish mitigation and compensation measures to the cave fauna. Hundred and ten caves were recorded in the study area, and 57 among them were biospeleologically explored. Literature review and field research have identified a total of 201 taxa, of which 65 troglobites and stygobites and 27 troglaphiles. Three species are listed on The IUCN Red List of Threatened Species, and 12 are included in the Red Book of Croatian Cave Fauna. Ten cave species are probably new to science, and 53 are endemic to more or less wider area. Out of 57 caves surveyed, 10 will be completely flooded, 6 partially submerged, and 6 may be under hydrological influence. From the 22 impacted caves, 33 species have been determined as important ones due to their endemism or endangerment. Two species are found only in caves that will be completely submerged and are not recorded anywhere else in Croatia. Unforeseeable consequences of building dams and reservoirs on the environment have been identified since the sixties. This is especially true in karst areas, where the underground cave habitats and fauna suffer a significant negative impact without the possibility of implementing any measures of protection as well as the specific compensatory measures in situ

Keywords: cave fauna, devastation, hydroelectric power plant, river Dobra, Croatia

PHYLOGENETIC POSITION OF ENDANGERED STYGOBITIC BIVALVE *CONGERIA KUSCERI* AND PHYLOGEOGRAPHIC STRUCTURE IN CROATIA BASED ON MITOCHONDRIAL AND NUCLEAR DNA MARKERS

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Congeria kusceri Bole1962 is the only stygobitic bivalve in the world. It is endemic to Dinarides and lives in Slovenia, Croatia and Bosnia and Hercegovina. In Croatia it is recorded in a total of fifteen localities, but at most sites only shells were found. Live populations were documented in only five sites, but the surveys in 2008 revealed that the two populations disappeared. In addition to being strictly protected by the Croatian law, the species is listed in the Annexes II and IV of the Habitats Directive. Nevertheless, two out of three remaining populations could be facing serious destruction if not extinction in the near future. The reasons will be discussed. All this led to the enlistment of *Congeria kusceri* in the Red list of Croatian cave fauna in the IUCN category CR.

Congeria kusceri is the only surviving species of the genus *Congeria* which was widespread in the tertiary. Its current distribution is quite disjunct. Mitochondrial 16S rRNA and COI and nuclear ITS and 18S rRNA markers were employed to examine the position of the genus within the family Dreissenidae as well as to infer the relations between different populations in Croatia. Our results support *Congeria* being the third extant genus of the family Dreissenidae as previous studies suggested. All four markers indicate that the population in Markov ponor (Lika region) is genetically distinct from the two populations in Neretva basin. These results are in congruence with biogeographical data since Markov ponor is several hundred kilometres away and hidrologically isolated from the rest of the localities.

Molecular data as well as recent field research point out the need for protection of each individual population in Croatia.

Keywords: *Congeria*, Dinarides, phylogeny, stygobitic, endangered

GENESIS AND DEVELOPMENT OF NOTCHES IN THE EASTERN ADRIATIC SEA

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We present new hypothesis on the genesis and development of the submerged tidal notch recognized along the Eastern Adriatic coast using new and published data on the position of the notch and on limestone lowering rates collected using the micro erosion meter (MEM) and the traversing micro erosion meter (TMEM). A well-carved notch has been surveyed at depth ranging between –0.5 m and –2.8 m (Antonioli et al. 2007, Benac et al., 2004, 2008). Its amplitude is comparable to the local tide. Following Faivre et al. (accepted), the studied notch could be post-roman in age, because of its depth, lower than Roman remains. At the same time, no present-day notch has been surveyed. Limestone lowering rates suggest that coastal limestones lower at rates ranging between 0.11 and 0.970 mm/y. Surface change rates, collected since 2007 on a vertical limestone slab in the Gulf of Trieste (Furlani et al., 2010), are compared to chemical and physical data acquired close to the slab site. Data suggest that surface change rates are closely related to physical/chemical parameters and their seasonal variations. Data support the hypothesis that notch is presently carving. Its lacking and its actual submerged position could be related to a still acting rapid tectonic downdrop and/or to increasing in weathering/erosion rates during the so-called warm Medieval Period, marked by more aggressive conditions than actual, both chemically, biologically and mechanically. These mechanisms could be triggered by increasing rainfall or variations in the acidity of seawater.

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Keywords: notch, Adriatic Sea, limestone lowering rates, traversing micro erosion meter

GEOMORPHOLOGY OF THE KARST PLATEAUS IN THE CROATIAN PART OF THE DINARIC KARST (EXAMPLE OF SLUNJ KARST PLATEAU)

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Karst plateaus are, together with karst poljes, the biggest landforms in Dinaric karst. They are characterized by polygenetic and polyphase genesis. In the small scale karst plateaus are big flat areas with very low relative relief. Dinaric karst plateaus can stand by it self like big plateaus or can be like part of the karst-polje bottoms or they can be small tectonic fragmented and uplifted plateaus in mountainous area. In Croatian part of Dinaric karst there are three big karstic plateaus: Istrian plateau, Karlovac's plateau (Una-Korana plateau) and North Dalmatian plateau. This large areas spread over about 4,000 km² witch is 7% of Croatian territory and 14% of Croatian kart area. Past researches were directed on exploration of processes and time of karts plateaus morphogenesis. There were three groups of karst plateau genesis: erosion, corrosion and abrasion theories while time of plateau genesis were assumed in range from Mesozoic to Pleistocene. This work is directed in research of morphogenesis of the surface and underground karst features in area of Slunj plateau witch is part of the extensive Karlovac's (Una-Korana) karst plateau expanding between the Dinaric Mountainous System in the south-west and Pannonian Basin in the north-east. The researched region is elongated in the Dinaric direction, its area figures out at 336 km², and its largest part is situated at the height of 250-400 m. The oldest rocks are the Permian sandstones, and the whole area is for the most part made of the Mesozoic platform carbonate rocks, which are in places transgressively covered with lacustrine and alluvial deposits of the Miocene, Pliocene and Quaternary age. Main structures and faults stretch in the Dinaric direction. As to exogenous processes, karst and fluviokarst ones are most significant, and fluvial, fluvio-denudational and slope processes are of somewhat less significance. In geologic past, the periods of more intensive exogenous processes were most frequent during and after orogenetic processes, and were interrupted by transgression periods. In the post Miocene period, the relief development was significantly influenced by denudation of the Neogene's clastic sediments and a gradual exhumation of carbonate bedrock. During that process, the karst relief area increased at the expense of the fluvio-denudational relief area. It resulted in development of numerous karst forms (dolines, grikes, uvalas), but also of karstified remnants of the surface paleohydrographic network (dry and blind valleys). In those conditions numerous caves developed, where horizontal caves dominated.

Keywords: karst geomorphology, karst plateau, fluviokarst, caves, speleogenesis, Croatia, Dinaric karst

GEOMORPHOLOGICAL CONDITIONS OF THE SPELEOGENESIS IN THE CROATIAN PART OF THE DINARIC KARST

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Croatian karst is part of the Dinaric karst area. It spreads over 23,000 km² which is about 50% of national territory. In this area more than 10,000 different caves were explored, mostly by Croatian amateur caving organizations and some of them by foreign cavers too. There are more than 50 caves longer than 1,000 m and more than 50 caves deeper than 250 m. The longest is Lukina jama – Trojama system (1,392 m) and the longest is Đulin ponor – Medvedica cave system (16,396 m). Different geomorphological characteristics are in inner, middle and outer karst belt. Inner karst belt is mostly characterized as big karst plateau with low altitude and relative relief. Middle belt is mainly composed of karst poljes and hills between them. And in outer belt there are coastal mountains, coastal plateaus, coast and islands. This work deals with geomorphological conditions of speleogenesis and comparison of the geomorphological and speleomorphological characteristics in the sense of the process of karst development. In some examples it will be shown how surface karst development is connected with karst underground forms.

Keywords: speleology, karst geomorphology, caves, speleogenesis, Croatia, Dinaric karst

MORPHOLOGICAL OBSERVATIONS IN THE CAVES OF NJEGUSKO POLJE, MONTENEGRO

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Njegusko polje, situated between Kotor and Cetinje, Montenegro, on an elevation of 845 m asl., belongs in geological aspect to the Dalmatian-Herzegovinian Zone of the Dinarids. The total thickness of the Mesozoic shallow marine carbonatic sediments is up to 3600 m in the region, of which some 2000-2600 m have already been eroded from the investigated area. The polje is flooded after snowmelts only, and is referred to drain towards the big karst springs in Kotor, some 5 kms westward from the main (but impenetrable) sink of the polje. Hungarian exploratory researches have increased the number of caves exceeding the length of 1 km and the depth of -100 m to four, and respectively, to six in this area since 2003; the two largest representatives of which (Duboki Do: 2.5 km, -506 m; and Njegos Cave: 4.5 km, -383 m) are situated within the polje. Although these both open in Lower Jurassic limestone on similar elevations and at a distance of a mere 2 km from each other, their morphology reveal significant differences. Duboki do is basically a meteoric system with branchwork pattern, deepening towards NW, that is, towards the theoretical line offering the shortest route between the main sink of the polje and the springs at the sea. The main development of the passages

explored that far is between the depths of -105 and -180 m. Its morphology is dominated by vadose canyons and shafts, the relatively short sections of phreatic origin occurring at its permanent and temporary sumps seem to be generic parts of the active system. Njegos Cave, on the other hand, displays a complicate multiphase system that deepens towards the opposite direction, i.e. SE. A great deal of its known passages are relic, subhorizontal phreatic galleries situated in a shallow depth (-20 to -50 m below the entrance), where a vadose entrenchment clearly discernible from the cross-cuts of the modern holokarst drains can also be observed. The morphology of the system, as a whole, gives the impression that certain parts of the system had evolved in different ages and at different conditions as individual caves and became connected by chance.

Keywords: Njegusko polje, Duboki do, Njegos Cave, cave morphology

HYDROLOGIC CHARACTERISTICS OF DINARIC KARST

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Dinaric karst covers about 60.000 km². It stretches the lengths of the eastern coast of the Adriatic Sea, from the Bay of Trieste in the north to the Drim River basin in the south, and the Western Morava valley in the east. This karst structure is some 600 km in length and up to 200 km in width, falling within the borders of the following seven states: Italy, Slovenia, Croatia, Bosnia and Herzegovina, Serbia, Montenegro and Albania. The Dinaric karst region is an area of dramatic variety of karst surface and underground forms, karst water phenomena, species, habitats and peoples.

Hydrology is a scientific discipline within the earth sciences. It concerns the occurrence, movement and composition of water below and on the earth's surface. Hydrology is based on water budget concept. In karst hydrological investigations, the basic problem is that subsurface water is highly heterogeneous in terms of location of conduits, location of vertically moving water toward the phreatic zone, and flow velocities. Due to this reason hydrological and hydrogeological methods and approaches should be closely connected in karst investigations.

The determination of the catchment boundaries and the catchment area is the starting point in all hydrological analyses. For water circulation in karst, this classical and relatively simple hydrological problem, in more homogenous types of terrain, represents extremely complex, sometimes unsolvable task. The differences between the topographic and hydrologic catchments in karst terrain are so large that data about the topographic catchment are useless. Generally the position of the karst catchment boundaries depends upon the groundwater levels which strongly and sharply change in time. In some situations very high groundwater levels causes the redistribution of the catchment areas, i.e. overflow from one to other catchment. Specific characteristics of karst floods due to strong groundwater rising, and limited swallow capacity of the ponors will be explained.

One of the almost unavoidable characteristics of karst open streams, creeks and rivers is that they either have partial water loss along their course or completely sink into the underground. Sinking, losing and underground streamflows are more typical, significant and relatively frequent karst phenomena in Dinaric karst. Hydrological characteristics of the Lika, Gacka, Dobra and Mrežnica Rivers will be explained.

Karst systems are known to change over time due to natural factors and in the recent time very fast due to anthropogenic influences. Anthropogenic intervention, especially constructions of dams and reservoirs as well as inter-basin water transfers can introduce instantaneous and distinct change in catchment areas and boundaries. Natural and anthropogenic changes in karst regions frequently cause strong, sudden and dangerous processes at the local and regional scale. The benefit resulting in one area was frequently smaller than damage caused in another area. Examples of Boljunčica Reservoir and development of hydroelectric power plant Gojak on the Dobra River will be given.

THE ROLE OF SPELEOLOGICAL EXPLORATIONS IN CAVE PROTECTION IN DINARIC KARST (CROATIA)

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The longest Croatian cave, more than 16 km long cave system Đulin ponor-Medvedica situated under town Ogulin and 8.5 km long cave Špilja u kamenolomu Tounj are among the most endangered karst phenomena in Croatia. One of the activities of Speleological Committee of the Croatian Mountaineering Association is stimulation of protection of speleological objects and karst underground as well as informing about it. In this work we discuss the role of speleological explorations in cave protection. We present a number of endangered caves in Croatia and discuss the difficulties in their protection. We analyze the scientific and natural values of endangered caves with the possible measures for their protection.

Keywords: Dinaric karst, cave protection, Croatia

CAVES OF SHALLOW PHREATIC AND EPIPHREATIC ZONE IN SABLJACI LAKE AREA (OGULIN REGION, CROATIA)

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First speleological researches of Ogulin region in the hearth of Dinaric karst in Croatia started in 19th century, but systematic researches of numerous cave springs and caves have been performing since 2006 during cave diving and biospeleological projects organized by SO HPD Željezničar (Zagreb) and Croatian Biospeleological Society. These researches include the coast and nearby surroundings of Sabljaci accumulation lake near the city of Ogulin. The lake was built in 1959 on the river of Zagorska Mrežnica for Gojak power station. It collects water from few karst springs and short tributaries feeding from the aquifer which hydrogeological conditions were determined by geological and tectonic settings. The permanency and relatively constant amounts of karst water that springs from this well developed system shows that they feed from a larger area. It is the mountain area of Mala Kapela that is dominantly built of highly karstified Cretaceous limestone beds with average amount of precipitation of 2000-3000 mm/year. The connections were confirmed by water tracing and speleological researches of wider area. The depth and flow conditions in the research area of Sabljaci lake were influenced by the depth of hydrogeological barrier and tectonic zones that controls flow directions. At the southern and south-western Sabljaci lake shoreline momentary the longest is Zagorska Mrežnica spring cave (1170 m long and 22 m deep). In its close vicinity there is Bistrac spring cave (500 m long and 56 m deep). Zagorska peć is a periodical spring cave with submerged shaft passage where cave divers went 76 m deep and in very demanding technical dive did not reached the bottom yet. According to historic documents it has the largest water level oscillation among all researched springs. During 2009 cave dive expedition and later dives on the west coast of the lake, Pećine – Veliko vrelo cave system was explored. It consists of lower submerged system of passages and upper periodically submerged cave passage. Up to now more than 1300 m of passages were investigated of which 725 m was surveyed. South of the lake Rupećica – Zeleno jezero system was researched. It starts with 80 m long Rupećica cave spring. Its stream flows through a closed depression (collapsed cave) and sinks to 160 m long and 22 m deep Rupećica ponor connected to Zeleno jezero lake which is a submerged shaft. Speleogenesis of submerged passages of shallow phreatic and epiphreatic zone in researched spring caves of Zagorska Mrežnica basin were determined by the position of complete barriers (dolomites and clastites), partial barriers (limestones and dolomites) and karstified beds (limestones) of Jurassic age. Besides geomorphological and hydrological features of the caves typical for shallow phreatic and epiphreatic conditions, it was found that all of them are important habitats with rare, specific and endangered cave species, like *Proteus Anguinus* and unique cave freshwater stygobitic sponge *Eunapius subterraneus*.

