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KRASOSLOVNI ZBORNIK

XXIV
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OF
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"MAN ON KARST"
Postojna, September 23-25, 1993

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1995

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MAN ON KARST

dedicated to 70th anniversary of the Academician
Prof. Dr. Ivan Gams

Postojna, September 23-25, 1993

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of Slovene Academy of Sciences and Arts

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UVODNIK

23. junija 1955 je predsedstvo Slovenske akademije znanosti in umetnosti potrdilo program oziroma gradivo za prvo številko glasila razreda za prirodoslovne in medicinske vede oziroma Inštituta za raziskovanje krasa Slovenske akademije znanosti in umetnosti, z naslovom "POROČILA - Acta carsologica". Še istega leta, decembra 1955, so bila Poročila tudi tiskana.

Ko človek gleda to prvo številko slovenskega vodilnega krasoslovnega glasila izpred 40 let in jo primerja z današnjo, se mu zazdi, da se na zunaj ni dosti spremenilo. Razpored napisov je bolj ali manj isti, besedilo tudi, vse skupaj na bolj enolični osnovi, prva številka na grobi rjavo-sivi lepenki, zadnja številka na beli, gladki.

Toda majhne spremembe, ki jih človek, ki naslovnico le pogleda, niti ne zazna, kažejo tudi na razvoj organizacije, inštituta in ne nazadnje tudi same vsebine glasila. Prva številka je imela naslov POROČILA (z velikimi in rdečimi črkami), pričujoča, XXIV. številka, ima ravno obratno, ACTA CARSOLOGICA veliko in rdeče, podnaslov pa ni več "poročila", ampak "krasoslovni zbornik". Glasilo se je v resnici iz inštitutskih poročil spremenilo v osrednje krasoslovno glasilo na Slovenskem, s težnjo prodora v svet. Prva številka je na vsega skupaj 175 straneh vsebovala tri razprave (avtorji so bili vsi sodelavci inštituta) ter šest poročil, prav tako večinoma izpod peresa sodelavcev inštituta. Pričujoča številka pa na skoraj 600 straneh prinaša 45 prispevkov 43 avtorjev iz 13 držav, od Španije do Rusije, od Velike Britanije do Italije, in vsi prispevki so v tujih jezikih.

V prvi številki je avtor enega od poročil (o jami in potoku Mitoščici) Ivan Gams, ki mu je posvečena tudi XXIV. številka. V njej so objavljeni prispevki, predstavljeni na mednarodnem simpoziju "Man on Karst" 1993 v Postojni, posvečenemu 70-letnici prof. Gamsa. Njemu, ki je bil sodelavec Acta carsologica torej od začetka, od njene prve številke, in je v teh 40 letih v njej vsega skupaj objavil za 221 strani prispevkov, je XXIV. številka posvečena v celoti.

In s tem tudi uredniški odbor dolgoletnemu sodelavcu zbornika in članu njegovega uredniškega odbora od 1983, nekdanjemu članu Inštituta za raziskovanje krasa in članu IV. razreda SAZU, jubilantu iskreno čestita!

Urednik

PREFACE

On June 23, 1955 the Presidency of the Academia Scientiarium et Artium Slovenica confirmed the program and the material for the first issue of the publication of the Academy's Classis IV: Historia Naturalis et Medicina, Institutum Carsologicum respectively, entitled REPORTS - Acta carsologica. The same year in December 1955 the publication was printed.

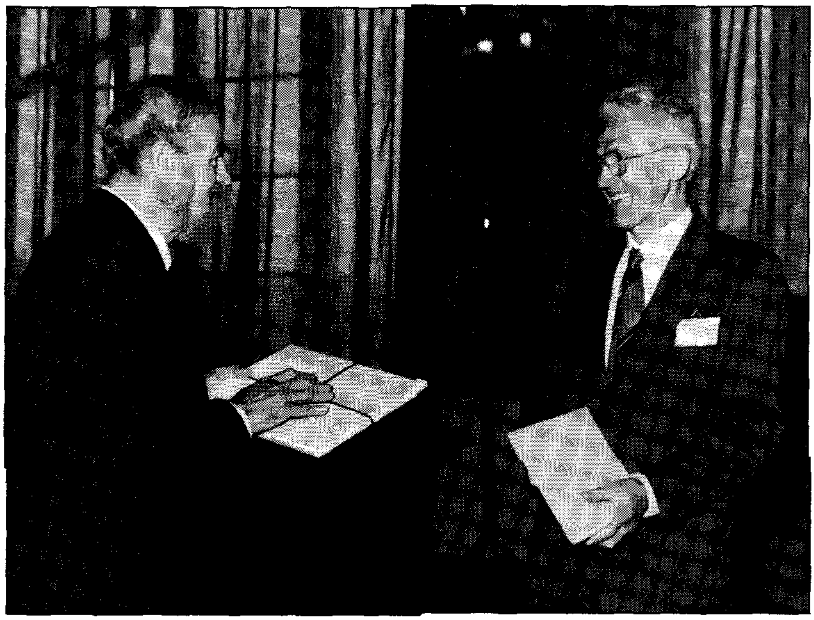
When one looks at this first volume of the Slovene leading karstological publication from 40 years ago and compare it with the actual one it seems, that the external appearance did not change much. The distribution of titles and texts is more or less the same on rather monotonous base, the first number on rough grey-blue carton and the last volume on white, smooth one.

But small changes, not evident at once if looking to the title-pages, indicate the development of the organisation, of the institute and, obviously the change of the content of the publication. The first volume was entitled REPORTS (capital red letters) and this one, the 24th volume is just the opposite, Acta carsologica in capital red letters and the subtitle is no more Reports but Karstological Miscellany. In fact the publication evolved from the Institute's Reports to central karstological gazette in Slovenia tending to make its way to the world. The first volume included on 175 pages three treatises (all the authors were Institute's employees) and 6 reports, mostly written by the Institute's workers. The present volume offers on almost 600 pages 44 papers of 42 authors from 13 countries, from Spain to Russia, from Great Britain to Italy and all the papers are presented in foreign languages.

The author of one of the reports in the first volume was Ivan Gams (About the Cave and Stream Mitoščica) and this volume is dedicated to the same person. These papers were presented at the International Symposium Man on Karst in 1993 at Postojna that was dedicated to the 70 anniversary of Prof. Ivan Gams. The whole issue is devoted to the professor who contributes to Acta carsologica since its beginning and have published in these 40 years 9 treatises on 221 pages.

In such a way the Editorial Board tries to thank to its member since 1983 and collaborator for long years, the former co-operator at the Karst Research Institute and member of the Classis IV: Historia Naturalis congratulating at his jubilee.

The Editor



LE RELIEF KARSTIQUE

Le gouffre ouvre une porte au monde souterrain,
Et la pensée suit l'onde en un cycle sans fin . . .

Reveur et médusé par l'áspect féérique
Emanant de l'étrange et beau relief karstique,
Laisse-moi te guidier, voyageur curieux:
Imagine l'acide et l'eau, silencieux,
Entamant, dissolvant, les massifs de calcaire,
Forant des galeries au tréfonds de la terre!

Karst? C'est une région de la Slovénie
Au musée naturel pour la géographie.
Regarde l'entonnoir que forment les dolines,
Serties du blanc chaos pareil aux champs de ruines.
Trouant l'âpre plateau, vois l'austere canyon;
Irriguant la vallée jaillit la résurgence;
Quel fertile poljé tapissé d'alluvions!
Une diaclase, un puits, lacs, galeries, siphons,
Et la calcite anime aventure et Science!