Keywords: spring cave, shallow phreatic zone, epiphreatic zone, speleomorphology

TYPES OF KARST IN PORTUGAL

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Portugal occupies the western part of the Iberian Peninsula. Paleozoic and Proterozoic terranes outcrop along the Hercynian segment of the Variscan orogen. Mesozoic and Cenozoic rocks make up two borders of the Iberian massif, one on the west side and the other on the south, respectively the Lusitanian basin and the Algarve basin. Karst areas in the northern parts of the Variscan orogen are thin strips squeezed among schistose and siliceous formations. There is no karst landscape except minor karren and isolated caves. However these metamorphic limestone or dolomite strips are important aquifers that may indicate a deeper and inaccessible karstification. In the southern parts of the Variscan orogen marble outcrops are more extensive. A few low mountains display a landscape of residual hills emerging above the vast peneplain of Alentejo although no typical karst landforms are noticeable. Caves are more widespread even if again small and isolated. In a region with a dry climate these karst aquifers are a very important resource of drinking water. West Mesozoic karst areas are strongly influenced by geologic structure resulting from extensional tectonics followed by inversion. Limestone hills limited by fault scarps rise above surrounding areas. Plateaus are dissected by graben corridors where poljes formed. Caves have here a significant development and aquifers are the most extensive. Diapiric valleys also show interesting features along their borders, namely karst springs. South Mesozoic karst areas display a broad monocline dipping south. This makes possible the development of karst depressions trending east-west, which is the main characteristic of the region. The country is bordered by Plio-Quaternary wave cut platforms well preserved where limestone outcrops, some of them with a characteristic fossil sea cliff. In the south Miocene carbonate rocks show interesting fossilized coastal karst.

Keywords: types of karst, Lusitanian basin, Algarve basin, Portugal

ICE CAVES OF EREBUS VOLCANO, ANTARCTICA

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The Erebus Caves Project was initiated in 2009 to systematically survey and monitor the unique fumarolic ice towers (FITs) and fumarolic ice caves (FICs) on Erebus Volcano, Antarctica. Data obtained during the 2009 – 2010 field season provides insight into the physical dynamics of these features and their relationship to the geology of the world's southernmost active volcano. Results show stable microclimates near gas vents (GVs) inside of the FITs and FICs with important biological potential. The cave microclimate also appears to be buffered by latent heat fluxes associated with

the melting and freezing of ice. Observed cave geometries and entrance locations suggest that the planform of horizontally developed FICs with large horizontal extent are formed by the confluence of heatflow from several discrete GVs, interacting with underlying lava topology.

DINARIC KARST - THE LOCUS TYPICUS OF KARSTIC UVALAS

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Karstic uvalas, as a particular type of karst closed depressions, are widely distributed throughout the Dinaric karst. Similarly to many other scientific terms used in karstology, the term uvala also originated from this area. In large parts of Croatia and western Bosnia, the word uvala is a component of numerous toponymes denoting exactly this form of karst surface relief. The total of 40 uvalas of the Dinaric karst have been included in the geomorphological study in which their position, elevation, geological settings, morphometry, and other characteristics are included in a GIS-based analysis, offering valuable information on this insufficiently studied karst landform. Further filling of the database with more examples from the Dinaric karst and from other karst areas will contribute to the improvement of the studies on this issue.

Keywords: karst morphology, karst depressions, uvala, Dinaric karst

CAVE SEDIMENTS AND ROCKS-SHELTER SLOPE DEPOSITS: RECORDS OF THE LATE QUATERNARY PALEOENVIRONMENTAL CHANGES IN CENTRAL PORTUGAL

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The paleoclimatic fluctuations of Marine Isotopic Stage (MIS) 2 and 3 are fairly well-known from the offshore Portuguese continental margin record. On the continent, geomorphological, sedimentological, stratigraphical and archaeological study of the sedimentary sequences preserved in the caves and rocks-shelter of the Sícó Massif (central Portugal), provide evidences for a main erosive phase that correspond to the peak of Heinrich 3 (H3) event, dated to ca. 32.0-29.5 kyr cal BP, during colder and moister conditions. This phase, in fact, testifies to a sudden change of the environmental background and the consequent modification of hydrographical and hydrogeological

dynamics, entailing river down-cutting, slope reactivation and endokarstic reorganisation. A second main erosive phase (dated to ca. 24.0 kyr cal BP) was detected in one of the caves studied, strengthening the proposed correlation with the H2 event. Other minor erosive phenomena are recorded between the H3 and H2 events. They may have been caused by hydrological changes or by the reactivation of karstic processes, which could indicate the transition toward harsher environmental conditions in an unstable rheistasy environment. The characteristics of the deposits comprise between these two main erosive events indicate an unstable environmental conditions, with alternating phases of sedimentation and non-sedimentation, phases of soil formation, gravity-driven processes and underground water flow.

Keywords: karst sediments, Heinrich Events (HE), geoarchaeological approach

IS CURRENT GLOBAL WARMING BEING RECORDED IN POSTOJNA CAVE AND THEIR STALAGMITES?

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Since mid 1980's the mean annual surface atmosphere temperature has increased by more than 1.5 °C in Postojna. This warming trend is in agreement with many places in Europe and is consistent with the current global warming. A monitoring program has been carried out in Postojna Cave since 2009 to evaluate if the cave and stalagmites are recording this change in temperature. Most of the Postojna Cave galleries are thermally very complex, since heat is affected by dynamic air and water flows. We focus our study in Pisanovi Rov which is a gallery in which these effects are negligible. The study site is 35 metres below surface and at this depth temperature is almost stable at 8.4 °C, with a seasonal cycle <0.015 °C. However, a slight warming trend is recorded which agrees with temperature modelling considering heat conduction from the surface. Based on monitoring and modelling data a delay in the in heat transfer from the surface of approximately 20 years is expected for this particular site. In consequence, this sector of the cave is already recording the current global warming, and an increase of the gallery temperature up to 1 °C is predicted during the next 20 years. Two stalagmites were collected from this site and the record of the last decades was studied. Both samples were confirmed to be actively growing by measuring the ¹⁴C activity in the top of the samples. Proxies analyzed in those stalagmites were stable isotopes and growth rates. Stable isotopes did not provide any clear trend, and its detailed interpretation would be conducted in depth in a near future. Measurement of growth rates at high resolution was possible in one of the stalagmites due to annual laminations in the top. A correlation exists between lamina thickness and mean annual surface atmosphere temperature ($r^2=0.68$). Ventilation dynamics in the gallery are

thought to be responsible for this quick response. This implies that although the cave temperature responds ~20 yrs later to surface atmosphere temperatures, stalagmites are capable to respond within the same year, and they are clearly recording the increased temperature trend in the last 25 years. In conclusion, the current global warming is already being recorded in some of the cave galleries and their stalagmites. However, mechanisms affecting temperature transfer into the system are complex and these conclusions can not be directly extrapolated to other caves in the region or even other galleries in Postojna Cave since depend in local conditions. Stalagmite records are even more complicated and even having found one stalagmite rapidly responding to current global warming, this do not imply that other samples in the same gallery would respond similarly, since drip controls are critical and very variable from one site to other.

Keywords: global warming, cave, stalagmite, temperature, Postojna

STUDY OF INFILTRATION WATERS IN SOME CAVES OF BUDA HILLS

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Under the surface of Budapest there are more than 200 caves with total length adds up to 20 km. 90% of the studied area are built up and this fact imposes numerous dangers to the karst. We investigated quality, pollution and time changes in the infiltration waters of three caves (Szeplő-hegy-, Mátyás-hegy- and Pál-völgy Cave). Measured components of the dripping waters: pH, total hardness, constant hardness, variable hardness, basicity, hydrocarbonate, Ca^{++} , Mg^{++} , Na^+ , K^+ , Cl^- , NH_4^+ , SO_4^{2-} , NO_3^- , NO_2^- , PO_4^{3-} , COD. The infiltration waters of these caves are significantly different than the waters of other Hungarian caves. This fact is due to special geochemical properties of the epikarst (marl stratas) and high rate of the built-up area. Contamination of the measurement points in the three caves are different. In some points of Szeplő-hegy Cave we detected high pollution of nitrate and phosphate (what suggests faults of public services, unlicensed bog-holes and siccatives and agrochemical activities). The water quality of Mátyás-hegy Cave shows the highest contamination, especially in chloride (which comes from hypochlorides, hypochlorites, washing additives and NaCl). The tendentially increasing sulphate content suggests organic refuse sources. In some points of Pál-völgyi Cave the chloride contents of the waters are increasing too. Changes in the principal parameters between 1987 and 2010 are showing that the water quality of most of the meaurement points are from bad to worse.

Keywords: cave, infiltration water, contamination

VARIABILITY OF FLUVIAL SEDIMENT TRANSPORT AND ACCUMULATION OBSERVED AT KARST SPRINGS – CONCEPTUAL APPROACHES AND FIRST RESULTS FROM THE FRANCONIAN ALB (SOUTHERN GERMANY)

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Fluvial activity includes the main processes responsible for transfer of clastic material within karst areas. Nevertheless, only a few studies exist how much and when clastic sediments are formed, and which conditions are responsible for the transportation and deposition. Solely, frequent turbidity measurements were presented, but these data can be used only for qualitative interpretations. Quantitative determinations of the suspension load are scarce. Data of bedload transport are almost absent. Probably, the restricted access to active karst streams and difficult measurements are the main reasons for the little number of studies on this topic. The Muehlheim karst spring (Southern Franconian Alb, Germany) was choiced for a detailed recording of the conditions for transport and deposition of clastic material. This spring exhibits several outlets of water showing different discharge and stream velocities. In front of them is a small sedimentation area subdivided into the stream beds and zones of reverse flow and quasi stagnant water. Here the accumulation of silt and sand occurs. Afterwards, the water is outflowing the spring area within two flumes. Such a spatial constellation can be compared with caves showing constriction and widening of karst cavities. Regarding the spring area of the Muehlheim karst spring as a natural laboratory the temporal and spatial variation of hydrodynamics and sedimentological parameters can be studied. Especially, the easy access allows weekly or daily measurements depending on the hydrodynamic conditions. In detail the following data will be recorded for one year starting in winter 2009/2010 at Muehlheim: Total discharge of the karst spring, partial discharge of each outlet, determination of the stream velocity across and along the single streams at different depths, measurements of turbidity and suspension load, bedload measurements at the different outlets and facies zones using Helley-Smith sampler, weekly determination of the accumulation rate by means of simple pit traps. Additionally, temporal modifications of the sediment surface and distribution will be estimated periodically (photographic documentation of sediment bars, morphological and sediment mapping, estimation of sediment thickness, mapping of sedimentary structures). Ultimately, scope of this study is the estimation of the relations between flow velocities, discharge, transportation rate and sedimentation rate for the different fluvial facies zones. By means of recording of the fluvial dynamic and sedimentological variability the transportation and sedimentation rates can be quantified with a high temporal resolution. Such data records provide a tool for similar investigations of the fluvial activity of cave streams regarding sediment mobility. The poster will present first results of the temporal changes of sediment mobility and the relations between hydrology and sedimentology for different karst springs of the Franconian Alb.

Keywords: karst, clastic sediment, karst spring

ESTIMATION OF AVERAGE END-PERMIAN AND EARLY TRIASSIC PALAEOTEMPERATURE FROM OXYGEN ISOTOPES (VELEBIT MT., CROATIA)

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The uppermost Permian and Lower Triassic dolomites of the Velebit Mt., Croatia, were deposited on the shallow-water carbonate platform of the western Paleotethys, close to the equator. The deposits are composed of two informal lithostratigraphic units – Upper Permian Transitional Dolomite and uppermost Permian and Lower Triassic Sandy Dolomite. Detailed palaeontological and geochemical characteristics of the analysed units are described by Fio et al. (submitted).

Late Permian whole rock $\delta^{18}\text{O}_{\text{carb}}$, with respect to V–PDB, vary from -3.2 to -1.3‰ (average $\delta = -2.6 \pm 0.4\text{‰}$) and Early Triassic range from -3.2 to -2.2‰ (average $\delta = -2.7 \pm 0.3\text{‰}$). The oxygen isotopes are prone to diagenetic change if the deposits are influenced by metamorphic processes or hydrothermal fluids. Regarding very low and negative correlation of carbon and oxygen isotopes ($r^2 = -0.04$, $n = 111$) and narrow range of oxygen isotope values (1.9‰) we can assume the primary magnitude of the isotope excursions.

According to the formula $t(^{\circ}\text{C}) = 16.1 - 4.64(\delta_{\text{c}} - \delta_{\text{w}}) + 0.09(\delta_{\text{c}} - \delta_{\text{w}})^2$ (Kim and O'Neil, 1997; Bemis et al., 1998), assuming seawater $\delta^{18}\text{O}$, relative to V–SMOW to be 0‰ (Korte et al., 2005), and δ_{w} correction from V–SMOW to V–PDB -0.27‰ , average Late Permian temperature was 27.4°C and Early Triassic 27.9°C . Minimal end-Permian temperatures were 21.0°C and maximal 30.5°C , while in Early Triassic from 25.4 to 30.5°C . Our isotope measurements and calculations therefore correspond to Kiehl and Shields (2005) palaeotemperature models, assuming western Palaeotethys temperatures from 28 – 30°C , and Kearsey et al. (2009) estimating latest Permian temperatures between 26 and 29°C .

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Keywords: oxygen isotopes, palaeotemperature, Upper Permian, Lower Triassic, Velebit Mt.

NATURAL-GEOGRAPHICAL FEATURES OF BASIN OF THE UPPER KRKA RIVER, AND OGULIN-PLAŠKI VALLEY

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The purpose of this study was to analyze the characteristics of two karst area. We have used the geological origin, structure, climatic, geomorphologic characteristics and influence of soils. The first karst area is Ogulin-Plaški polje represents a transient zone between the deep and shallow karst belts and it belongs to the Dinaric karst. The most important facts causing the characteristics of the karstic hydrology are considerably dissected vertically, separated areas of pervious sediments. Under these conditions numerous smaller karstic poljes originated, Ogulin, Oštarije, Plaški. They are composed of the limestones, dolomites. The specific form in Ogulin-Plaški polje is Dobra River sink which constitutes a cave system known as Djula-Medvedica. The sink canyon is more than 30 m depth, and flooded discharges are not so rare. The second karst area is area of Krka River. Its tributaries make the system of composite valleys in the karst. The Krka valley is of polygenetic origin. In the canyon sections there are many characteristic slope relief details. On steeper slopes crumbling and collapsing is significant. River has its upper parts in the streams on the pervious rocks. The relief of the upper basin waterfalls highlights three parts: the hills, plateau with canyons and fields. The terrain descends from north to south and in this direction and provides all the rivers. Part of which will speak the most comprehensive genealogy research area Knin and Kosovo Polje, which together are long about 24 km, and built from the underlying older rocks and younger floodplain on the surface. Among the quaternary deposits emphasizes the tufa, which is important for understanding the origin of the current forms of river Krka.

Keywords: geomorphology, karst area, tufa, sink, Krka river, Ogulin-Plaški valley

GEOLOGICAL CONDITIONS FOR SPELEOGENESIS IN CROATIAN PART OF DINARIC KARST

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Till today in Croatian speleogeology 14 main types and 6 semi types types of speleogenesis were recognized. There are data for about 11500 caves in different regions of Dinaric karts in Croatia and also with different geological conditions which have influence in speleogenesis of these caves. Speleogenesis is a part of karstification and knowledge about types of speleogenesis will help in knowledge about processes of karstification. It is going to prove that speleological features in neotectonic active zones in Croatian karst always have very important hydrogeological role, such as springs or sinking holes. All these speleological features (caves) have their origin from Miocene till the begging of Quaternary, so means they are "young", and they are not in last phase of speleogenesis. With research in caves new types of karstifications, speleomorphology and velocity, direction and quantity of ground water in karstic rocks will be found. Mainly locations for such research are near neotectonics zones, with strongly hydrogeological functions of caves, near tunnels etc.. Sometimes special geophysical methods and measures were done outside and in the caves and tunnels in the line of lithostatigraphic reasons. The thirds phase solve speleomorphology. In the fourth (main) phase it will be done plenty speleogeological methods inside and outside caves. This is the longest phase duration. In fifth phase samples will be in laboratory testing. After that it will be some addition measures in tunnels. And finally all data will be collected, discussed and put on papers presentations. The research goal is to determine the types, sorts and karstification intensity inside speleogenesis, as one of the main process that exist in the karst area of Croatia. Also to determine new, unknown to date groundwater connections between caves, determine quantity, quality and types of groundwater inside the karst underground. To protect the water where there is construction of tunnels, roads, dams, airports etc. With geophysical methods it could be found correlation with results and existing caves. Numerological shows measured neotectonic moving in some karst areas. In Croatian Karst intensive constructing were made like tunnels and roads, which cross tens bigger and hundreds of little caves (together more than 1000 caves we found in civil engineering activity). As the Karst is built of water porosious rocks, pollutions is direct, fast and intensive. In case the groundwater moving is not determined and known, there might be catastrophic consequences in certain areas. On basis of speleogeological research the quantities, quality and way of groundwater protection shall be determinate when new construction is begun in the Karst. This is of essential importance in the tectonically active zones. This is the reason why neotectonic measurements are made inside caves. Speleogeological research in the karst areas shall directly add new data necessary for geological sciences in order to make detailed hydrogeological maps and structuraltectonical maps. Besides this, the knowledge on speleogenesis as one of the processes inside karstification shall be additionally extended. Underground water distribution water boundaries shall be finally determined in areas where are no drilling results, or where they are not possible.. Natural recourses (groudwater) research fits significantly into the scope of this research, because the possibilities of possible ground water accumulation exploration may thus be determined directly. The rate of flow, physical and chemical properties shall be measured, and the groundwater quantity estimate shall also be made. It is of significance to apply the results of speleohydrogeological researches and building tunnels and underground accumulations in Karst. For instance- there are around ten tunnels

being built in Croatia now, and soon construction of more tunnels shall begin. These are going to be cardinal construction projects, which by no means should alter the direction, quantity and quality of groundwater flow, which shall, certainly, The application of speleogeological research results was essential in making detailed hydrogeological maps of karst areas, in carrying out morphostructural and tectostructural analysis and in getting basic knowledge on speleogenesis, karstification processes. As the area in question is being researched in recent history by Croatian experts and scientists only, the literature in the world referring to this knowledge is tied to the results obtained by our people. Results of our speleological researches in the Kordun, Gorski kotar, Lika, Istria, Velebit, Dalmatia. Velebit and Biokovo areas are significant. More than 11500 caves in the Croatian Karst have been registered and researched up till now. This is a very large number in comparison to other countries in the world. The success is even more significant, if the small number of our scientists dealing with this matter or having dealt with this matter is considered. But, today's modern geoscience, and especially speleohydrogeology connect only some parts of descriptive speleology, morphology, and special attention is paid to groundwater research and speleogenesis, as well as various types of processes belonging to the extended idea of karstification which also includes the idea of "okršavanje", (because "okršavanje" is not the only process going on in the Karst areas. Determination of the karstification types has been made, general division of caves with water according to speleogenesis. At several points inside caves, neotectonic measurements are being made. The results are significant, but the network of caves measured should be made more dense. Regretfully, some of the instruments have been lost or taken away due to war circumstances. During construction of several tunnels choice of water protection and drain system were made possible on basis of speleohydrogeological research. The savings at construction were significant. A great part of our Karst area has not been researched thoroughly enough in the caving hydrological sense. Around 35 % of all caves in our country are those which in some way have groundwater in them. But, this means that it is possible to use it or protect it. Preliminary research using speleohydrogeological methods have been carried out only on several locations (eg. Crveno Jezero - The Red Lake). This applies primarily to the cave structures very reach in groundwater. Among other, caving diving techniques had been used for such research. Direct measuring of neotectonic activity within caves has not been evidenced yet in the world, nor are there connections made between neotectonic research and speleohydrogeology. Accent is put more on solving certain problems of some caves.

Keywords: cave, speleogenesis, karst, Dinaric karst, Croatia

HISTORY OF RESEARCH AND AN OVERVIEW OF ANCHIALINE CAVES IN CROATIA

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The eastern Adriatic coast is a part of the karstic Dinaride mountain chain. With more than 6278 km of the coastline and over the 1200 islands and isles, the Croatian part of the shore comprises more than 90 % of the total length. However, only 64 anchialine caves have been partially explored and/or described in the literature up till now.

The first information of an anchialine cave in Croatia was published by S. Vuksan in 1909. The next exploration was done by the Croatian geologist J. Poljak in 1920. Since then various researchers explored anchialine caves along the Adriatic coast, but these studies have mostly been sporadic and unsystematic. Each of the explorers focused on a different research aspect. Biology has been most studied and this was done by S. Karaman, B. Sket, R. Riedel and B. Ozretić. B. Sket also published the ecological scheme of the anchihaline water bodies: salinity stratification, local oxygen depletion, and faunistic stratification by biotic exclusion. Great contribution to subsequent explorations was made by the geographer I. Baučić who completed the list of caves on the Adriatic coast and islands. Geology was studied by S. Božičević and paleontology by M. Malez. Recently T. Rađa sampled fauna of the anchialine caves, and some research was done by the Natural History Museum of Rijeka and the University of Zagreb.

Research became more intense after 2005 due to B. Jalžić and the cooperation of Croatian Biospeleological Society, Croatian Natural History Museum, Ruđer Bošković Institute and Institute for Oceanography and Fisheries. Extensive interdisciplinary field work was done and various data on water, sediment and biota of anchialine cave environments were published.

All anchialine caves in Croatia are situated near the shoreline (up to 300 m) and most of them have a pit-like entrance. They are mostly small and usually speleologically not interesting; the longest one is 245 m long cave Medvjeđa špilja, and the deepest is Jama u Podstražišću pit with 45 m deep dry part and over 50 m deep water layers. Tides are more or less notable in all anchialine caves and in several a stream of fresh water which flows over brackish and marine layers was noticed. Caves mostly don't have clear connection to the sea.

There are few very specific anchialine caves in Croatia: the cave Rudnik kod Medveje is of artificial origin, the caves Sumporača velika and Sumporača mala are sulphuric, cave Orljak is connected to the estuarine (brackish) water. Anchialine cave Jama Vrtare Male is one of the greatest finding sites for Pleistocene fauna.

From the biological aspect anchialine caves are very interesting habitat for a variety of phylogenetically and biogeographically interesting animal taxa. For instance deep-sea sponges are known from several localities. Also, 21 various animal taxa was described from 7 anchialine caves in Croatia. The most remarkable is the cave Šipun, a type locality for 14 animal taxa, 8 troglobionts, 2 troglaphiles and 4 stygobionts.

Tourism, pollution and rapid urbanization are major causes for endangerment of anchialine habitats. All speleological objects as well as all subterranean fauna is strictly protected by the Croatian laws, however, active protection is still missing.

Keywords: anchialine caves, Dinarides, Croatia

COMPARATIVE STUDIES ON MICROBIAL COMMUNITIES OF SOILS FROM TWO HUNGARIAN KARSTIC AREAS

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From two characteristic karstic areas of Hungary - Aggtelek National Park and Tapolca-basin – 17 different soil samples were taken in autumn 2009. We analysed the most important chemical properties of the soil samples: humidity, pH, acidity and organic matter content. The physical characteristics of the samples were determined by grain size analyses (by laser-diffraction method). Microbial biomass C and N were determined by chloroform fumigation extraction method. The activity of microorganisms in soils were followed up by measuring basal- and substrate induced respiration (RESP and SIR) using gas chromatography. The phylogenetic diversity of bacterial communities was investigated by 16S rDNA based Denaturing Gradient Gel Electrophoresis (DGGE). In each soil samples multiple microbial biomass C- than N- values were detected. The lowest MBC/MBN rates could be calculated from the samples of the shallowest soil layers. Higher biomass as well as RESP and SIR values were characteristic to the surface and near-surface soil samples. The highest RESP, SIR, biomass C and N values were measured in the black rendzina soils from Aggtelek. The soil type influence on bacterial community structure was confirmed by the DGGE results as phylogenetic diversity of black rendzina soils was the most different. On the basis of each investigation, microbial communities of other soil samples separated mainly according to the sample depths and types, irrespectively of the sampling sites. The study was carried out in the frame of grant project of the Hungarian Scientific Research Found (OTKA) No. 79135.

Keywords: microbial activity, soil, karst

SEISMOTECTONIC STUDY OF TWO CAVES IN RHODOPES MTS, SOUTH BULGARIA

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The caves are a medium favorable to the conservation of damaging evidences caused by tectonic events. The aim of this paper is to report the results of the accomplished seismotectonic investigation of two caves in Rhodopes Mountains, Southern Bulgaria. The Yamata Cave and Shepran Cave are located in the Dobrostan karst massif of the Rhodopes, south-east of the city of Plovdiv. Both caves are located in the hanging wall of the clearly morphologically expressed Dobrostan fault. The spatial orientation of the fallen and inclined stalagmites, recovered with new generations of speleothems is measured. The rose-diagrams of the preferred directions are similar for the two caves. The results from the U-series dating of deformed speleothems in Yamata Cave suppose an activation of the Dobrostan fault during the Pleistocene.

Keywords: speleothems, paleoseismology, Rhodopes Mts, Bulgaria

SHORT HISTORY OF DINARIC KARST RESEARCH

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Dinaric Karst is the landscape where the sciences of karstology and speleology took their origin and started to develop thus contributing several karstological terms to international karst terminology. In the antiquity already some of karst phenomena were mentioned from the Dinaric Karst, but the author considered published sources mostly from the 16th century on, when the modern karst research started. In those times Dinaric karst belonged to different states and the author tried to use adequate sources. It was a difficult task yet not completely achieved but it presents a relatively new approach. For the older period some Venetian and Turkish works are included. Emphasized are later Austrian and Austro-Hungarian researchers working in Bosnia and Herzegovina as well as Serbian researchers. The paper which can be no more than an unpretentious overview mentions early philosopher N. Gučetić discussing karst phenomena, and travellers through the Balkans like B. Hacquet, B. Kuripečič, E. Čelebija, and A. Fortis, and also well-known geomorphologists and speleologists A. Penck, E.-A. Martel, J. Cvijić, A. Melik, and J. Roglić.

Keywords: hystory of karst exploration, Dinaric Karst

ROLE OF HUMIC AND FULVO ACIDS IN CARBONATE WEATHERING, EXAMPLE FROM SW PART OF VIS ISLAND

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Carbonate rocks cover more than 50% of Croatian territory. Together with tectonics, carbonate weathering is the main driver (most important process) of karst relief formation. For area of investigation south-western part of the Vis Island was selected. Vis Island represents symmetric anticline; east-west orientated, and is built of Cretaceous carbonate sediments, clastic sediments with gypsum and anhydrite in association with pyroclasts as well as spilites and diabases of Triassic age, and quaternary cover. Due to intensive agricultural production, surface of Vis Island is almost completely covered by thin soil cover, with anthropogenic terra rossa, calcocambisol and colluvium as most common soil types. Since, surface of the Island is covered by soil cover, percolated water that reaches carbonates in the base is enriched by dissolved humic and fulvo acids from organic matter. That dissolution causes carbonate weathering that results in different morphological forms compared to those exposed only to meteoric conditions. Three locations in the south-western part of the Vis Island were selected; one covered by calcocambisol, and two by anthropogenic terra rossa. Soil analyses included determination of humus content (Tjurin method), composition of humus (Schnitzer, 1982) and E4/E6 ratio by UV-VIS spectrophotometer. Humus content varied from 4.9 to 8.7 % on first location (calcocambisol), 1.8 to 4.8 % on second (anthropogenic terra rossa) and from 3.5 to 7.2 % on third location (anthropogenic terra rossa). In all samples E4/E6 ratio exceeded 5, which indicates fulvo acids domination, therefore increases carbonate weathering. Since soil layer that covers carbonate rocks retents more moisture, time of rock exposure to such solution is prolonged. Therefore, weathering of those rocks results in different morphological forms compared to those exposed only to meteoric conditions.

Keywords: Vis Island, humic and fulvo acids, soil cover

GEOECOLOGICAL FEATURES AND TYPOLOGY OF KARST LANDSCAPES OF THE EASTERN PART OF THE VIS ISLAND (CROATIA)

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On the eastern part of the Vis Island the analysis and typology of karst landscapes was conducted. Analysis of structural and functional characteristics and patterns, obtained from parameters of lithology, geomorphology (slopes) and vegetation, was the base for this kind of research. Main goal was to distinguish complex landscape types and to determine their structural and functional features, on the basis of their dimensions, morphology, frequency of occurrence in the landscape and their interrelations. Since specificity of this landscape features is of great influence on stability and sensitivity of existing geo and ecosystems, as well as on their internal and external dynamics this kind of research had to be provided. Obtained results can be reliable indicators of abiotic and biotic landscape elements balance, as well as of existing processes. They can be also useful as methodological framework for estimation of future landscape and environmental changes in whole and for future landscape management relevant for preserving karst landscapes of the Vis Island, as well as other similar areas in Adriatic and Mediterranean. For more detailed analysis and evaluation of specific parameters relevant for determination of complex landscape types we used GIS. It enabled us to synthesise, through determination the relationships between elements of internal structure, spatial function, interrelations between landscape types and their complex influence on natural and changed cultural landscapes and environment of the eastern part of the Vis Island.