Jean SARRAMEA

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NAGOVOR MINISTRA ZA ZNANOST IN TEHNOLOGIJO REPUBLIKE SLOVENIJE
GREETINGS OF THE SLOVENE MINISTER OF SCIENCE AND TECHNOLOGY

Ladies and gentlemen,

Allow me to say a few words at the beginning of your interesting gathering. The Ministry of Science and Technology has initiated an ambitious programme of activities with the aim not only of bringing Slovene science closer to the European and world level, but also of increasing the contribution of Slovenia's scientific and research potential to the European and world treasury of permanent and new knowledge.

Research of the Karst area, which has a long tradition in Slovenia, undoubtedly belongs to those spheres of research into the cultural and natural heritage which are not only important for the Slovene nation but also for European civilisation.

"The most wonderful and peculiar of the natural wonders in the country of Carniola are three lakes which are now visible and the next moment invisible, but each of them in its own way . . .". With this account, Slovene polymath J. V. Valvasor opens his description of three Karstic lakes, one of them being now the world-famous Cerknica lake.

Thus the phenomenon of the Karstic landscape and its people was recognised, long before anyone else, by one of the most famous and valuable men to have lived and worked in Slovenia in a book which is an expression of our traditional liaisons with Europe and of our cultural openness to the world, the 300th anniversary of whose death is celebrated this year. As if he had known that the Karstic natural landscape, with its attractive Karstic formations and phenomena, would be of exceptional scientific strategic importance not only for the Slovene nation but also for a broader environment.

Thanks to many Slovene and foreign scientists, Karstology and speleology began to develop as scientific disciplines in this very Karst in Slovenia, the name which has entered international terminology, as have a number of other Slovene expressions. Thus Slovenia has become the original Karst country, for the Karst covers more than a third of this state.

More than 12 scientific research institutions in Slovenia are in some way connected with studies on Karst, one of the most prominent being the Institute for Research of the Karst of the Slovene Academy of Sciences and Arts, which was established in 1947 in Postojna. If in the past the priority was fundamental research of Karstic processes and speleology, then the research of life in the Karst, its economic development, Karstic tourism and related measures for the protection of the environment have been gaining importance in recent years. The relationship between people and nature, which will be the topic of this distinguished scientific board, has also been paid considerable attention by Dr. Ivan Gams, Member of the Academy and one of the most distinguished Slovene scientists to have contributed to the Slovene and world treasury of knowledge on the Karst. It is a great honour to express my congratulation on his 70th birthday.

I wish to make particular mention of the international liaisons and cooperation established by research institutions and individuals in Slovenia with important institutions in Europe (especially in Austria, France, Italy, Hungary, Germany and Great Britain) and the rest of the world (Canada and China). At the moment there are approximately 250 international projects in course in Slovenia, some of which deal with Karstology and are incorporated into international programmes and projects: allow me to mention only a few of them: Geological Correlation Programs - UNESCO, the COST Program, the Association of Tracer Hydrology Symposia and the Phare program.

In this country we see justified efforts towards preserving the natural and cultural heritage of our country, which have in the last years been expressed in numerous initiatives and professional endeavours to establish a natural park in the Notranjska and Karst area (also as a joint internationally protected area on the Slovene and Italian side of the border) on the one hand, as well as the needs of regional economic development with possibly controversial interventions in the environment, demanded by the construction of industrial areas, airports, sports and recreational premises and so forth, on the other. An international race track is, for instance, only 10 km away from the Škocjan caves, one of the monuments of the UNESCO world natural heritage. Science must also participate more meeting economic interests and needs. Science would face less difficulty in making its contribution if it participated more actively in the development and environment programmes of the Karstic region.

In my opinion, your symposium entitled "Man on Karst", as well as the messages and conclusions which you will make and reach, could represent an important contribution to further activities in the scientific spheres of Karstology and in applying this knowledge in development programmes of the region.

Prof. dr. Rado BOHINC

NAGOVOR GENERALNEGA TAJNIKA SLOVENSKE AKADEMIJE ZNANOSTI IN UMETNOSTI
GREETINGS OF THE GENERAL SECREATARY OF THE SLOVENIAN ACADEMY OF SCIENCES AND ARTS

Spoštovani udeleženci mednarodnega simpozija KRAS IN ČLOVEK

V imenu Slovenske akademije znanosti in umetnosti ter v svojem imenu Vas iskreno pozdravljam in Vam želim uspešno delo. Dovolite mi, da se s tem v zvezi zahvalim organizacijskemu odboru, ki je ta simpozij pripravil in ga bo tudi realiziral.

Mislim da gre za simpozij, ki poteka na pravem kraju in ob pravem času.

Kar zadeva kraj bi vendarle želel poudariti, pa čeprav vsi to veste, da gre v ožji in zlasti v širši okolici Postojne, tja proti Tržaškemu zalivu za klasičen kras, ki ga poznajo pod nemškim imenom Karst zlasti geografi, geologi, biologi in hidrologi po vsem svetu. Slovenska imena kraških pojavov kot so to npr. dolina, uvala, polje in vrtača uporablja tudi večina tujih znanstvenikov.

Kar zadeva čas, pa bi Vas najprej spomnil na to, da so nudile kraške jame in spodmoli stalno prebivališče ali začasno zatočišče paleolitskim in mezolitskim prebivalcem marsikje po svetu in tudi pri nas. Kraška polja in doline so dajale in še danes dajejo hrano prebivalcem, ki tam žive. Na krasu so v številnih deželah nahajališča boksitov - ki vsebujejo rude pomembne za pridobivanje aluminija. Kraške jame so dandanes vse bolj zanimivi turistični objekti. Predvsem pa bi želel opozoriti na dejstvo, da vsebujejo kraška območja v svojih nedrih rezervoarje pitne vode, ki je že danes, bo pa brez dvoma v prihodnje eno izmed najpomembnejših naravnih bogastev.

Toda človek je marsikje s pretirano uporabo pesticidov, s slabo urejenimi komunalnimi objekti, z industrijsko dejavnostjo, ponekod pa tudi s turizmom že resno prizadel kraška območja in prišel je čas, da se kras ne proučuje le kot naravni fenomen, temveč da se na omenjeno problematiko resno opozori z zahtevo, da se na krasu škodljiva dejavnost omeji, če že ne prepreči.

Slovenski kras se je začel znanstveno proučevati že v prejšnjem stoletju in raziskave so bile intenzivirane v začetku tega stoletja. Kot veste se s krasom tudi sedaj ukvarja vrsta znanstvenikov z različnih področij znanosti. Med njimi naj danes omenim le akademika prof. Ivana Gamsa, ki je letos praznoval svojo 70-letnico. V imenu Slovenske akademije znanosti in umetnosti mu tudi ob tej priliki iskreno čestitam.

Še enkrat Vas vse skupaj lepo pozdravljam in Vam želim uspešno delo.

Akad. prof. dr. Matija DROVENIK

Distinguished Members of the International Symposium "Man on Karst"

It's my special privilege and satisfaction to welcome you on behalf of the Slovenian Academy of Sciences and Arts and to express to the Organizing Committee our deepest appreciation for the very big job carried out in order to render this symposium a perfect one.

In my opinion it's going on in the right place and in the right time.

Regarding the place I would like to emphasize the fact that in the narrower and especially in the broader surroundings of Postojna, in direction of the Gulf of Trieste, there exists a classic Kras, well known especially to the geographers, geologists, biologists and hydrologists around the world by the German name Karst. Names as *Polje*, *Dolina*, *Uvala* and *Vrtača*, which are used by most scientists, are originally Slovenian names for the surface karstic phenomena of the mentioned area.

Regarding the time I would like to remember you that the karstic caves and overhangs have offered opportunity to the paleolithic and mesolithic inhabitants as a permanent or only temporary residence in many countries all over the world. *Polja* and *Doline* have been providing, and still provide the food to the people living there. Beauxite ore, which is the most important raw material for the aluminium industry, occurs in the Karst region in several countries. Karstic caves are becoming more and more interesting for the tourists. But first of all I would like to stress the fact that the karstic regions include often reservoirs of drinking water, which is already today and which will be in future too the most needed natural resource.

However, in many karstic regions the man has seriously affected the environment by using pesticides, with badly regulated communal objects, with industrialization and in some places with tourist activities as well.

Now it is the time, not to study Karst only as a natural phenomenon but also to point out the problems mentioned above and to reach an understanding that in the karstic environment the noxious activities should be stopped or at least limited for the present.

In our country the Karst has been studied in general in the past century, while the researches have been intensified in this century. Several Slovenian scientists from different fields of work are at present engaged with the problems of Karst. Among them all, on this occasion I would like to mention only the academician professor Ivan Gams who has recently celebrated his 70th birthday. In the name of the Slovenian Academy of Sciences and Arts I want to congratulate him once again.

Finally, I would like to express to all of you, my best wishes for most successful work in this Symposium.

Akad. prof. dr. Matija DROVENIK

NAGOVOR PREDSEDNIKA MEDNARODNE SPELOLOŠKE ZVEZE GREETINGS OF THE PRESIDENT OF THE INTERNATIONAL SPELEOLOGICAL UNION

I thank very much all the Friends of Slovenia who have given to me and to the International Community of Karstologists this excellent opportunity of thanking Prof. Ivan Gams for his great contribution to the development of Karst sciences.

Before all Prof. Gams is a friend of all of us - I remember with pleasure the first excursion in Slovenia I organised in 1974 with my students and Italian Speleologists, led by Prof. Gams.

After that Prof. Gams came with his students to see some Italian Karst for Alpine groups.

At an international level Prof. Gams was able to give new enhancement to Karstological research inside IGU, creating and leading a study group about "Man's impact in Karst", which outlined the large geographical interest of Karst areas.

The geographical community has to recognise that, due to Prof. Gams if Karstology is more considered inside the International Geographic Commission. The expression of this acknowledgement is the existence of a specific Commission about Karst inside IGU.

Thank you, Prof. Ivan Gams

Prof. Paolo FORTI

NAGOVOR NESTORJA FRANCOSKIH KRASOSOLOVCEV
GREETINGS OF THE NESTOR OF THE FRENCH KARSTOLOGISTS

Cher Professeur GAMS,

Avant même le IV ême Congrès International de Spéléologie, à Ljubljana - Postojna, j'avais fait votre connaissánce lors d'un symposium en Grèce. Mais c'est aux sources de la Ljubljanica, en 1965, que pour la première fois je me suis rendu-compte de tout l'intérêt de vos méthodes d'étude, en matière d'hydrologie et d'hydrochimie karstique.

Au cours de près de trente années, le Professeur GAMS a fait parcourir, les multiples détours des karsts slovènes, sur terre et sous terre, à de nombreux karstologues français, lors des colloques qu'il a organisés ou à l'occasion des échanges avec l'Institut za Raziskovanje Krasa. Grâce à lui et à ses élèves nous avons pu prendre connaissance de ses recherches et, l'avoir eu comme guide pour admirer les splendides paysages et les innombrables trésors souterrains de la Slovénie. Nous avons pu examiner aussi, sous sa direction quelques problèmes d'impact anthropique en cours d'étude. Aussi au nom de mes collègues karstologues, je prie Ivan GAMS de recevoir le témoignage de notre haute estime et de notre vive gratitude.

Prof. Jean NICOD

POZDRAVNE BESEDE PREDSEDNIKA IZVRŠNEGA SVETA POSTOJNA

V veliko mi je zadovoljstvo in v posebno čast si štejem pozdraviti Vas ob današnjem začetku mednarodnega simpozija Človek na Krasu!

Posebno sem vesel, ker Vas lahko pozdravljam kot župan občine in mesta Postojna, mesta torej, ki se kar nekoliko samo vsiljuje kot najprimernejše za temo tega srečanja. Verjetno v svetu ni lepšega primera, kako je človek te prečudovite lepote kraške zemlje, živalstva in rastlinstva na njej, kamna, vode in seveda podzemlja znal, ob priklenjenosti na to okolje in to naravo, izkoristiti sebi v prid, ter se obenem dovolj na široko vključiti v svet okrog sebe.

Pri tem naš človek na krasu ni in ne pozablja, da je to edinstven svet, ki se mora varovati, ohranjati in na svojski način razvijati, da bo na njem lahko živel, delal in preživel tudi v prihodnosti.

Prepričan sam, da te skromne besede ne morejo nadomestiti vseh strokovnih in znanstvenih razprav in ugotovitev zaradi katerih ste se tukaj zbrali, so pa iskren odraz odnosa človeka na krasu do krasa, hrepenenje njegove duše za kras in njegove lepote, duše, ki jo je prav kras naredil za kleno in včasih grobo, toda vedno prijazno in gostoljubno.

In prav v imenu tega človeka, človeka na krasu, Vam v imenu Skupščine občine Postojna danes izrekam dobrodošlico in Vam še posebej želim, da bi se ob uspešnem in za Vas gotovo koristnem strokovnem delu, med nami kar najbolje počutili.

Poseben pozdrav velja tudi g. Radu Bohincu, ministru za znanost in tehnologijo v vladi R Slovenije, akademiku, prof. dr. Ivanu Gamsu, slavljencu, kateremu je ta mednarodni simpozij posvečen, pa ob njegovi 70 - letnici, posebne čestitke.

Igor Bratina

WELCOME BY THE MAYOR

It is my great pleasure and a special honour to greet you at the opening of your International Symposium Man on Karst!

I am specially pleased to greet you as a mayor of the Postojna commune; this is the town which itself seems to be the most appropriate place for such a meeting. Probably in the world there is not a better example how man succeeded in using all these beauties of karst nature, fauna and flora, rock and water, and in particular underground, being part of the environment and of nature, and at the same time linked into the world around.

Our "man on karst" did not and does not forget that this is a unique world which must be protected, and preserved but also developed in a specific way to provide living, working and survival in the future.

I am sure that my modest words cannot replace all the professional and scientific discussions and statements that are the reason that you have gathered here, but they are a sincere reflection of man's attitude on karst to karst, the longing of a soul for karst and its beauties, the soul that karst made strong and sometimes rough, but always kind and hospitable.

And just on behalf of this man, "man of karst", I bid you welcome on behalf of the Postojna Commune, wishing you especially that during your successful and, without doubt advantageous, professional work you will feel at home among us.

Special greeting goes to Dr. Rado Bohinc, the Minister of the Science and Technology of the Republic of Slovenia.

I heartily congratulate Academician Prof. Dr. Ivan Gams; this international symposium is dedicated to his 70-th anniversary.