Keywords: geoecology, karst landscape, typology, GIS, Vis Island

WHAT DO PEOPLE KNOW ABOUT DINARIC KARST AT ALL?

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By its origin, the Dinaric Karst is a natural science concept and its perception out of professional circles is still very modest, and karstologists are not sufficiently aware of it. It also means that the ordinary inhabitants of the Dinaric Karst are generally not aware that they live on the unique karstland. Social sciences have spread the information about the Dinaric Karst outside the scientific circles, but in some aspects it resulted with a negative perception of it, because the most famous

attribute assigned to the Dinaric Karst is “violent Dinaric mentality” what is strongly connected with political violence. Interesting fact is that both of mentioned perceptions are significantly influenced by Jovan Cvijić, who is generally considered to be the founder of karstology. This cultural use of karst goes hand in hand with industrial use, which sees karst as a desert landscape that “should be improved and enriched”. Contemporary ecosystem visions of karst provide a perspective for complex evaluation of the Dinaric Karst, which would enable its whole public image, and it should be followed by the sustainable use, protection and popularization of this unique geoecological space.

Keywords: Dinaric Karst, perception, "Dinaric mentality", the traditional cultural areal

CAVE FAUNA OF THE DINARA MT., CROATIA

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Dinara Mt. is at 1913 m above sea level, situated in the middle of Dinarides on the border between Croatia and Bosnia & Herzegovina. State Institute for Nature Protection financed analysis of the literature and collection data of the cave fauna during 2009. Biospeleological cadastre for Dinara Mt. and surrounding springs was made and the most interesting caves, but also karstic springs, were pointed out. A total of 99 different taxa have been recorded, 26 of them being troglobites and 13 stigobites. Among analyzed material especially interesting are further terrestrial (A) and aquatic (B) invertebrate taxa: A: Araneae with species *Troglohyphantes dinaricus*, *T. wiebesi* and *Pseudotegenaria bosnica*; Pseudoscorpiones: *Chthonius radjai* and *Microchthonius rogatus*; Isopoda: *Alpioniscus verhoeffi*; Diplopoda: *Macrochaetosoma troglomontanum troglomontanum*; Collembola: *Oncopodura cavernarum*; Coleoptera: *Lovricia jalzici*; B: Amphipoda: *Typhlogammarus mrazeki*, *Niphargus salonitanus* and *Niphargus trullipes*; Isopoda: *Sphaeromides virei mediodalmatina*; Decapoda: *Troglocaris pretneri* and *T. neglecta*. Ten taxa are endemics for Dinara Mt. and 12 taxa are endemics for Croatia. Ten endangered taxa are listed in the Red book of Cave fauna of Croatia (in press). According to high biodiversity and endemism of flora and fauna, Croatian part of Dinara Mt. will be protected in appropriate level of protection according to Nature Protection Act. Numerous stenoendemic species of cave fauna have been identified from Dinara region so far. Wide areas of

Dinara Mt. are still completely unexplored and only through future systematical speleological and biospeleological exploration a more complete checklist of cave fauna can be made.

Keywords: cave fauna, distribution, biodiversity, Dinara Mt., Croatia

SPELEOLOGICAL EXPLORATIONS AND GEOMORPHOLOGICAL PROPERTIES OF DEEP PITS IN CROATIA

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The data about the deepest and longest caves and pits in Croatian part of Dinaric karst with general geomorphological properties were presented. There are 53 pits deeper than 250 m, 15 of them are deeper than 500 m and three deeper than 1000 m. The Mt. Velebit and Mt. Biokovo karst areas are conducive to the formation of deep pits. Explorations of deep pits in Croatia started in 1957 when pit Čudinka (depth 203 m) was explored. In 1975 on cave expedition in pit Puhaljka the depth of 318 m was reached. In pit Ponor Bunovac in 1977 the depth of 534 m was reached making it first pit deeper than 500 m in Croatia. In 80s several deep pits had been explored on Biokovo. Expeditions to pit Lukina jama in National park North Velebit were organised in period 1993-1995. Cave system Lukina jama—Trojama is explored to the depth of 1392 m which made it 9th deepest pit in the world at that time, and is still the deepest cave in Croatia. In 1994 on the depth of 1349 m Zoran Stipetić-Patak and Teo Barišić dived through 57 m long and 6 m deep siphon. In Slovačka jama, 1320 m deep pit on North Velebit, it was explored in period 1995-2002. In Amfora located on Biokovo the exploration lasted in period 1998-2002. In 2003 pit Velebita was discovered in National park North Velebit, where during last years the depth of -1026 m was reached and the exploration still lasts. Velebita is today 3rd deepest Croatian cave. In Velebita, the one of the world's longest verticals was found with the length of 513 m.

Keywords: deep pits, speleology, Velebit Mt., Biokovo Mt., Croatia

ISOTOPIC SIGNALS FROM SPELEOTHEMS OF POSTOJNA CAVE, SLOVENIA

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Investigations of speleothems and cave environment can provide insights into climate and environmental changes. Postojna cave (Slovenia) is one of the most famous karst caves in South Eastern Europe. Numerous carbonate deposits (flowstone, speleothem) formed during last 50 ka can be used to investigate climate changes during the last glacial and Holocene because variations in their growth rate and isotopic composition reflect climate changes on the land surface above the cave. There is also evidence that vegetation above the cave was changing during the past. Currently, the land area is covered by forest but 150 years ago there was a bare pasture, meadow. These recent changes in land use may additionally effect the cave environment. In planned work we will asses to which extent these changes can be reflected in isotopic composition of flowstone in the cave system. Additionally, there was also a change in cave structure itself through time. Some parts of the recent cave system were isolated at about 30 ka before present. These changes can be detected by isotopic investigations of speleothems also. We will test the hypothesis that changes in isotopic composition of speleothems on the path from the cave entrance to the deep and stable cave environment are related to seasonal changes in air circulation. There are pronounced winter and summer types of circulations with condensation of water in summer and evaporation in winter time. These seasonal variations should cause distinct differences in the isotopic composition of recent precipitated carbonates in young speleothem formation.

Keywords: Stable isotopes, Postojna cave, Paleoclimate research, climate changes, speleothems

GEO PARK - MODE OF GEOHERITAGE CONSERVATION AND PROTECTION ON THE ISLAND OF RAB

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The Island of Rab, a large and most developed north Adriatic island, is distinguished by great geological and biological diversity, rich historical and cultural heritage, and also a hundred years long tradition in tourism. Can it have more than it has? Can it show more than before? Can it attract new visitors with different interests than of those who eagerly await for summer on the beach? Can this island develop in new directions? There is a single answer to all of the questions: YES! Let's establish a

geopark. An idea of a geopark, born in Europe some twenty years ago, led to foundation of the European Geopark Network ten years ago and several years later the Global Geopark Network under auspices of UNESCO. The “geopark” as a form of integral approach to a sustainable development of a local community or a region, based primarily on its geoheritage, brings us to the Island of Rab, an island with nearly 10000 inhabitants, an island whose fine mediterranean climate had always attracted many tourists and even those world famous. Even prehistorical people were there and many artifacts found on Lopar testify on their presence during the Pleistocene when the Adriatic coast had been far south. What then makes the Island of Rab so unique? Its geological diversity on such a small area of about 1000 km² (including three islets Sv. Grgur, Goli and Dolin) manifests in various rock types, from hard limestone rocks to sandstones and fine sands, which in favorable climate produced different soils good for diverse vegetation specific for this island. In general, the Rab Island is composed predominantly of Cretaceous limestones and of Tertiary and Quaternary clastic deposits. The geological structure is dominated by folded Cretaceous limestones forming anticlinal ridges and Tertiary clastics preserved in sinclines. One major reverse fault is present along with many smaller ones. Rab island and the islets structurally belong to the Dinarides, and especially Grgur shows a complex tectonic structure not yet interpreted. Predominating carbonate rocks are characterized by variety of karst features. The key geological feature are 3-D exposures of Paleogene clastics - an excellent training area for the study of SEQUENCE STRATIGRAPHY OF PARALIC CLASTICS. Rab Island tidal flats are excellent for the study of TIDAL SEDIMENTARY PROCESSES and AEOLIAN SEDIMENTARY PROCESSES. Mountainous (carbonate) part of the island has interesting KARST PHENOMENA and KARST HYDROGEOLOGY. Rab island also has many unique geomorphological features, such as erosional features, badlands, weathered rocks with unique shapes and textures, and over 300 fresh water springs. This distinct geodiversity of Rab island inspired us to propose a project “Geopark Rab Island” that should enable sustainable conservation and protection of the geoheritage. Geopark as an integral form of development includes natural heritage with geoheritage as a fundamental source, all-life education, challenge to new resources and expectations, alternative in tourism, local development, and already recognized historical and cultural heritage. A non-scientific approach to local authorities was crucial to explain the values and potentials of the rich geological heritage they see in their everyday life but did not recognize. This was the first successful step towards a projected sustainable conservation of the Rab island geoheritage and the benefits it should bring to the local communities. The long-term goals of the project are formal establishment of the geopark, foundation of an international educational and training center that will facilitate various types of programmes for all-age groups, and recognition of the Geopark Rab Island as an international educational polygone for geoscience. Worthwhile to mention is the fact that continuous education of the local population and visitors through life-long learning programmes is the best way to preserve and protect geological heritage. About 100 km long network of geological trails is part of an outdoor learning program with help of handy printed guide. Rab with its three islets, which will be included in the geotrail network, make an excellent multidisciplinary training ground both for students and scientists. Its closeness to the mainland gives an excellent opportunity to study geology of the coastal Dinarides within an organized study course or workshop. In perspective, such continuous educational visits will encourage the local population to learn and motivate them to protect their own geoheritage as part of sustainable development of Rab communities.

Keywords: geopark, geoheritage, protection, Rab, Dinarides

PALAEOKARST SURFACES RECOGNIZED IN LOWER JURASSIC CARBONATES ON VELEBIT MT., CROATIA

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Numerous surfaces showing evidence of ancient exposure to subaerial conditions and dissolution from meteoric water are recognized in shallow-marine carbonates recorded on Velebit Mt.. Each of these surfaces point to subaerial exposure of various duration, but few of them show macroscopic and microscopic diagenetic features produced during prolonged chemical dissolution and associated modification of a carbonate rock, i.e. show signs of karstification. Such surfaces are therefore called palaeokarst surfaces (Choquette & James, 1988). Two potential palaeokarst surfaces are recognized in the studied succession and will be here described. Two sections of Lower Jurassic carbonate succession that belonged to the shallow inner ramp environment of the Adriatic-Dinaridic carbonate platform (ADCP) were studied in detail. Both sections are situated in the Velebit Mt. area (Kubus and Mali Alan passes). Today, these localities are 50 km apart. According to first appearance of foraminifer *Mesoendothyra* sp. and other characteristic fossil assemblage, studied succession is determined to be of Early Jurassic, or more precisely of Early Sinemurian age (Velić, 2007). Palaeokarst surfaces are recognized due to the data collected in the field (sedimentary structures) and during laboratory investigations (microfacies analysis from thin sections). In the field, these surfaces are of irregular relief, often show brecciated appearance due to the dissolution processes. Upper bedding planes show centimetre to decimetre sized irregular and circumgranular cracks filled with lighter coloured, often early diagenetic dolomitized limestone rock. Rarely these cracks contain yellow-brownish marly sediment. Cracks observed on upper bedding planes often penetrate as irregular fissures up to 15 cm downwards into the bed. The angle of dip of studied beds is 65°, but observed fissures pervade perpendicularly into the bed in relation to the upper bedding plane, pointing to their palaeokarst character and excluding the possibility that they are result of a recent karstification. Fissure walls are sharp and rough indicating that dissolution occurred in completely lithified rock. Fissure infill contains many angular millimetre to centimetre sized fragments of host rock. Dolomitized limestone found as fissure infill probably formed during marine transgression that followed exposure period, while yellow-brownish marly sediment, found on rare occasions, is probably washed away due to the same event. Limestones showing palaeokarstic features mostly have micritic texture (mudstones and wackestones) and under the microscope show small cracks and voids sometimes with preserved brownish coating on its wall indicating corrosion in subaerial conditions. According to the observed features, two surfaces studied in Lower Sinemurian carbonates are recognized as possible palaeokarst surfaces. Whereas these surfaces display micro-relief (penetrating few cm up to 15 cm into the rock) and no caves or larger dissolution features were observed, they can be attributed to a micro-karstification of lithified carbonates or formation of epikarst underneath a soil cover (Wright, 1992; Hillgärtner, 1998). These two palaeokarst surfaces are recorded at both studied sections and correlate very well, indicating contemporaneous subaerial exposure event that took place on the studied part of the ADCP and lasted long enough for palaeokarst structures to develop.

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Keywords: palaeokarst surfaces, carbonates, Early Jurassic, Velebit Mt.

HYDROGEOLOGICAL INVESTIGATIONS IN THE WATERSHED OF SPRING PALATA, CROATIA

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Palata is a gravity spring which is tapped and included in the local water supply system of the Neretvansko-Dubrovačka County, Republic of Croatia. This spring is situated on the Adriatic coast. Inflow area of this typical karsts spring is composed of the Mesozoic carbonate rocks and minor part of Eocene Age flysch deposits. Occurrence of the spring is related to the fault contact upper Triassic dolomites and Eocene Age flysch deposits. The aim of this survey is to define location of waste management center and confirm hydrogeological characteristics in the watershed of the springs between Luka Slano and Rijeka Dubrovačka. Ground water flow is established by hydrogeological investigations with dye-tracing techniques, respectively. Dye-tracing was done with 48 kg Na-fluorescein which was poured into the pit Zadiljke. Observed springs are situated on the Adriatic coast at the distance of 6.0 – 17.2 km from the pit Zadiljke. The apparently velocity of the monitored spring Palata is 6.07 cm/s. There is no confirmed connection between the pit Zadiljke and springs Usječenik, Studenac and Ombla by ground water analysis. Investigation showed that the watershed of the spring Palata does not belong to the springs: Usječenik, Studenac and Ombla. Results of the ground water dye-tracing test shows that the pit Zadiljke is directly connected with spring Palata in the settlement Mali Zaton.