Igor Bratina

PAPERS PRESENTED AT
PREDAVANJA, PREDSTAVLJENA NA

International Symposium

MAN ON KARST

dedicated to 70th anniversary of the Academician
Prof. Dr. Ivan Gams

Postojna, September 23-25, 1993

THE KARSTOLOGISTS IN THE SECOND HALF OF THE 20TH CENTURY

KRASOSLOVCI V DRUGI POLOVICI 20. STOLETJA

PETER HABIČ

Izvleček UDK 551.44(497.12)(091)

Peter Habič: Krasoslovci v drugi polovici 20. stoletja

V uvodnem prispevku je avtor predstavil jubilanta Ivana Gamsa in čas, v katerem je raziskoval klasični kras. S svojimi študijami je prof. Gams pomembno prispeval k razvoju slovenske speleologije in krasoslovja. S svojim delom se je uveljavil tudi v svetu. Na podlagi citatov iz krasoslovnih monografij je uvrščen med deset najvidnejših krasoslovcev druge polovice 20. stoletja.

Ključne besede: krasoslovje, klasični kras, krasoslovci, Ivan Gams

Abstract UDC 551.44(497.12)(091)

Peter Habič: *The karstologists in the second half of the 20th Century*

In the plenary paper the author presented Ivan Gams and the time during which he was investigating the Classical Karst. Prof. Gams contributed a lot to the development of Slovene speleology and karstology by his studies. He is famous also in the international sphere. Based upon the citation from the karstological monographies he is ranged between the top ten karstologists from the second half of the 20th Century.

Key words: karstology, Classical Karst, karstologists, Ivan Gams

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THE KARSOLOGISTS IN THE SECOND HALF OF THE 20th CENTURY

I have a special duty and honour to greet you, dear and esteemed guests, speleologists and karstologists on behalf of Tourist Organization Postojnska jama where I started to work half a year ago. Before, for good 30 years, I worked one kilometer away only at the Karst Research Institute ZRC SAZU. For external world this difference is not essential as Postojna and the whole Classical karst around it established its reputation not as a touristic curiosity only but as a focus of modern views to karst.

Karst is natural, geological and hydrological, physico-geographical and in particular sensitive ecological phenomenon. This is the landscape where man survives during ten to hundred thousands of years. The problem how to preserve the karst to be friendly to a man and how man can take care that his survival remains easier will be the topics of this symposium. The colleagues of the Institute dedicated it to a special occasion of 70th anniversary of our the most eminent karstologist, academician prof. dr. Ivan Gams to honour his exceptional contribution to the Slovenian and universal karstology and at the same time to review and to define the directions for future explorations and international co-operation in the new conditions of our independent Slovenia.

Regarding my physical capacities of this very moment my contribution will be relatively short but in future I intend to describe the evolution of our karstology in the second half of the 20th century. This is the time of the extreme progress related to all the human activities, to various branches of science in particular, and the same could be said for the speleology and the karstology. I would like to present you the circumstances in which dr. Gams and his companions worked.

One has to know that the Classical Karst experienced in the era of the great discoveries in the past century (the explorers Schmidl, Putick, Martel, Müller, Hanke, Marinitsch) and increased interest for it at the beginning of this century (Cvijić, Grund, Katzer, Perko) two fatal war periods. These two catastrophes inflicted deep wound into the rising Slovenian amateur and professional speleological and karstological activity. During the First World War the Slovenian cavers lost an important part of the Classical Karst, the area from Trieste to Postojna and Planina became Italy. The Society for Cave exploration, Ljubljana hardly revived its activity and again the work was interrupted in the period 1941-1945. New initiative reappeared after 1947 only when the karst between Postojna and Sežana was given back to the Slovenia. But during the war the caving groups thinned and everything must be started from the beginning again.

The biggest burden was loaded to the youngest of the pre-war cavers, valued as a researcher and scientist due to his studies. In 1947 Dr. Alfred Šerko took over the duties of the director of Postojnska jama and other show caves of Slovenia and at the same time he was the head of the Speleological Institute, founded in Postojna by the SAZU. But the very next year, when the lectures about karst on the Ljubljana University have to start, the Slovenian spleology was literally struck by a lightning, as a virtual lightning struck dr. Alfred Šerko during his voyage on Karst. This heavy blow tried to fulfill older Slovenian cavers and thus dr. Bohinec took over the presidency of the Society for Cave Research in Ljubljana, biospeleologist Egon Pretner became the director of the Postojnska jama, and the geographer dr. Roman Savnik the head of the Institute for Karst Research; from eastern Slovenia dr. France Habe moved to Postojna and founded here the Caving Club Luka Čeč. The exploration of the Postojna underground was taken over by Ivan Michler, already retired at that time, helped by France Hribar and younger cavers. The geographer dr. Anton Melik and the anthropologist dr. Srečko Brodar have, similar as the biologist dr. Jovan Hadži, dedicated more of their scientific interest to the karst.

In Ljubljana prof. Pavel Kunaver, the cave photographer Franci Bar and the brothers Kuščer, geologist and physician, animated young cavers and they together explored the karst in the Ljubljanica river basin, on Dolenjska and in Julian Alps. The oldest among the young cavers was Ivan Gams. At the beginning of the fifties he studied geography, after degree and thesis he almost entirely dedicated to the caving and to the karstology. He has taken part at all bigger explorations, within the Institute for Geography he wrote about karst and about the results of the karstologists in the world. His extreme research and creative energy produced great results and at this moment we are not yet able to revise and to estimate his work entirely.

The karstological activity of dr. Gams could be divided into various periods with rounded research themes. His student period is linked to the caving activity in the Society and to publication of reports and shorter contributions in the periodicals Geografski vestnik and Proteus. After his doctoral thesis, in the second half of the fifties, the independent researches of the karst phenomena, underground systems and superficial features started. He wrote about Logarček, Globodol, about blind valleys, snow-fields in Alps, and a larger treatise was consecrated to the geomorphological development of Bela krajina. In the sixties, when he came to the Karst Institute in Postojna, he started to measure the corrosion intensity and to study the factors of corrosion dynamics, accelerated corossion in particular, on karst. His research field was Slovenia in the triangle among Postojna - Planina - Cerknica, he studied the forms and the growth of the speleothems in Postojnska jama and he was active at the series of other caving activities characteristic of this time. Among the most popular is, without doubt, the expedition to the Triglavsko brezno. Beside geomorphological and caving researches, the hydrological researches are very important too as he tried to prove the connection among particular superficial and underground waters by water tracings; he studied the maximisation of the underground water flow and other hydrological laws of the underground drainage.

In the middle of the sixties his important activity was the organization of the International Speleological Congress. He contributed a series of original lectures to present the Slovenian karst to the international public; his efforts to found the International Speleological Union are very important too.

Soon after the International Speleological Congress he started the pedagogical work. As professor at the Ljubljana University he introduced a new subject Karst Geography. In addition he started a series of research studies and thus contributed to the development of the Slovenian karst terminology, to the classification and topology of various karst phenomena, karst poljes in particular. He initiated the study of human impact on karst, studied the climate, vegetation and soil on karst and the human interventions to the karst surface. We owe to dr. Gams the original views on the transformation of the karst surface on the Classical and Mediterranean Karst. The most important work of the seventies is his monograph Kras.

In the eighties there stands out his experiment with carbonate tablets, the experiment of direct measurements of the corrosion intensity under various climatic conditions. With international cooperation dr. Gams contributed original data about the recent corrosion controlled by various conditions.

In the nineties he returned to the problems of contact karst started several times before. He added new views to the systematization, classification and typology of special karst phenomena at the contact of permeable and impermeable karst surface.

His karst opus comprises more than 200 works but this is one qaurter of his publications only. No doubt that his extreme energy and capability to write aroused the interest all over the world. Most of his contributions are written in the Slovenian language but those published in foreign languages aroused the interest of the international karstological public.

His position among the most eminent karstologists in the second half of the 20th century could be presented by rather objective procedure although not the most reliable one. I have chosen seven karstological monographs, namely: Sweeting (1972), Gams (1974), Bleahu (1974), Jakucs (1977), Jennings (1985), White (1988) and Ford-Williams (1989) and I have compared the frequency of the cited works and the citation without taking into the account the autocitations.

The result is interesting and worth to be treated more in detail in respect to the contents and the importance of the cited works. The scale of the cited units in the mentioned monographs is as follows: on the first place with 107 cited units is Bögli, followed by Lehmann with 93 units, then comes Ford with 87 units, Sweeting by 77, followed by Williams with 74 units, then comes Corbel 72, Roglić and Gerstenhauer 68, Cvijić and Jennings with 65 units, and the ninth place occupies Gams with 58 cited units; those following are White (51), Renault (40), Smith (35), Warwick (29). The continuing scale of other hundred authors could be interesting mostly for regional sources and the authors which are isolated due to language barrier maybe. This language barrier is an important obstacle in mutual understanding and in the development of the scientific explanation of karst. A common effort should be needed to overcome this isolation.

I am sure that the ratio of Gams should be much bigger if his monographs would be published in some foreign language. The same could be said for the Roumanian Bleahu and for the Russian Maksimovič and for some others as well. But nevertheless this "sport" ranging of Prof. Gams among the ten the most eminent karstologists means a great personal achievement. The reputation of the first Slovenian karstologist in this international company put on new duties to our younger researchers of the classical karst (for example Čar, Habič, Kranjc, Kogovšek, Šušteršič, Slabe) to whom prof. Gams was at the same time supervisor and co-worker.

At the end, permit me to thank on behalf of the Slovenian geographers, cavers and karstologists to the academician prof. dr. Ivan Gams for his outstanding contribution and efficiency at discovering the basic laws of origin and development of the karst surface and the underground and for his care for human being and his impact on the sensitive karst nature. My best congratulations to his personal jubilee with wishes to have a lot of creative power and to be in good health.

REFERENCES

Bleahu, M. D., 1974: Morfologia carstica. Conditionarea geologica si geografica a procesului de carstificare.- Stiintifica, 1-588, Bucuresti

Ford, D. C. & Williams, P. W., 1989: Karst Geomorphology and Hydrology.- Unwin Hyman, XV, 1-601, London

Gams, I., 1974: Kras. Zgodovinski, narovoslovni in geografski oris.- Slovenska matica, 1-360, Ljubljana

Habič, P., 1988: V slovo prof. Pavlu Kunaverju.- Geografski vestnik, 60, 182-184, Ljubljana

Habič, P., 1991: Melikov prispevek h geomorfologiji in krasoslovju.- Geografski vestnik, 62(1990), 43-50, Ljubljana

Jakucs, L., 1977: Morhogenetics of Karst Regions. Variants of Karst Evolution.- Akademiai Kiado, 5-283, Budapest

Jennings, J. N., 1985: Karst Geomorphology.- Basil Blackwell, X, 1-293, Oxford

Kranjc, A., 1977: Dr.Alfred Šerko - speleolog in raziskovalec krasa (1910-1948) (Summary - Dr.Alfred Šerko as a caver and karst researcher(1910-1948)).- Naše jame, 18(1976), 3-10, Ljubljana

Kranjc, A., 1988: France Habe - osemdesetletnik.- Naše jame, 30, 96-98, Ljubljana

Kranjc, A., 1988: Franci Bar (1901-1988).- Naše jame, 30, 100-101, Ljubljana

Novak, D. (zbral in uredil), 1988: Gradivo za slovensko speleološko biografijo z bibliografijo.- Naše jame, 30, Dodatek, Ljubljana. (Gesla: Bohinec (17-19), Brodar, S. (25-29), Gams (39-44), Hadži (60-61), Kuščer, L. (98-99), Kuščer, D. (97), Michler (115-117), Savnik (158-159))

Novak, T. & Kranjc, M. & Kranjc, A., 1982: In Memoriam Egon Pretner (1896-1982).- Mémoires de Biospéologie, 10, 7-9, Moulis

Sweeting, M. M., 1972: Karst Landforms.- MacMíllan, 1-362, London

White, W. B., 1988: Geomorphology and Hydrology of Karst Terrains.- Oxford University Press, 1-464, New York, Oxford

KRASOSLOVCI V DRUGI POLOVICI 20. STOLETJA (Ob 70-letnici akademika prof. dr. Ivana Gamsa)

Povzetek

Uvodnemu pozdravu jubilanta in udeležencev simpozija sledi opis razmer, v katerih je potekalo raziskovanje klasičnega krasa v 20. stoletju, ko so vojne razredčile domače raziskovalce. V drugi polovici tega stoletja se je s svojim delom najbolj uveljavil geograf Ivan Gams. Njegovo krasoslovno dejavnost lahko razdelimo na nekaj obdobij z zaokroženo raziskovalno tematiko. V študentskem obdobju se je uveljavil predvsem kot jamar. Po končanem študiju geografije sledi čas znanstvenega obravnavanja posameznih vidnejših kraških pojavov v Sloveniji. Sledi obdobje meritev in preučevanj intenzivnost kraške korozije in še posebno preučevanje takoimenovane pospešene korozije. Poglobljenemu raziskovalnemu delu sledi tudi organizacijsko povezovanje slovenskega jamarstva in nato univerzitetno poučevanje geografije krasa. Znanstvena identifikacija pojavov je dograjena z znanstveno klasifikacijo krasa, zlasti njegovih fizičnogeografskih procesov in pojavov, ki jih je skušal eksaktno mersko opredeliti. Terensko delo je v tem času povezano z neposrednimi meritvami korozije. S pomočjo karbonatnih ploščic, razposlanih po vsem svetu, so bili zbrani zanimivi merski podatki o današnjih razmerah po krasu v raznih delih sveta. Pomemben delež zavzemajo tudi razprave o človekovem poseganju v kras in zlasti o razgaljanju kraškega površja in odnašanju rodovitne prsti pod vplivom človeka.

Številne objavljene razprave so vzbudile tudi zanimanje krasoslovcev po svetu in tako se prof. Gams po citiranih delih v sodobnih krasoslovnih monografijah uvršča med deset najvidnejših krasoslovcev druge polovice 20. stoletja.

KARSTOLOGY, AN INTEGRATED SYSTEM OF SCIENCES ON KARST

KRASOSLOVJE, INTEGRALNI SISTEM ZNANOSTI O KRASU

VLADIMIR PANOŠ

Izvleček UDK 551.44

Vladimir Panoš: Krasoslovje, integralni sistem znanosti o krasu

Prispevek podaja pregled osnovnih potez in sestave današnjega krasoslovja kot modernega integralnega sistema znanosti o krasu. Ta sistem se je razvil v 70-tih in 80-tih letih 20. stoletja iz multidisciplinarnega sklopa posameznih vej različnih znanosti, ki so preučevale specifična kraška vprašanja razmeroma neodvisno. Zahvaljujoč naraščajočim potrebam izvirajočim tako iz teorije kot iz vsakdanjega življenja, je sklop postal integralni sistem znanosti, ki je sposobna kompleksno preučevati ne le ozemlja na različnih vodotopnih kamninah ampak tudi ustrezne procese in medsebojne vplive naravnega in družbenega okolja.