Keywords: karst, groundwater protection, dye-tracing techniques, spring Palata, Dalmatia

HYDROCHEMICAL CHARACTERISTICS AND REGIME OF OPITSVET - BEZDEN KARST SPRINGS (BULGARIA)

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Opitsvet-Bezden karst springs are located on the southern slopes of the Western Balkan. They represent a complex of separate springs with a total flow rate often more than 1000 l/s. The catchment area is built of Triassic and Jurassic carbonate rocks. The recharge of karst groundwater is mainly from precipitation and surface waters. The data from water chemical analysis of the three main springs are taken under consideration. It is established that they have relatively similar nature and genesis, which indicates the uniformity of hydrogeological karst system and presences of common saturated zone. The variations of springs flow rate have not got direct effect on groundwater chemical composition. The relatively high values of variation coefficient and concentrated water outflow to surface imply groundwater movement through wide channels. However, there are some differences between the springs which could be explained by some hydrodynamic special features. The most western source, the spring Opitsvet, has the lowest dynamics of changes of its main hydrochemical parameters. This fact and its relatively high total dissolved solids give a reason to suppose that the spring drains the deeper parts of the saturated zone. Its higher temperature of 19-20°C and weak indications of the presence of dissolved helium suppose deeper recharge through faults. The other two springs, Bezden and Bistretz, have got similar hydrochemical features with variable values of the basic parameters due to draining of the "fast flow" through them. Relatively high maximum value of Mg^{2+} in waters of the two springs during higher flow rates is due to increasing the role of the infiltration of surface waters at the eastern part of the karst basin.

Keywords: karst springs, hydrochemical characteristics, regime, Bulgaria

MODERN CALCITE DEPOSITIONS RATE ON ARTIFICIAL SUBSTRATE IN THE DINARIC REGION. PRELIMINARY RESULTS FROM SREDNJA BIJAMBARSKA CAVE (BOSNIA AND HERZEGOVINA)

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Nowadays there is a rapid growth in the scientific interest towards stalagmites and stalactite as proxy for determination of paleoclimatic settings. However, the relationship between calcite deposition and the surrounding cave environmental conditions is not yet fully understood and may hide important clues for a better interpretation of data recorded in speleothems. In addition, the calcite deposition subtract inorganic carbon from dripping water and thus participate to the overall carbon

dioxide balance of the unsaturated zone. In this study three dripping sites have been monitored monthly for a total of 5 months by measuring flowrates and analyzing water composition. In addition external and cave temperature have been recorded. Under each drip site have been left a circular sand blasted glass tablet with a diameter of 8 cm. The tablets have been replaced monthly and after drying at constant temperature (105 °C) weighted on an analytical balance with a resolution of 0.1 mg. The preliminary results show deposition rates in the approximate range between 0.5 mg/d and 1.5 mg/d. The variability of deposition rate has been found to be influenced mainly by drip rate. It is however expected that with the future increase number of samples and wide seasonal coverage other parameters may become significant in effecting the quantity of calcite left on the tablets.

Keywords: calcite deposition rate, stalagmite, paleoclimate

THERMOMINERAL WATER OF OVCAR BANJA SPA, DINARIDES OF WESTERN SERBIA

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The Ovcara Banja Spa is situated in central part of Serbia, 60 km far from Belgrade. The Western Morava River that flows through the Ovcara Banja Spa has formed a gorge stuck meander, in the middle of which, a thermo mineral water discharge has been detected. The area of the Ovcara Banja Spa is characterised by moderate continental climate. The mean perennial sum of rainfall amounts about 731.1 mm, while the mean perennial air temperature amounts 10.6°C.

As regards to the geotectonic point of view, the area of the Ovcara Banja Spa belongs to the belt of the Inner Dinarides of Western Serbia, with mountains of Dinaric strike. The geologic structure of the terrain is highly complex. Sedimentary rocks of Triassic, Jurassic, Cretaceous, Miocene and Quaternary ages are distributed in the area of the Ovcara Banja Spa.

The most distinctive fracture structure in the area of the Ovcara Banja Spa is of the NW-SE strike direction. It is made of mutually parallel reversible faults with dimensions ranging from hectometre to kilometre, and they all together constitute an overthrust. The NE-SW strike is another prevailing fault strike, normal to the previous one. These fracture systems have conditioned the formation of the Ovcara–Kablara Gorge.

In the area of the Ovcara Banja Spa, in relation to a structural type of porosity, a compact aquifer within alluvial sediments of the Western Morava River, a karst aquifer within carbonate sediments of Upper Triassic and Cretaceous ages, a fissure aquifer within the conglomerate of Middle Cretaceous and sediments of Middle and Upper Miocene can be singled out. The rock complex singled out as a diabase-horn slate formation has been classified as a conditionally “arid region”.

A karst aquifer in the area of the Ovcara Banja Spa is the most significant one as regards to the point of view of the possibility of forming, storage and tapping of thermomineral groundwater. Carbonate

strata of Triassic age are largely distributed in the region of western Serbia and they can be followed along the whole Inner Dinarides belt. Almost all mountains with Dinaric northwest-southeast strike are made of Triassic limestone, and the groundwater stored in the karst aquifer formed in the mentioned sediments has regionally essential reserves.

The carbonate sediments of Triassic age are represented by massive and locally dolomitized limestone occurring in the form of blocks with the width of 500 to 1000 m, and length of 2500 to 4000 m. The mentioned blocks are in the process of overthrust carried to the surface of the terrain. The vertical circulation of water along preferential directions is characteristic of carbonate sediments of Cretaceous age, which, as well as sediments of Triassic age are characterized by high fissility and karstification. Atmospheric precipitation contributes mostly in recharging of a karst aquifer. Besides the infiltration of atmospheric precipitation, a karst aquifer is recharged, additionally, by the inflow of water from surface streams.

Thermomineral water of the Ovcara Banja Spa is formed within Triassic and Cretaceous limestone. The way of formation of the Ovcara Banja Spa thermomineral water has not been determined completely. It is assumed that water infiltrates and passes through the limestone of Triassic age within which it is heated at certain depths. The occurrence of thermomineral water at the surface of the terrain is related to fault zones in the carbonate complex. Thermomineral water of the Ovcara Banja Spa discharges to the compact aquifer formed within alluvial sediments of the Western Morava River where it is mixed with the ground water formed within the Western Morava River alluvium.

Thermomineral water of the Ovcara Banja Spa is drained both in natural and artificial way. The thermomineral water is drained in a natural way by linear discharging into the Western Morava bed. Thermomineral water on the territory of the Ovcara Banja Spa used for balneology purposes is tapped by a dug well at a depth of 10 m. After conducted pumping tests, the well capacity of $Q \sim 50 \text{ l/s}$ at the temperature of 37.5°C for the lowering of 2 m is determined, while the static level amounts 4 m from the surface of the terrain.

Thermomineral water of the Ovcara Banja Spa was discovered during working of the IB -1 test hole, within which the water temperature at 60°C was measured at a depth of 48 m, where the drilling was completed.

On the basis of previous explorations, it can be assumed that thermomineral water at the temperature ranging from 70 to 80°C can be obtained at depths of 1000 m (Simic V. 1990).

A calcium ion plays a dominant role in the composition of mineral water of the Ovcara Banja Spa, while a hydrocarbonate ion is the most distributed one as to anions. The high content of calcium, the mineralization of 636 mg/l, the dry residue of 442 mg/l, pH-7, as well as the overall hardness of 18.8°C by Clut (Dimitrijevic 1975) point out the formation and transport of this water through limestone sediments. Among colloidal solutions, silica, aluminium and iron oxide are present in the mineral water, and there are also sulphur free hydrogen, free carbon acid, little lithium, strontium, and caesium. As to a gas content, thermomineral water of the Ovcara Banja Spa is characterized by the content of carbon dioxide (50 mg/l), hydrogen sulphide (50 mg/l) and radioactive radon (3.7 Bq/l). Thermomineral water of the Ovcara Banja Spa contains the following micro components: lithium, rubidium, caesium, barium, bromine, iodine, cobalt, phosphorus, fluorine and manganese.

On the basis of physical properties and chemical composition, thermomineral water of the Ovcar Banja Spa is classified into a group of low mineralized hydrocarbonate–earth alkaline homeothermal water (Dimitrijevic, 1975). The basic physico-chemical properties of thermomineral water of the Ovcar Banja Spa are represented in Table.

Dug Well	Well Depth (m)	T (°C)	pH	M (mg/l)	Na ⁺ (mg/l)	Ca ²⁺ (mg/l)	Mg ²⁺ (mg/l)	HCO ₃ ⁻ (mg/l)	Cl ⁻ (mg/l)	SO ₄ ²⁻ (mg/l)	CO ₂ (mg/l)	H ₂ S (mg/l)	O ₂ (mg/l)
	10	37	6.9	636	22	74	36	427	8	32	50	0,1	10

The obtained value for the absolute age of this water calculated by the Kozlov formula is 320 000 years (He/Ar x 25 x 106).

Thermomineral water of the Ovcar Banja Spa is used for curing of rheumatic, neural, and skin diseases, and injury consequences. There are cured: rheumatic diseases, and degenerative rheumatism, spondylosis, and arthrosis, consequences of bone fracture, muscular tissue, skin diseases.

HYPOGENE SPELEOGENESIS IN THE FOOTHILLS OF THE JELOVICA MASSIF (NW SLOVENIA): EXAMPLES FORM TURKOVO BREZNO AND JERALOVO BREZNO CAVES

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In Slovenia, known as the country of classical karst, caves of predominantly hypogene origin have not been described in the literature so far. However, individual rock features and parts of the “common” caves have been classified as phenomena related to some past hypogene phase of cave development (Osborne, 2008; Knez & Slabe, 2009).

Large calcite crystals have been reported from individual caves and quarries in the surroundings of the Jelovica massif in the Gorenjska region (NW Slovenia) by cavers and geologists attracted our attention as possible indicators of hypogene speleogenesis. In this study, two caves located in the lower parts of isolated limestone hills considered as south-eastern detached erosional patches of Jelovica massif in the hilly area towards the Ljubljana depression have been investigated. A relatively thin, not much over 100 metres thick, Middle to Upper Triassic carbonate succession overlying the Middle Triassic volcanogenic and/or Lower Cretaceous siliciclastic deposits hosts the caves. In this area various carbonate and non-carbonate Mesozoic rocks are overlain by Oligocene deposits, mainly conglomerate and marl. The area is dissected by a few distinctive NW-SE striking faults that still control the position and discharge of one mineral and a few subthermal and thermal springs.

Turkovo brezno cave in Mali vrh (821 m a.s.l.) above Rovte village is a 892 m long and 92 m deep labyrinth cave. The main passages are approximately 5 metres wide and up to 10 meters high, while side dead-end and looping channels are narrower and lower. The central passage is a 75 m long, up to 10 m wide and more than 10 m high slightly deepening conduit. Jeralovo brezno cave in Rovnik (707 m a.s.l.) close to Njivica village is an approximately 500 m long and 80 m deep cave. In general, its passages are narrower, lower and even more interwoven than in Turkovo brezno cave. The biggest chamber, which is located in the lower part of the cave, is over 30 m long, up to 6 m wide and up to approximately 10 m high. Both caves reveal a relatively complex 3-D pattern of passages guided by faults or joints. The main trunks of the caves are surrounded by channels smaller in size arranged in network or even spongework mazes or smaller channels forming loops along the major joint or set of joints. Relatively large central chamber/conduit, dead-end passages, abrupt variations in passage cross-section and rising shafts are common in both caves. Commonly two or more passages developed close together along the same joint are separated only by thin partitions and remnant pillars. Locally passages are jointed together by spherical/elliptical rounded windows or amalgamated along their longer section giving rise to the keyhole shape of the cross section of the joined passage. In places the rock partition between passages has collapsed.

In general, cave walls are highly irregular or undulated but mainly rounded while cross sections of the passages are usually irregular and heightened although those of narrower conduits are commonly spherical to elliptical in shape. In the lower parts of the caves, predominantly subvertical up to a metre wide conduits have developed along major joints that join the main passages and chambers from below and from the sides. These could be classified as feeders, especially when they join to a larger conduit or chamber, they continue into rising wall and ceiling channels that may end with cupolas or ear-shaped orifices. Rising wall channels are commonly developed in the continuation of the side dead-end passages. The rising wall channels of this type could be mistaken for the above mentioned amalgamated parallel cave passages. Cupolas literally cover the ceilings all over the cave chambers and passages. They may be simple or complex, shallow and deep (up to few metres) and may pass over to channels (mainly up to a few tens of cm wide) that connect larger passages. Both caves have a single entrance at the end of a steeply rising passage that could be defined as an outlet channel. In Jeralovo brezno cave this outlet is represented by a group of subvertical elliptical smoothed channels locally amalgamated together while in Turkovo brezno cave a steep outlet channel was mainly formed by a sequence of rising and parasiting domepits and cupolas. Locally where the ceiling of the chamber is inclined at a relatively steep angle the density of rising wall (ceiling) channels is such that ceiling pendants have formed between them.

In addition to the infrequent appearance of various vadose flowstones locally thin coatings of coralloid and moonmilk-like flowstone occur. In the lowermost parts of both caves, fine-grained sediments occur locally containing pebbles of carbonate and non-carbonate lithology commonly coated with ferrigenous crusts (i.e. ferrigenous nodules).

The distribution of cave passages, passage patterns, joint controlled passages, and the morphology of cave walls and wall rock features indicate a hypogenic transverse origin for the caves studied. Labyrinths where every accessible opening was enlarged to a comparable size, lack of rapid flowing water scallops, and above the mentioned rock features are characteristics of buoyancy or free convection dissolution. Additionally, the caves are developed immediately above the contact of the carbonate succession with the non-carbonate deposits, while upper confining beds, which cover the

Mesozoic carbonate and non-carbonate rocks have been eroded during the uplift of the Jelovica massif and the investigated area nearby. Thus, the geological situation is consistent with conditions required for hypogene transverse speleogenesis. Although it is difficult to directly correlate recent hydrothermal activity of certain springs in the area and the high concentration of dissolved ions in one of them, it is obvious that some past recharges to the confined aquifer could be concentrated along the same or similar active faults.

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Keywords: hypogene speleogenesis, hypogenic cave features, foothills of the Jelovica massif, Turkovo brezno cave, Jeralovo brezno cave

DEEP PIT IN DINARIC KARST AS UNDERGROUND LABORATORY

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Deep pits are natural windows into the depth of karst area. As such, they are, despite a very complex access to the measuring locations, suitable for studying the geological, hydrological, physico-chemical and other properties and processes, by in-situ measurements and laboratory analysis of collected samples. The measuring locations are defined by the position (depth), the geological, morphological and other characteristics. In the same pit we can find the considerable changes in geological properties, the transition between the hydrological zones, temporal and spatial variations of microclimatic parameters. That allows us to obtain a complex image of the karst underground. In our presentation we review our current scientific research in the deep caves of the Dinaric karst on Croatian territory, and perspectives and ideas for future research.