Ključne besede: krasoslovje, integralni multidisciplinarni sklop, členitev krasoslovja

Abstract UDC 551.44

Vladimir Panoš: Karstology, an integrated system of sciences on karst

The paper reviews basic traits and structure of the present-day karstology as of a modern integrated system of sciences dealing with karst. This system developed in the seventies and eighties of 20th century from a multidisciplinary set of partial branches of various sciences that studied specific karst problems rather independently. Due to growing theoretical and practical demands this set became an integrated scientific system that is able to study completely not only the regions built of variably soluble rocks but also pertaining processes and interactions between the natural and social sphere.

Key words: karstology, integrated multidisciplinary system, classification of karstology

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INTRODUCTION

The second half of 20th century is noted, especially on the field of science, by unprecedented advance of international collaboration and broad exchange of experiences, by foundation of non-governmental world organizations or commissions, by birth of new specialized branches of existing sciences and, at the same time, by formation of modern integrated interdisciplinary systems of science.

The advent of this development stage was promoted, all the world over, by enthusiastic and experienced investigators who opened fully their admirable scientific ability and initiative retarded by the gruesome 2nd World War. It was the generation of present-day seventiers that succeeded to position of pre-war generations and those of ancestor classic periods.

The same traits can be traced also on the field of Earth's sciences, where the need of solution of complex questions in individual types of landscape sphere stimulated formation of several integrated interdisciplinary scientific systems (e. g. ecology, glaciology, karstology, oceanology, vulcanology a. o.).

One of developers of modern karstology is Ivan Gams, a son of classical karstland of Slovenia, a respectable continuator of long national tradition initiated by Ivan Vajkard Valvasor, a reputable but very demure geographer and karstologist, and a co-founder of the International Speleological Union a. s. o.

The pioneer research activities of Ivan Gams contributed considerably, for example, to the origin and development of new important branches of karst studies, and to the constitution of karstology as an integrated interdisciplinary system of science. In order to commemorate the value of this unusually fruitful scientific effort as well as the seventieth birthday of that excellent man the following sections of submitted paper review basic traits and existing structure of modern karstology.

BASIC TRAITS

The present-day karstology is an independent integrated scientific system of individual branches that take up complex studies of regions underlain with rocks being variably soluble by water.

The system assumed its present-day form in the seventies and eighties of this century due to differentiation and abreast with integration of a former, rather loose multidisciplinary set of several scientific systems that were primarily rooted firmly in geology, geography, speleology and archeology at the close of 19th century. Karstology of that time objectivized venerable knowledge of human society on karst phenomena as well as prehistoric man's experiences from their practical use.

However, the bearing of modern karstology is much wider. The object of this scientific system is a karst landscape, all its abiotic, biotic and socioeconomic elements and components, but also their internal mutual interactions as well as external relations of the karst itself with adjoining landscapes of other type and with outer factors.

The tasks of this system of science involve:

- collection of data on territorial distribution of the karst landscapes, on their geological structure, on factors and processes controling their development in a whole as well as of their individual elements and components;
- analysis and a complete synthetic evaluation of acquired partial informations;
- formulation of conclusions, integration of these in the theoretical base of the system, their utilization for elaboration of prognosis of future development as well as for rational application in the socioeconomical praxis.

Regarding specific features of the karst landscape, especially the existence of complicated subterranean zone of endokarst, the modern karstology had to create and use numerous specialized methods of investigation, adequate to particular features of the entire karst environment and of the individual objects of study. Nevertheless, the present-day karstology cannot dispense with methods of geology, geography, biology, ecology, mathematics, cybernetics, physics, chemistry, technical and other sciences, nor even with experimentation, modelling and formation of an uniform international information system.

One of important peculiarities of karstology is the fact that especially some of its branches use not only the scientifically or technically educated specialists but also numerous informed laymen joint mostly in well organized, trained, equipped and experienced teams and important national or international societies. Any research and investigation in karst cannot be realized without close collaboration of scientists with those teams. Therefore also pedagogical, educational and sport branches become integral parts of the modern karstology system.

Nowadays especially the social branches of karstology develope very quickly due to pressing demands for rational and effective application of theoretical conclusions in the socioeconomical, medical or cultural praxis, utilization of natural karst resources and effective conservation of karst nature and environment.

STRUCTURE

The structure of the system of karstological sciences reflects the basic structure of the karst landscape. That is to say, the karst landscape is also a system that consists of natural components and elements created by natural processes and thus directed by natural laws, of social components created by the activity of man and accordingly directed by social laws and, finally, of natural-technical components subjected to laws of both types mentioned. Among components and elements of all three types there exist numerous and complicated relations and interactions. Investigation, revelation and explanation of these interactions evoke development of new specialized branches of karstology. That is why the internal differentiation of the system of sciences on karst has not been yet finished up.

The peculiarity of karst landscape, i. e. the existence of two individual vertical zones (exokarst and endokarst), united in development and function, is also reflected in the structure of karstology and, moreover, in denominationss of its partial branches. The disciplines that exclusively deal with the endokarst zone retain denominations derived from a traditional term "žspeleology" which was introduced by E. Martel at the end of 19th century. Though this denomination refers mainly to amateur and sport activities in karst caves some investigators tend to use it until recently in a wider sense instead of "karstology".

Neither full accord of views on the comprehension of the content of the system of karstological sciences nor the definitive limits of all its partial branches exists until now. Nevertheless its actual structure, regarding the best developed branches may be implied as follows:

1. **Group of sciences on natural complexes of karst landscape**
   1. 1. **general physical karstology**
   deals with general regularities of natural complex of karst landscape at the present;
   1. 2. **paleokarstology**
   studies general regularities of natural complex of karst landscape in the past.
2. **Group of sciences on natural components of karst landscape**
   2. 1. **karst geology** deals with regularities of geological structure, its development, territorial location, geological properties of soluble rocks as well as with processes of rock formation and alteration;
   2. 2. **karst sedimentology**
   studies regularities of development, territorial distribution and properties of sedimentary and weathering covers on the karst surface as well as of allogeneous and autochthonous fillings of endokarst cavities; special lines are **speleomineralogy** dealing with

regularities of formation and constitution of speleothems and **speleochronology** studying relative and absolute age of cave fillings;

2\. 3. **karst geophysics**
studies regularities of geophysical factors and processes in karst cavities (radioactivity, ionisation, geomagnetism, geotidal movements, seismicity, geothermal power etc.); besides of it it deals with location of endokarst systems;

2\. 4. **karst geomorphology**
a science on development regularities of exokarst forms and on pertaining morphogenetic processes and interrelations; its special line -**speleogenetics** - deals with development regularities of the endokarst cavities, whereas **speleomorphology** studies the shapes;

2\. 5. **karst climatology**
deals with regularities and spacial differentiation of climatological factors in karst landscape as well as their part in modification of karst processes; a special line is **speleoclimatology** that deals with microclimatic conditions of cave environment; it studies also dynamics of cave atmosphere and its part in modification of physical and chemical processes;