Keywords: geology, hydrology, cave climate, radon concentration, deep pits, Dinaric karst, Croatia

SPATIAL DISPOSITION AND MORPHOLOGICAL PROPERTIES OF BIGGER KARST DEPRESSION IN CROATIA

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Bigger depressions of different geomorphological, geological and hydrogeological properties represent one of the most important landform in the karst morphology of the Dinarides. Previous geomorphologic classification was mainly based on descriptive analysis of genetical, morphometrical and hydrogeological properties. In order to quantitatively define their morphological parameters the bottom of depressions was cartographically defined, the spatial morphological properties of their bottoms and of their surroundings (till maximally 2 km) was analysed. In the first phase all the bottoms of bigger depressions have been vectorised from the topographical maps in the scale 1:25 000 and Landsat images. For the spatial analysis of disposition and morphology of depression bottoms the GIS tool of the ArcGIS (ESRI) software package has been used. The morphology of the depression bottoms are expressed through the index of compaction, that is, with flattening and direction of the longer axes of the standard deviation ellipse. The standard deviation ellipse represents the trend of objects spreading (depression bottoms) through the values of standard deviation of distance of points located on the depression rim, from the point representing the average value of the depression centre. The index of compaction is related to the value of the depression size and to the size which would get the circle circumference of that bottom. The analyses of the depression surroundings includes the inclination of slopes (gradient slope), their exposures, the transversal and lengthwise slope curvature as well as the vertical relief dissection using the surface unit of 1 ha. According to the obtained parameters the morphological classification of depressions was done from which an important correlation between the shape of depressions their lithological and structural properties derive what directly reflect the main cause of their genesis.

Keywords: karst depression, GIS, spatial analysis, morphology, Dinarides

CAVE SEDIMENTS DIAGENETIC HISTORY RECORDED IN PHOSPHATE MINERAL ASSOCIATION

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Cave sediments are regularly enriched in phosphates, mainly originating from bat guano or vertebrata skeletal remains. One of such deposit, rich in phosphates, is situated near Ervenik, at the foot of the SE part of Mt. Velebit, Croatia. The phosphates are probably Lower Pleistocene in age, situated in caves within Cretaceous limestones. The phosphorus source is phosphate-rich guano material originating from bats and birds. These primary phosphates, in relatively short time (days or weeks) during sedimentation and early diagenesis, transform into geochemically most stable mineral phase. Stability of new mineral phases is result of physical and geochemical conditions in the cave sediment in the time of their formation. The main factors controlling phosphate phase stability in the cave environment are pH, Eh and ion activities (Nriagu, 1976). In described case, phosphate infillings determined as hydroxylapatite and crandalite in spherulitic form were found inside cave deposit. To explain the precipitation in the spherulites and diagenetic environment the stability fields for apatite and crandalite were calculated. Environmental conditions favoring apatite precipitation, with high phosphate, lower aluminum and higher pH, prevailed during precipitation of the spherulite core. Crandalite was formed during higher aluminum and lower phosphate concentrations, and lower pH. Variation in pH was probably caused by guano and other organic material decay during sedimentation and early diagenesis. Apatite was formed in the first phase of the sediment diagenesis during organic material decomposition which released significant amount of phosphate, carbonate in the environment buffered solution to higher pH values. Crandalite precipitated after apatite, when phosphate activity was lower. Due to the given example, associations of authigenic phosphate minerals can be used to reveal sedimentary and diagenetic conditions during fossil cave sediments formation.

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Keywords: cave sediments, phosphate, diagenesis, phosphorite

REGIONAL HYDROLOGICAL ANALYSES OF WATER RESOURCES IN DINARIC KARST AREA IN CROATIA – QUANTITY AND RISK ASSESSMENT

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As basis for water resources quantity assessment which is being conducted in accordance with the EU Water Framework Directive, the regional hydrological and hydrogeological analyses have been conducted in the Croatian karst area. The Croatian karst areas are a part of a widely spread regional geological structures of Dinarides which follows the whole coastal part of Croatia and its hinterland as well as the Adriatic islands. Almost half of the Croatian territory belongs to the karst area characterized by specific surface and underground morphological features and discharge conditions. What prevails in the geological structure are carbonate rocks with fully developed karst forms. The interaction between the surface and underground waters is extremely prominent and variable in time. Consequently karst catchment areas are not constant in time (depending on hydrological conditions) and not easy to determine. Seventeen groundwater bodies were outlined in Croatian karst area. The largest part of the Croatian karst area belongs to the Adriatic catchment area and is subterraneously drained towards the coastal springs and hydrologically uncontrolled vruljas along the Adriatic coast. The measured climatological and hydrological data as well as data of different water usage have been used when assessing the quantity of water. The regional hydrological analyses and assessments as well as the assessment of time trends of water state have been conducted. The period used for the assessment of the recent quantity amount is the one from 2000 – 2007. The hydrological conditions of this period were compared to the referential 30 year period from 1961 – 1990. Due to the prominent heterogeneity of karst area drainage and the presence of significant unlocalized groundwater discharges directly to the Adriatic sea, the hydrological monitoring covers only a smaller part of water resources. Therefore, in order to make a water quantity assessment of hydrological conditions, a series of regional hydrological analyses have been conducted also by using original approach in hydrologic interrelationships analysis. Seventeen delineated groundwater bodies in the Croatian karst area cover the surface of about 26,750 km². The mean annual water balance of Croatian karst area was estimated at 610 m³s⁻¹ and has the specific flow capacity of 22.8 l/s/km². The total mean water balance, the water balance of transboundary waters included, was estimated at 1082 m³s⁻¹. On the other hand, the global degree of water resources utilization for water supply, industry and irrigation in relation to the total water potential is relatively small – only 2.3% in average. Based on the regression analyses, the water balance estimates of minimum mean annual own waters flow capacity for the recent period (from 2000 – 2007) was also provided (380 m³s⁻¹), as well as the minimum mean monthly flow capacities of the 5 year (84.3 m³s⁻¹) and 20 year (65 m³s⁻¹) recurrence interval. It has been established that during the critical draught periods certain water resources exist within the dynamic water resource emptying cycles, but also that those resources are relatively limited. The resulting minimal monthly water amounts of 5 year probability of occurrence have the total volume of only 218.5 mil m³ which equals the volume of a single fresh water lake in the Croatian karst area (Lake Vrana on the island of Cres). It has been established that the largest water resources are situated in the area of groundwater bodies

of rivers Lika and Gacka while the smallest amount is to be found in south part of Istria and Ravni kotari. In these areas problems with occasional deep intrusions of sea water into the coastal karst aquifer occur even at the existing water use level. Besides some coastal water supply interventions (e.g. several springs of Zadar water supply system), due to the present climate changes/variations and sea water level increase, the most endangered area is the coastal Lake Vrana in Dalmatia of 82.5 mil m³ in volume which suffers from the increased salinization and whose salinization model analyses has been used in this paper as an example. Besides the final quantity assessment for the ground water bodies the paper also deals with the regional analyses of water resource sensitivity to the hydrological condition changes, that is, the present flow capacity decrease trends. The results have shown that the smaller catchment areas, that is, the catchment areas with smaller flows show greater sensitivity to such water balance decrease occurrences.

Keywords: Dinaric karst, water resources, regional hydrological analyses, EU Water Framework Directive, ground water bodies

COMPARISON OF POCKET BEACHES AREAS AND THEIR TORRENTIAL FLOWS CATCHMENT CHARACTERISTICS

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Most beaches on the Dinaric karst coast are small pocket gravel beaches formed mostly by the deposition of sediment from torrential flows. Morphological characteristics of pocket beaches such as beach shape, area, volume and slope are function of sediment supply, its transport paths and mechanisms responsible for potential loss. Areas of 16 pocket beaches in the NE part of Cres Island were analysed and compared with their catchment morphological, geological and hydrological characteristics. The Cres Island is located in the Kvarner area. This is semi enclosed part of the Adriatic Sea located between the Istrian peninsula and the Vinodol– Velebit coast. In the terrestrial part of the Island of Cres Cretaceous and Paleogene carbonate sedimentary rocks (limestones, dolomites and carbonate breccias) prevail. Quaternary sediments (terra rossa, talus fragments and coarse grained ravine sediments) sporadically cover carbonate bedrock. Mechanical marine erosion caused by wave impact is not very pronounced along the eastern coast of the Island of Cres due to its sheltered position and relative resistency of coastal carbonate rock. At sea level bioerosional processes prevail over mechanical erosion. In the places where the rock mass is tectonically crushed or/and karstified, marine erosion is expressed. The Cres island catchments are small and steep, characterized by torrential flows, with rare, but extreme runoff. They contribute to majority of sediment supply of the coastal zone. The sediment supply from torrential flows is dependent on catchment characteristics such as: size of catchment, topography, geology, soil and soil cover, land use, upland erosion and climate. Catchments characteristics such as area, slopes, length and slope of torrential flows, land coverage are derived from the Digital Elevation Terrain Model

(DETM, 1:5000) and low-altitude aerial imagery. A regression models between the beach area and catchment characteristics and runoff were developed. The full paper will present regression model results.

Keywords: karstic coast, beach area, catchment characteristics, regression models

SPELEOLOGICAL PROSPECTING ON SAINT AUGUSTIN TROPICAL KARST PLATEAU (TULEAR, SOUTH-WEST MADAGASCAR)

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Some years ago, the Gruppo Speleo Ambientale Sassari caving club organized a pre-expedition trip in Madagascar, the African big off-shore island in the Indian Ocean. The aims of this mission were to focus about the tropical karst in the west part of this micro-continent and to collect as much information as possible about logistic organization for a future caving expedition. The small village of Saint Augustin, near Tulear (South-Western part of Madagascar coast) have been the base camp for research activities in the dry forest of Belomotra plateau. This sub-horizontal karst massif is a West-dipping Eocene monocline bordered on the West by a steep cliff over the Mozambico Channel and towards linked to Vineta plateau on the East, while on the South is cut by the Onilahy River. Out of the classic caving route, that since the '60s have interested the Northern and Western karst area of Madagascar (mainly led by French cavers), the wide spread carbonate rocks of this area were unveiled, due to the lack of practicality to investigate this area. This trip on the South-West of Madagascar allowed to collect several important information about the karst geomorphology of Belomotra limestone massif, to find some water outlet along the coast and the Onilahy River, and to explore some small caves. In this work, after a geological setting of the investigate area, follows a short report about the results of this speleological prospecting.

Keywords: Belomotra plateau, Saint Augustin, Madagascar, tropical karst, caves

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Večini dobro znani slovenski “pol mraza” je Babno Polje, kjer na podlagi uradnih podatkov za najnižjo izmerjeno temperaturo v Sloveniji velja tista izpred več desetletij. Takrat, 15.2. in 16.2.1956 ter 13.1.1968, so izmerili – 34,5 °C; poleg tega pa se je živo srebro še večkrat spustilo pod – 30 °C. Če veliko hodimo po skritih kotičkih Slovenije in ob tem opazujemo pokrajino, kmalu ugotovimo, da tako mrzlo ne more biti le na Babnem polju. Zaradi tovrstnih spoznanj smo v sklopu Slovenskega meteorološkega foruma oblikovali skupino raziskovalcev mrazišč – “mraziščarjev”.

Mrazišča so manjša območja, kjer je temperatura zraka ob jasnih nočeh bistveno nižja od okolice. Pomembna je konkavna reliefna oblika, kamor se težji mrzli zrak steka, nabira in tekom noči nadaljnje ohlaja. Mrazišča so lahko manjša (vrtače, uvale) ali večja (drage, konte, kraška polja), vsekakor pa je za pojav ekstremno nizkih temperatur ugodno, da v mraziščih ni strnjene gozda. Zanje velja, da njihov potencial ohlajanja z nadmorsko višino narašča, kar pomeni, da lahko v višje ležečih mraziščih temperatura pade nižje, kot v nižje ležečih mraziščih. Na Komni je nekaj takšnih mrazišč: Planina Govnjač, Krošnja, Mrzla Komna, Luknja itd.

Meritve temperature zraka v letih od 2004 do 2008 so potrdile, da je ohlajanje v mirnih in jasnih nočeh zelo intenzivno, prisotnost snežne odeje pa ta proces še okrepi. V jasnih in mirnih nočeh so temperature na dnu mrazišč 20-25 stopinj nižje od. Pozimi te razlike lahko presegajo 30 stopinj Celzija na manj kot 100 metrih višinske razlike. V jasnih in mirnih dneh se hitro ohlajanje začne takoj po zaidu Sonca in se postopno umiri do sredine noči.

Za merjenje temperature v mraziščih uporabljamo samodejne registratorje temperature in klasične alkoholne minimalne termometre z merilno skalo do –60 °C. Meritve potekajo tudi v standardni meteorološki hišici.

KARST RESEARCH AT VANCOUVER ISLAND UNIVERSITY, BRITISH COLUMBIA, CANADA

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Vancouver Island University is situated on the east coast of Vancouver Island, 30 km to the west of Vancouver – the largest city of British Columbia (BC). The main campus for Vancouver Island University (VIU) is located in Nanaimo, while there are three smaller regional campuses in nearby cities. Approximately 18,000 students are enrolled in VIU programs that vary from basic literacy courses, vocational/trades programs, to undergraduate and graduate degrees. Karst research at VIU started in 2006, and evolved from a recognized need to understand more about the forested karst landscapes that occur in Coastal BC, and more specifically on Vancouver Island. This research also contributes to an Earth Science course at VIU on Cave/Karst Landscapes & Systems (GEOL 301) which covers the fundamentals of karst processes and systems. Students play an active part of the karst research being carried out at VIU. A number of undergraduate students have completed fourth year Directed Studies (GEOL 490) research projects on various karst topics. The field locations of the karst research are also used as training sites for the GEOL 301 course. Students enrolled in the geology field mapping course (GEOL 206) have also been involved by completing a detailed bedrock mapping exercise for one of the research sites on Quadra Island. Up to 4% of Vancouver Island is underlain by karst on much of which is covered by temperate rainforest. This particular type of forested karst is relatively rare and only found in a few other regions of the world such as Southeast Alaska, Tasmania and New Zealand. Much of the forested karst on Vancouver Island has undergone some level of industrial forest development activity with only a small portion of unlogged (or old growth) karst left. Much of the forested karst is now covered by second or third-generation forests. Other land-use activities on karst landscapes such as quarrying, urban development and domestic water usage are less common, but are of concern. In BC, the concept of managing karst landscapes as integrated natural systems was only formally recognized by the BC government in 1997. Before this time the focus for anything to do with karst was just on caves – which although important in their own right, form only a small part of a karst landscape in BC. The BC Ministry of Forests and Range developed and released a 'Karst Management Handbook for BC' in 2003, and a guidance document for evaluating forested karst lands in 2001 - the 'Karst Inventory Standards and Vulnerability Assessment Procedures for BC'. However, a scarcity of information on forested karst landscapes in Coastal BC persists. Hence research and quantitative data is needed to further understand how these forested karst systems function, and to refine the methods for their evaluation and management. The primary objectives of the karst research program at VIU is to examine the processes related to forested karst landscapes so as to better understand how they operate as part of a complex and interconnected system. The research also aims to assist in management decisions made on karst lands, and to develop simple and cost-effective monitoring techniques. Two particular aspects of research have been selected as key areas for investigation - karst groundwater and karst springs, and karst sinkholes (dolines). Preliminary research activities have been carried out at various sites on Vancouver Island and nearby Quadra Island. These include:

- Investigating the nature of karst springs, their associated catchments and subsurface hydrology using dye tracing and various hydrological monitoring techniques. A particular interest has been on a series of karst springs that are used for domestic water supply.
- Examining the soil, hydrological and geomorphological processes of karst sinkholes.
- Studying microclimates associated with larger sinkholes.