2\. 6. **karst hydrology**
studies regularities controlling function of karst hydrosphere, especially of superficial water regime; problems of endokarst hydrosphere are studied by **karst hydrogeology**; a special line of both branches is **karst hydrochemistry** that deals with chemism of water, with causes of its quantitative and qualitative changes in space and time as well as with consequences of those changes concerning intensity of karst processes;

2\. 7. **pedokarstology**
studies genetic processes and regularities of spatial differentiation of soil covers upon karst surface;

2\. 8. **biokarstology**
a very differentiated branch studying actual development of biosphere in karst conditions; the branch has been traditionally divided into **phytokarstology** (studying floral elements of exokarst zone), **zookarstology** (studying faunal elements of exokarst zone) and **biospeleology** (dealing with higher and lower floral and faunal elements of endokarst zone); a special, well developed line of biospeleology is **hydrobiospeleology** that studies biotic elements in subterranean karst water;

2\. 9. **karst paleontology**
studies development regularities of biosphere in karst landscape in the past; it deals especially with fossil biological remnants in

weathering and sedimentary covers of karst surface and in fillings of cavities;

2. 10. **cryokarstology**
studies regularities of karst development in permafrost conditions;

2. 11. **glaciokarstology**
studies regularities of karst development in glaciers and development of ice forms in glaciated cavities;

2. 12. **vulcanospeleology**
studies cavities in volcanic rocks by means of speleological methods;

2. 13. **resource karstology**
studies regularities of formation, spacial location, quantity and quality of natural resources in karst landscape as well as develops methods of their rational and ecologically acceptable exploitation.

3. **Group of sciences on socioeconomic complexes of karst landscape**

3. 1. **general socioeconomic karstology**
studies general regularities of actual socioeconomic complexes of karst landscape;

3. 2. **historic karstology**
deals with general regularities of socioeconomic complexes of karst landscape in the past;

3. 3. **history of karstology**
a science on development of karstological sciences in course of development of human society and its intellectual level.

4. **Group of sciences on socioeconomic components of karst landscape**

4. 1. **karst archaeology**
studies general regularities of prehistoric man's development in karst landscape: an important line of this branch of science is **speleopaleontology** that studies products and conditions of production process of prehistoric man in karst, especially in caves;

4. 2. **cultural karstology**
deals with types of cult (religious) and other cultural utilization of caverns and other karst landscape features by prehistoric, historic and recent man, his artistic, creative and literary activities motivated by anorganic, organic and human elements of karst landscape;

4. 3. **anthropogenic speleology**
studies artificial (man-made) subterranean cavities; it falls into: **suburban speleology** (concerning in prehistoric or historic suburban, subseat objects and military saps), **mine speleology** (dealing with cavities of abandoned mines) and **housing speleology**, (concerning in cavities used by recent man for dwelling);

4. 4. **military karstology**

studies influences of karst landscape outlines upon strategy and tactics of war activity and upon kinds of use of exokarst and endokarst objects for military purposes;

4. 5. **operational speleology**
deals with operational, organizational, economical and conservational needs of touristic caves and of natural cavities adapted for production, warehousing, transport purposes etc.;

4. 6. **speleophysiology**
studies behaviour of human, faunal and floral organisms in the cave environment as well as causes of ascertained states and determined changes;

4. 7. **speleotherapy**
studies environmental elements, components and processes of natural or man-made cavities and their part in medical treatment of various diseases as well as their positive impact upon immunological system of human body; along with it this branch deals with formation and application of adequate medical methods.

5. **Group of sciences on complexes dealing with general regularities of karst landscape**

5. 1. **mathematics karstology**
deals with formation and application of methods of exact sciences (mathematics) in karstological studies;

5. 2. **constructive karstology**
deals with planned transformation of karst landscape for purposes of rational permanent use by human society;

5. 3. **karst landscape theory**
studies general regularities of karst landscape, its structure, dynamics, functions, outstanding properties and their spatial and temporal differentiation;

5. 4. **environmental karstology**
falls into **karst ecology** (or eco-karstology) that studies relations and interactions among the abiotic and biotic spheres of karst landscape as well as types, intensity and consequences of human impact, and **karst landscape conservation** that deals with solution of theoretical and practical problems of effective conservation of a very delicate balance of karst system as well as with formulation, enforcement and observance of pertaining rules;

5. 5. **thematic karst cartography**
deals with compilation of thematic maps and plans of exokarst and endokarst subjects in form of specific image models and implies progressive analytic methods of observation and surveying (incl. far distance research methods, automatic map construction etc.);

5. 6. **karstological documentation and informatics**

deals with development and application of modern methods of documentation, preservation and conveyance of karstological informations (karstologic data-banks) at international level;

5. 7. **pedagogic karstology**
develops and applies effective didactic methods in outside-the-school education of adult laymen who take interest in research, sport and other voluntary activities in karst landscape.

6. **Group of sciences on regional complexes dealing with specific regularities of karst landscape**

6. 1. **regional karstology**
studies the complex of natural and socioeconomic components and interactions of given karst landscapes in frame of individual states or administrative regions (older concept);

6. 2. **zonal karstology**
studies the complex of natural and socioeconomic components and interactions of karst landscapes of individual natural provinces and climatic zones of the Earth (modern concept).

7. **Group of technical sciences on karst landscape**

7. 1. **technical speleology**
deals with technical and organizational aspects of adjustment of caves for touristic or other utilization;

7. 2. **karst hydroeconomy**
deals with technical and organizational aspects of utilization of water resources in exokarst and endokarst zones regarding the supply of drinking or industrial water, with conservation of its quantity and quality as well as with management of pertaining natural-technical water systems;

7. 3. **karst hydroenergetics**
deals with technical and organizational aspects of utilization of exokarst and endokarst water resources for the production of energy as well as with management of pertaining natural-technical hydroenergetic systems.

CONCLUSION

The reviewed system of sciences on karst develops rapidly. The most outstanding aspect of this process is represented by inception of new partial branches with specific methodology and with continuing integration of the entire system. Another important aspect is determined by the fact that the practical realization of karst research and investigation in the frame of all partial branches requires - due to difficult conditions in both the exokarst and endokarst zones - development and application of several subsidiary disciplines, techniques and crafts which do not exist in other systems of sciences. There are especially technical activities connected with the invention, construction and utilazation of special research and documentative instruments and equipment, methodology of training in speleoalpinism, speleodiving, speleorescue service etc. Along with it also the mining technique for the speleological research or for adaptation of caves for tourism and other kind of utilization, have to be developed and applied.

Growing demands of socioeconomic utilization and along with it of effective conservation of karst landscape and its environment as well as of solid prognosis of its development necessarily contribute to profundization of karst recognition. Due to it, no wonder, karstology discovers new problems that have to be urgently studied and explained. Consequently, the evolution of the system of science on karst is not completed by far. It will be a matter of future generations.

KRASOSLOVJE, INTEGRALNI SISTEM ZNANOSTI O KRASU

Povzetek

Za drugo polovico 20. stoletja je značilen napredek v mednarodnem sodelovanju in izmenjavi izkušenj, značilno je ustanavljanje nevladnih svetovnih organizacij ali komisij, nastanek novih vej že obstojelih znanosti in nastajanje modernih integralnih interdisciplinarnih sistemov znanosti. K temu je največ rpipomogla prav generacija današnjih sedemdesetletnikov. Tak razvoj je mogoče slediti tudi na področju znanosti o Zemlji, kjer je potreba po reševanju kompleksnih vprašanj v okviru posebnih tipih zemeljskega površja vzpodbujala nstanek številnih integralnih interdisciplinarnih sistemov znanosti (npr. ekologija, glaciologija, krasoslovje). K takemu razvoju krasoslovja je pripomogel tudi Ivan Gams, znan a skromen geograf in krasoslovec, soustanovitelj Mednarodne speleološke zveze in pionir kasoslvnih raziskav, ki je veliko pripomogel k uveljavljanju nove znanstvene veje - krasoslovja.