Some of the preliminary findings of the research to date are as follows:

- Large forested sinkholes (>30 m diameter) appear to have discernable microclimates based on distinctive daily summer and winter differences in air temperatures when comparing measurements of their drainage foci to nearby forest control points.
- The differences in daily summer air temperatures between the drainage foci of large partially logged sinkholes (0-25°C) as compared to similar-sized unlogged sinkholes (5-15°C) appears to be at least double.
- The size and shape of forested sinkholes appear to be a factor in the type of the microclimate, as does the density of the canopy cover. However, even smaller sinkholes (10-15 m diameter) record some evidence for some form of microclimate.
- From an examination of soil profiles in and around some sinkholes it is apparent that forest floor material is significantly thicker at the base of the sinkholes than on the sinkhole sideslopes or rims, and that larger sinkholes have greater thickness of forest floor material. This organic material may play an important role in sinkhole development.
- From investigation of karst springs in an area of Quadra Island it is readily apparent that sinking streams play an important role in the flow rates of these springs and the nature of their associated aquifer.
- Dye tracing on Quadra Island has indicated relatively linear flow paths with little cross-connections between subsurface stream systems.
- Spring monitoring techniques on Quadra Island have been able to correlate rainfall events to changes in flow rate, water temperature and electrical conductivity, suggesting relatively shallow aquifers strongly influenced by (allogenic) surface water recharge.
- Bacteria counts associated with karst spring water are not uncommon and for the most part are likely related to natural sources - vegetation or soil.

Funding for much of this research has primarily come from internal sources at VIU in the form of small competitive grants and scholarships. It is anticipated that over time outside funding sources will become available for more extensive and longer term projects.

Keywords: Vancouver Island, temperate rainforest, karst management, monitoring techniques, karst springs, karst sinkholes, microclimates, soil profiles, dye tracing

BATHYPHREATIC CHARACTERISTICS OF SOME LARGE SPRINGS IN DINARIC KARST OF CROATIA

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The Dinaric karst region covers approximately 26000 km² in Croatia, which is 46% of the national territory. Croatian Dinaric karst is composed of largely prevailing thick carbonate deposits that belong to a stratigraphic range from the Middle Permian to the Eocene. The carbonates are sporadically intercalated by Palozoic, Triassic and Paleogene clastic deposits. The recent geomorphology as well as speleogenesis and evolution of karst aquifers have been strongly affected by Neotectonic deformations. The large thickness of carbonate sediments and intensive tectonic disturbance result in very deep and irregular karstification of the area. Beside numerous surface karst landforms and probably more than 10000 explored caves, the strong karstification of the carbonate rocks is confirmed by appearance of very large karst springs. Maximum yield of these springs can be higher than 100 m³/s. During last decade deep cave diving explorations partly revealed morphology of some of the most significant springs. The exploration results are often surprising and impressive: the conveying karst conduit of the Una spring extends steeply to the depth of more than 205 m, and the Kupa and Sinjac springs extend to the depth of more than 155 m, without reaching the bottom in any of these springs. The significant depths were reached also in the Glavaš springs (115 m, Cetina River), Majerovo spring (104 m, Gacka river), Krnjeza spring (98 m), Kamačnik spring (95 m) and Dubanac spring (94 m). Majority of the mentioned springs have relatively simple morphology (shafts) in the explored sections, and continue to the depth, i.e. divers didn't reach morphological bottom. The explored sections of some springs show characteristics of deep phreatic looping. In the Majerovo spring looping reaches the water surface, and in the Glavaš spring looping channel is explored to the beginning of ascending section. Based on presented results, it seems that deep phreatic morphology is common and maybe prevailing type in the case of karst springs located in mountainous Dinaric karst terrains. A development of the bathyphreatic channels is probably conditioned by the tectonically active zones, i.e. transcurrent and reverse faulting. Moreover, significant impact is related to the difference in elevation between the recharge and discharge areas that enable high hydraulic potential and consequent deeper water circulation.

Keywords: Karst spring, bathyphreatic morphology, speleogenesis, Dinaric karst

DETECTION AND MAPPING OF KARST DEPRESSIONS THROUGH REMOTE SENSING APPROACH: AN EXAMPLE FROM SIERRA DE LÍBAR (MALAGA, SW SPAIN)

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In recent times remote sensing data have become more and more popular for geomorphological investigations because of their increasing level of detail and wide accessibility. In this context, the present work aims to provide a time-saving and effective method for meso to macro-scale karst depressions detection, classification and mapping in extensive study areas. This semi-automatic approach has recourse to Image Sharpening merging techniques of any software apt to the visualization, analysis, and processing of all types of digital imagery. These tools permit to automatically merge a low-resolution color, multi-, or hyper-spectral image with a high-resolution gray scale image (with resampling to the high-resolution pixel size). Our aim was to improve the spatial resolution of very high resolution color orthophotos with the Landsat 7 ETM+ 2000 imagery, in order to get best enhanced merged aerial imagery for the visual interpretation of karst depressions of Sierra de Líbar study area. This zone, mostly located in Malaga province (Andalucia, Southern Spain), is mainly formed of Jurassic dolomites and limestones, and Cretaceous marls and marly limestones. Jurassic rocks form a large anticline, whereas Cretaceous rocks fill the synclines and tectonic grabens. The lithology and geological setting contributes to shape a peculiar landscape characterized by steep slopes and plateau-shaped mountain ridges. Besides, a large variety of well-developed karst landforms, including karrenfields, vertical shafts, cave systems and poljes (developed in the synclines) are present. Performing Principal Component Analysis (PCA) as merging technique we were eventually able to get high spectral and spatial resolution imagery of the study zone. Band ratioing (VNIR B3/B1 and SWIR B5/B4) in the high resolution imagery was then applied in order to detect, locate and finally map karst depressions filled by iron oxide and hydroxide-rich sediments.

Keywords: karst geomorphology, Remote Sensing, Landsat 7 ETM+ 2000, Image Sharpening, Sierra de Líbar, Spain

GROUNDWATER POLLUTION RISK ASSESSMENT – APPLICATION OF EPIK METHOD – EXAMPLE: SPRING CATCHMENT AT ZLATIBOR (WEST SERBIA)

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The Kotren spring is situated at Kriva Reka on the slopes of mountain Zlatibor which stands for a natural pearl and the tourist capital of Serbia. The spring is that of a contact-gravity type and it outflows from Triassic limestone of Zlatibor in contact with younger neogene, noncarbonate substances, with minimum yield of 3 l/s. In wider area of the spring there is a whole range of potential and active groundwater polluters. Since karst terrain in certain parts is very vulnerable to the penetration of underground polluters, it is necessary to form adequate foundations and perform hydro geological researches in order to direct karst spring water. As a result, by subliming all the research results, The Groundwater Vulnerability Map has been made. Even though The Vulnerability Map was intended for the Kotren spring catchment, it includes a much larger area (186 km²). By forming such a foundation, a condition is established for certain limitation which will preserve the quality of water. On the other hand, by this foundation certain areas can be categorized as non-vulnerable from the aspect of endangering groundwater quality; so it is possible to allow different economic activity in these areas and as a result rational usage of water resources. EPIK method was applied to draw the map. To obtain the vulnerability map, four parametres were determined: E-epikarst diffusion; P-diffusion of protective cover; I-infiltration environmental conditions; K-development of karst channel network. All the parametres were implemented to define The vulnerability Map of the Kotren spring. The map is completely integrated into Geographical Information System (GIS) and can be used for any further planning and for different purposes. On the Vulnerability Map there are four separate EPIK categories according to the groundwater vulnerability. On a wider research area more parties were singled out with high vulnerability of groundwater and three groups are made: The total area of the first category (EPIK 1) is about 10 km², i.e. 5.5% of the total area analyzed. The first EPIK category is bordered by separated categories of EPIK 2 (second category) which are characteristic of high vulnerability of groundwater and occupy an area of about 13.75 km² i.e. 7.4% of the total area analyzed. Category three occupies central and Si parts of the wider area with the total of 75.8 km² (40.7%), while the category four occupies 86.55 km² or 46.5% of the total space analyzed.

Keywords: karst aquifer, risk assessment, groundwater vulnerability, epikarst, EPIK

HYDROGEOLOGIC REVIEW IN THE RIVER SANA BASIN

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Hydrogeologic review is given in the work. Three hydrogeologic areas can be separated inside the researched area. The south and the south-west parts of the basin belong to holokarst part of the south-west Bosnia; central parts belong to central-Bosnian area whilst the north parts of the basin are constituent parts of the ofiolitic zone area. According to that, the researched area has dominant terrains with aquifers of karst-fracture porosity, and yet there are separated terrains with aquifers of intergranular, intergranular and/or fracture and fracture porosity as well as terrains without aquifers

Keywords: the river Sana basin, hydrogeology, rock porosity, spring

THE CAVE DWELLERS OF ŠPILJA NA VRELU MOKRANJSKE MILJACKE CAVE

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Špilja na Vrelu Mokranjske Miljacke Cave is the longest cave in Bosnia and Herzegovina measured thus far. It is very complex system assembled from one active canal, the main canal, and lot of smaller side canals. There are a few fossil canals, and the largest one is on the entrance of the cave. Very interesting forms of cave dwellers inhabit this cave, and few of them are considered to be new species. The cave is also new Pleistocene fauna locality of *Ursus spelaeus* (Rosenmüller & Heinroth, 1794) in Bosnia and Herzegovina. Almost complete cranial skeleton of young adult male was found in fossil canal at the beginning of the cave. In the Cave was also found cranial skeleton of *Castor fiber* (Linnaeus, 1758), which is very interesting found because this species hasn't been spotted in surrounding region for a long time.

Keywords: cave dwellers, cranial skeleton, *Ursus spelaeus*, *Castor fiber*, Špilja na vrelu mokranjske Miljacke Cave

PRELIMINARY OBSERVATIONS ABOUT THE KARST OF THE WESTERN SLOPE OF MAJA ARAPIT MOUNTAIN (ALBANIA)

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The studied area is situated in Albanian Alps between Shkodra Lake and the border with Montenegro and Kosovo region. Maja Arapit summit 2217 m - called also “ albanian Matterhorn “, dominate this area with 1000 m of limestone wall. On the surface of high fractured different Jurassic and Cretaceous limestones, the main hydrographic collectors Boga and Theth valleys are cutted. Durind the Adriatic sea level oscilations a large variety of macro exokarst features as gorges, corrosion plains, antithetic steps, depressions, as well as underground forms like Maja Arapit 2537 m long Cave, were developed.

Keywords: corrosion plains, cave

TRAVERTINE CUPOLA IN LASKI (SILESIAN UPLAND, SOUTHERN POLAND) – NEW DATA FOR ORIGIN AND PALAEOENVIRONMENTAL RECONSTRUCTION

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Travertine cupola (mound) in Laski site (Silesian Upland, Southern Poland) was described several times (Tyc 1996; Tyc & Polonius 1998; Gradziński et al. 2001; Alexandrowicz 2004; Tyc, Gradziński 2004). It was rather unanimously interpreted as form originated in ascending spring environment though its age and development conditions were explained in different ways. Gradziński et al. (2001) published the most complete and thorough description of travertine deposition in Laski. Authors summarized up the research results, obtained to date and presented the only consistent model of development so far. New, complex, interdisciplinary studies of origin, age and development conditions of travertine cupola in the Laski have been undertaken in 2009. The studies included: (1) new geological survey of the object environs, detailed survey of travertine cupola using GPS and GPR as well as taking cores with undisturbed structure for detailed laboratory analyses, (2) sedimentological analysis of carbonate series and underlying sandy-silty deposits, (3) new

malacological analysis of travertine deposits, (4) new radiocarbon dating of travertine deposits and analysis of carbon and oxygen stable isotope composition in the travertine series, (5) TL dating of deposits underlying the travertine series. Sedimentological analyses compared with stable isotopes and radiometric dating, show that it was one cycle of carbonate deposition lasting only ca. 1000 years. The activity of discharging ascending groundwater has been different in that time, what is documented by vertical facial diversity of travertine series. That interpretation is confirmed by malacological analysis. Malacofauna of the travertine cupola is connected with open and wet habitats, which were seasonally shallow water reservoirs. Age of the travertine deposition in Laski (taking into account corrections of the radiometric age resulted by reservoir effect) should be associated with the Late Glacial, the most probably with late Allerød (beginning of the cupola formation) and the whole Younger Dryas period.

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Keywords: travertine cupola, radiocarbon dating, malacofauna, Silesian Upland

HYPOGENE ORIGIN OF CAVES IN THE PIEDMONT CRIMEAN RANGE

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The cuesta-shaped Piedmont Crimean Range, composed by Cretaceous and Paleogene (the Inner ridge) and Neogene (the Outer ridge) formations with distinct limestone beds, rims the Main Range of the Crimean Mountains in the north. The latter is composed mainly by Jurassic limestones and is a part of the Alpine folded belt, while the Piedmont Range belongs to the Scythian platform, being an

uplifted and partially eroded (since Middle-Late Pliocene) edge of the Prichernomorsky artesian basin. Stratified Cretaceous and Paleogene sequences in the Piedmont Range dip at 3-4 to 15-20 degrees to the north-west and north, where they plunge into the basin, and are exposed in cliffs generally facing to the south-east, forming a series of distinct cuestas. Recent studies of various karst features in the Piedmont Range suggested that most of them are now relict manifestations of transverse hypogene speleogenesis, which was regionally operative before the uplift and exposure. Caves in the area are the key features indicative of dominant speleogenetic processes. There are 27 known caves in the Piedmont Range, including five caves with length of more than 100 m. The most significant are Tavrskaya (507 m), Zmeinaya (310 m), Mangupskaya (230 m) and Alimova (125 m). The caves are stratiform, horizontal or slightly inclined (concordant to bedding) passages, with smaller side passages pinching out from the main ones. In Tavrskaya Cave two sub-parallel main passages are connected by a connector passage. Morphologic features demonstrate the complete suit of features indicative of ascending transverse flow in a stratified artesian system: point-like and rift-like feeders (vertical conduits that join the master passages from below), rising wall and ceiling channels, abundant ceiling pockets, cupolas and pendants. Arrangement and morphology of particular features suggest a role of upward-pointed dissolution due to natural convection. Clastic sediments in the caves are dominated by fine clays, among which grey, yellowish (filling pockets) and red varieties are distinguished. The caves are devoid of any sediments indicative of stream flows, and are not related to any surface recharge features. Features characteristic of cave morphology are commonly distinguished in the exposed cuesta cliffs, suggesting that similar caves provided zones of structural weakness along which cliffs retreat by blocks falls. The entirety of characteristics of significant caves in the Piedmont Range strongly suggests their hypogene origin. They represent the pattern distinguished for hypogene caves as "single passages, or rudimentary networks of passages", also known from the continental areas of the Prichernomorsky artesian basin.

Keywords: hypogene speleogenesis, cave morphology, Crimean Mountains, Piedmont Crimea

KARSTIFICATION MODEL BASED ON SOLUTION RATE CALCULATION OF LIMESTONE IN JAPAN

Kazuko Urushibara Yoshino

Solution rates of limestone tablets were measured in air 1.5 m above the ground and in B horizon soils at seven points in Japan over a course of twelve years. The solution rates of the tablets in B horizon soils were always 3 to 5 times larger than in air at 1.5 m at the seven points during the twelve years. The solution rates in both conditions increased from north (44°N) to south (26°N). That is: strong effect for the solution in air was WS-WD (Water Surplus-Water Deficit). Strong effect for the solution in B horizon soils was Precipitation. On Minamidaito Island, which is an uplifted atoll, differences in the solution rates in the air and in B horizon soils were used for calculating the formation time, which is the modification time of the uplifted atoll through karstification. The calculation results using the twelve-year solution rates show us that the present karst terrain of this

island has been forming for about 1.6 million years. According to the dating of speleothem in Point 7 Cave by Prof. Stein Erich, the last ice age with lowering sea level was wetter than present climate. If this condition can be applicable in Minamidaito Island, there is a possibility that value about 1.6 million years should be shorter.

Keywords: solution rate of limestone, modeling of karstification

RECONSTRUCTION OF QUATERNARY POPULATIONS OF CHAMOIS *RUPICAPRA RUPICAPRA* SPP. *TATRICA* APPEARANCE IN THE AREA OF WESTERN CARPATHIANS BASED ON FINDINGS FROM SUBFOSSIL CAVE SEDIMENTS

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Several interesting findings of chamois' bones were discovered in cave sediments of Western Carpathians caves in the past. Some of them were dated by radiocarbon method ^{14}C . The findings are integrated into the time period between 4700 ± 40 BP and 11620 ± 390 BP. They represent the remains of Late-Pleistocene to Holocene fauna representatives. The findings belong to the old population, from which the present Tatra chamois (*Rupicapra rupicapra* spp. *tatrica*) autochthonous population was formed and naturally occurred only in the area of Tatra Mts. The geographical diapason of fossil findings shows to the wide area of the Quaternary chamois population occurrence. All the findings come from the karstic areas without high-mountains character. That indicates the different ecological requirements of the former chamois population in this area. The appearance of autochthonous chamois in the area of Western Carpathians during Quaternary period is proved, based on the findings from cave sediments, from the areas of Muránska Plateau (Goat Cave), Low Tatras Mts. (Bear Cave, Dry Hole, Demänová Ice Cave, Okno Cave in Demänová Valley) and Choč Mts. (cave in the middle part of Choč Mts.).

Keywords: Tatra chamois, *Rupicapra rupicapra* spp. *tatrica*, chamois, *Rupicapra rupicapra*, Pleistocene, Holocene, caves, cave sediments, palaeontology, Western Carpathians

THE ENDOKARST PHENOMENA EVOLUTION IN THE KRÍŽNA NAPPE TECTONIC SLICES ON THE NORTHERN SLOPES OF LOW TATRAS MTS. (WESTERN CARPATHIANS)

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The Low Tatras Mts. are represented as core mountains of the Central Western Carpathians, composed of Lower Palaeozoic crystalline basement with Late Palaeozoic to Mesozoic sedimentary cover (Tatricum Unit) and alpine nappes, which consist of Lower Triassic to Cretaceous sedimentary rocks (Fatricum and Hronicum Unit). Fatricum Unit is represented by Iľanovo succession of Krížna nappe and Hronicum Unit by Biely Váh succession, or Choč nappe s. s. respectively. From the geological point of view, the area of Low Tatras Mts. is characterized by well-marked fold-fault structure of superposed nappe figures. Several caves and cave systems, which comprised the longest and deepest caves of Western Carpathians (e. g. Demänová Cave System – 35,291 m/-201 m, Hipman's Caves System – 7554/-495 m, Zlomísk Cave – 10,688 m/-147 m, Štefanová Cave – 10,047 m/-111 m), occur in Mesozoic carbonate rocks of this area. The underground spaces of many of them intersect wide-ranging lithostratigraphic sequences inside the karstic massifs and show their inner geological structure. From this point of view, Javorová Cave (2261 m/-313 m) with related Kosienky Cave (350 m/-98 m), which are situated on the southern slope of Krakova hoľa Mt. (1752 m n. m.) rank among the most interesting caves. The top parts of Krakova hoľa Mt. consist of Middle Triassic limestones and dolomites of Choč nappe. The décollement zone and the contact with underlying Krížna nappe carbonate rocks document the spaces of Slnecný lúč Cave (760 m/-133 m). The lithological – tectonic evolution of Krížna nappe and its contact with sedimentary rocks of Tatricum basement cover sequence reveal the underground passages of Javorová Cave. In the past, some authors supposed on this area a difficult folded structure with reverse strata sequences in part of Krížna nappe. The results of geological research in Javorová Cave show the complex of tectonic nappe slices with duplicated strata sequences. The lowermost slice lies discordantly on the Lower Triassic quartz sandstones formation of Tatricum Unit. The cave spaces were created preferentially 1) in lithologically suitable conditions, 2) along the bedding planes, 3) axis-correspondently with major faults directions, 4) in structurally weakened zones. Many of superposed lithological types of rocks are known in the cave. The most suitable rocks for karst processes are the light- or dark brown to reddish, Lower to Middle Triassic limestone breccias and zebra limestones with gypsum pseudomorphosis and/or microbreccia structure. Less suitability show the light- to dark grey, Middle Triassic limestones. The most unsuitable rocks for karst processes in this cave proved the Middle Triassic dolomitic limestones and dolomites. Lithological resistance/predisposition of rocks to karst processes is reflected in the morphology and morphometry of cave passages. In many places, the passages directions correspond with directions of bedding planes or dip directions; generally the cave slope follows the nappe slope direction, directed into the massif of Krakova hoľa Mt. The passages deeper in massif were created along the major fault structures, the slope of which

conditioned the morphology of cross profile of passages. In most cases there are linear high passages, originated on subvertical faults in the cave. As structurally weakened zones, from lithological point of view, we perceive the breccia zones or distinctive lithological changes, which create local predispositions to preferential karstification of rock massif. Here, we comprise also the structural weaknesses in the zones of complicatedly folded basis of tectonic slices and structurally inhomogeneous zones of fold hing areas. Often, the cave passages follow the dip direction of fold crest surfaces. Some faults in the cave show the recent tectonic activity marks and in the subsurface zone, the morphology of underground spaces determine also the slopes gravity processes.

Keywords: endokarst phenomena, speleogenesis, caves, Low Tatras Mts., Krížna nappe, geology, lithology, tectonics, tectonic slices

SEASONAL WATER BALANCE OF THE TRANSBOUNDARY AQUIFER ŽUMBERAK AND SAMOBORSKO GORJE MTS. - CROATIAN PART

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Žumberak and Samoborsko gorje in Croatia and Gorjanci in Slovenia respectively are a mountain range bordered by the rivers Krka, Sava and Kupa and represent a Croatian-Slovenian transboundary aquifer. The area of research was Croatian part of the mountains - protected as a Nature Park. It stretches over 342 km² rising from 180 to 1178 m above sea level (Sveta Gera or Trdinov Vrh). The main part of Žumberak consists of Upper Triassic dolostones (46%) and Upper Cretaceous carbonates or flysch (35%). Until now, 137 caves were explored in this border area of the Dinaric karst. During the last four years a comprehensive hydrogeological research was carried out to determine the hydrogeological characteristics of the Samoborsko gorje and Žumberak area. The first stage of the research resulted in 847 mapped springs whose basic physico-chemical parameters and discharge „in-situ“ were measured at least once. The seasonal water balance was calculated on the basis of measured spring's data, precipitation, air temperature, evapotranspiration and discharge data of the main watercourses of the rivulets Kupčina, Bregana, Lipovečka Gradna and Rudarska Gradna. Calculations for the entire researched area and for the researched area without impermeable rocks indicate the greatest losses at the western Cretaceous flysch part where water flows at the surface or underground to Slovenia or Kupa River. These results are in accordance with a water tracer tests for this open hydrogeological system.

Keywords: transboundary aquifer, Žumberak and Samoborsko gorje Mts., seasonal water balance

COASTAL KARST IN ITALY WITH SPECIAL REGARD TO SARDINIA

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Almost 20% of Italy is characterised by the outcropping of sometimes large carbonate massifs ranging in age from Cambrian to Quaternary. Also gypsum areas are widespread reaching important extensions especially in Sicily. In some Italian regions, such as Emilia Romagna, these evaporite karst areas are the only ones hosting important cave systems. All these carbonate and evaporite karst plateaux host more than 35,000 caves for a total development of over 2,500 km.

The major karst areas are located in the mountain chains: the Alps and the Apennines. Large carbonate outcrops also occur in the Apulian foreland and in several other regions. Most of these carbonates are of Mesozoic age, from Triassic to Cretaceous, but there are also important areas in Miocene limestones (Sassari, Sardinia) and Cambrian metalimestones and dolostones (Iglesiente, SW Sardinia).

The best known areas are the Classical Karst around Trieste, the alpine karsts of Piedmont, Lombardy and Veneto, the marble alpine karst of the Apuan Alps (Tuscany), and the Apulian platform karst. Also quite renowned are several alpine karst massifs in the Apennine chain (Frasassi, Monte Cucco, southwards up to the Monti Alburni near Salerno).

Coastal karst is present in many Italian regions: Capo San Vito, Siracusa coast and Marettimo in Sicily, Salento and the Adriatic coast of Apulia (including Gargano), Maratea, Cilento and Gaeta in Campania, Circeo in Latium, Argentario and Giannutri Island in Tuscany, the southernmost part of the Ligurian Alps, the Gulf of Trieste, the Conero south of Ancona (Marche) and, especially, in Sardinia.

Sardinia has carbonate rocks touching the sea at Capo Sant'Elia (Cagliari), Capo Teulada, the coast of Buggerru, Sinis, Capo Caccia-Punta Giglio, coast of Balai near Porto Torres, Capo Figari, Tavolara Island and the Gulf of Orosei.

In this last area, in particular, recent explorations are bringing important new information. The Gulf of Orosei is a 37 km long vertical Jurassic limestone cliff hosting many cave systems and submarine springs. Caves lacking fresh water outlets normally have limited underground development related to wave action along fractures. Extensive cave systems have developed instead where significant amounts of water are discharged into the sea. Cave diving exploration has allowed documentation of several extensive underwater caves for a total development of more than 30 km. Geomorphological observations made in the explored sections allow us to draw preliminary conclusions about their evolution. The development of these passages has clearly been influenced by a series of factors: 1) type (autigenic or allogenic) and amount of recharge; 2) hyperkarst in the salt-fresh water mixing zone; 3) Quaternary climate and sea level changes; 4) neotectonics and 5) Plio-Pleistocene volcanism.

These coastal karst systems are fed by allogenic streams in the upstream part. The Codula Ilune cave system, with over 42 km of surveyed passages, is the most popular among these. This system has its outlet south of Cala Luna beach, and its underground stream has been discovered very recently in an

intermediate cave, Su Molente. A connection with the Bue Marino show cave, with around 15 km of development, might be possible, making this cave system over 100 km long.

The major coastal spring, Bel Torrente cave, appears to be fed by the sinks of Su Clovu and Lovettecannas, although dye tests have never confirmed this clearly. Explorations and researches are organised this summer at Lovettecannas and might give more straightforward answers to this enigma.

The enormous Utopia cave system must get its water from the Codula Sisine fluviokarst canyon, but no important caves are yet known in these areas.

Although the Gulf of Orosei is one of the most interesting and well studied coastal karst areas of Italy, many other carbonate massifs are important playgrounds for coastal karstologists and cave divers.

Although the Gulf of Orosei is one of the most interesting and well studied coastal karst areas of Italy, many other carbonate massifs are important playgrounds for coastal karstologists and cave divers.

In Sardinia, besides the Gulf of Orosei, long coastal carbonate outcrops are located near Alghero (Capo Caccia, NW Sardinia), in Iglesiente (SW Sardinia) and at the Island of Tavolara en Capo Figari (near Olbia, NE Sardinia).

Coastal karst is also present in many other Italian regions: Capo San Vito and Ragusa coast in Sicily, Salento and the Adriatic coast of Apulia (including Gargano), Cilento and Gaeta in Campania, Circeo in Latium, Argentario and Elba Island in Tuscany, the southernmost part of the Ligurian Alps, the Gulf of Trieste, the Conero south of Ancona (Marche).

Keywords: coastal karst, distribution, submarine caves, sea level change, Gulf of Orosei

ALPINE KARST IN SARDINIA (ITALY)

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Sardinia is characterised by the outcropping of more than 2000 km² of carbonate rocks, corresponding to almost 9% of its total surface, mainly distributed in the North-Western, South-Western and Central-Eastern part of the island. These karst areas host more than 3000 caves for a total development of about 300 km typically organized in rather long subhorizontal passages (up to 10 years ago the deepest known cave did not even reach 300 metres in depth) and include the most extensive cave systems of Italy (e.g. Codula Ilune 42 km, Bue Marino 15 km, Su Bentu/Sa Oche 16 km,

Ispinigoli/San Giovanni Su Anzu/Sos Jocos 14 km, Sa Rutta 'e S'Edera 13 km and Is Angurtidorgius 12 km).

Caves on the Island are notorious to be warm, relatively dry and abundantly decorated with many kinds of speleothems. More a typical place for tropical cavers, not for those acquainted with deep alpine shafts. The only Sardinian alpine cave known in the last century was Sa Rutta 'e S'Edera (Urzulei), now over 13 km long, located in the southern part of the Mesozoic Supramonte massif (Central-East Sardinia).

In recent years, however, new discoveries have allowed to change this view drastically. In the same karst plateau, along Riu Flumineddu canyon the opening of new entrances has allowed to discover three caves, Su Eni 'e Istettai, S'Orale 'e Su Mudrecu and Su Colostrargiu, respectively 500, 340 and 150 metres deep, all with a river flowing at their bottom. A series of shafts connect rapidly to a horizontal cave level, developed close to the contact between Palaeozoic phyllite basement and carbonate rocks, along which the underground water flow concentrates. All of these streams appear to feed the main outlets at the northern edge of Supramonte (over 15 km away), the most famous of which is certainly Su Gologone spring. Cave temperatures are between 7 and 11 °C and speleothems are rather scarce and concentrated in a few places. These caves have a typical alpine feature and increase the knowledge of the variability of speleogenetic processes active in Sardinian karst areas.

Keywords: Supramonte, Alpine caves, speleogenesis, hydrogeology, exploration