Današnje krasoslovje je samostojni intregralni sistem znanosti poameznih vej, ki kompleksno preučujejo ozemlja na različno topnih kamninah. Objekt tega sistema znanosti je kraško ozemlje, vse njegove abiotske, biotske in družbenoekonomske elemente in komponente, a tudi tako njihovo medsebojno vplivanje kot tudi zunanje odnose samega krasa s sosednjimi ozemlji.

Sedanja struktura krasoslovja bi lahko bila taka:

1. **Skupina znanosti o naravnih sklopih kraškega sveta**
   1.1. splošno fizično krasoslovje
   1.2. paleokarstologija
2. **Skupina znanosti o naravnih sestavinah kraškega sveta**

- 2.1. geologija krasa
- 2.2. sedimentologija na krasu
- 2.3. geofizika krasa
- 2.4. geomorfologija krasa
- 2.5. klimatologija krasa
- 2.6. hidrologija krasa
- 2.7. pedokarstologija
- 2.8. biokarstologija
- 2.9. paleontologija krasa
- 2.10. kriokarstologija
- 2.11. glaciokarstologija
- 2.12. vulkanospeleologija
- 2.13. surovine na krasu

3. Skupina znanosti o družbenoekonomskih spletih kraškega sveta

- 3.1. splošno socioekonmsko krasoslovje
- 3.2. zgodovinsko krasoslovje
- 3.3. zgodovina krasoslovja

4. Skupina znanosti o družbenoekonemskih komponentah kraškega sveta

- 4.1. arheologija na krasu
- 4.2. kulturno krasoslovje
- 4.3. antropogena speleologija
- 4.4. vojaško krasoslovje
- 4.5. uporabna speleologija
- 4.6. speleofiziologija
- 4.7. speleoterapija

5. Skupina znanosti o kompleksnem preučevanju splošnih zakonitosti kraškega sveta

- 5.1. matematično krasoslovje
- 5.2. konstruktivno krasoslovje
- 5.3. teorija krasa
- 5.4. kraško okolje
- 5.5. tematska kartografija na krasu
- 5.6. krasoslovna dokumentacija in informatika
- 5.7. pedagogika na krasu

6. Skupina znanosti o regionalnih kompleksih kraškega sveta s specifičnimi zakonitostmi

- 6.1. regionalno krasoslovje
- 6.2. zonalno krasoslovje

7. Skupina tehniških znanosti v krasoslovju

- 7.1. tehnična speleologija
- 7.2. hidroekonomija na krasu
- 7.3. hidroenergetika na krasu.

PEDOGENESIS AND ECOLOGY OF KARSTIC LANDS IN TURKEY

PEDOGENEZA IN EKOLOGIJA KRASA V TURČIJI

IBRAHIM ATALAY

Izvleček UDK 551.311, 23(560)
631.48:551, 44(560)

Ibrahim Atalay: Pedogeneza in ekologija krasa v Turčiji

Članek podaja glavne značilnosti nastanka in razvoja prsti na izbranih lokacijah v jugozahodni in zahodni Turčiji. Ker so značilnosti prsti odvisne od značilnosti matične kamnine, so v prispevku tudi fizikalne in kemijske lastnosti apnencev, predvsem njihova prepokanost. Na razpokanih apnencih, še posebej, če vključujejo lapornate oziroma peščeno-meljaste plasti, je prst globlja, kot na masivnih apnencih. Večina kraških rdečih plasti v Turčiji je nastala tekom terciarja oziroma v toplih in vlažnih obdobjih kvartarja.

Ključne besede: pedologija, pedogeneza, krasoslovje, ekologija, Sredozemlje, Turčija

Abstract UDC 551.311, 23(560)
631.48:551, 44(560)

Ibrahim Atalay: Pedogenesis and ecology of karstic lands in Turkey

Characteristics of evolution and development of soils from chosen locations of southwestern and western Turkey are presented in the paper. Because the characteristics of the soils depend on basic rocks, the paper includes phisical and chemical properties of limestone too, their fissuring emphasized.On fissured limestones, specially if they include marl and sandy-silty layers, the soils are deeper than on massive limestones. In Turkey, most of the red karst soils developed during the Tertiary and the hot and humid periods of the Quaternary.

Key words: pedology, pedogenesis, karstology, ecology, Mediterranean, Turkey

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INTRODUCTION

Red Mediterranean soils are not found on the steep slopes of the karstic lands which are widespread in the Taurus mountains, in southern Turkey. But these land surfaces are densely covered by a forest and maquis where natural under the natural conditions. There are two major questions that deserve some explanation.

Although the land surface is very steep there may be thin soil cover under the forest canopy. The presence of thin and stony soils is attributed to erosion, especially when natural balance has been affected by man. As a result of this process, the bare and rocky surfaces of karstic lands were exposed. One can explain that bare karstic lands were exposed due to soil erosion, and transportation of soil materials which were accumulated within wide cracks and in the karstic depressions. But, this explanation is not true. According to author's study the soil formation has not developed on the inclined surfaces because of the fact that all rain infiltrates along the cracks (Atalay, 1988, 1991). One can clearly see there is no run-off even if heavy rainfall occurs. Indeed, although the mean annual precipitation is over 1500 mm on the upper slopes facing south in the Taurus Mountains, there is no run-off evidence.

Crack position and chemical composition of limestone appear to be very significant in soil formation. It is known that water easily infiltrates along the cracks. Therefore, soil formation does not proceed on the steep slopes because of the fact that water is not detained on the bare surfaces and also weathered materials are transported along the slopes. Soil develops along the cracks and between the layers due to the fact that water remains in thin cracks and between the sedimentary layer surfaces. Clay, which is the minor constituent in the limestones and the other materials such as quartz remain in place when $CaCO_3$ is dissolved. The residue is generally clayey, and soil derived from this material is also clayey in texture. As a general rule, it can be stated that the main material remaining in karstic lands is clayey and thus the soil material is of clay and clayey in texture.

The main purpose of this paper is to explain how Red Mediterranean soil develops in the karstic lands.

2. MATERIALS AND METHOD

Almost all parts of the karstic region of Turkey were examined during the field observations. The stratigraphic and lithologic properties of the karstic areas were taken into consideration. Especially, the relationships between soil formation and karstification processes were studied. Soil samples were collected from the different parts of the karstic areas.

Laboratory analysis such as pH (1:1 H_2O) and cation exchange capacities were determined according to Richards (1954). The $CaCO_3$ content by Black (1956), and mechanical analysis by Bouyocous (1952). These analysis were made by Forest Soil Research Laboratory at Eskişehir. Determination of clay minerals were carried out on suspended slides by Jackson (1979)'s method using a PHILIPS X-ray difractometer at the Laboratory of Soil Department, Faculty of Agriculture, Çukurova University. In order to reveal the ecological properties of karstic land, field observations were made.

3. RESULTS AND DISCUSSIONS

Soil forming process in the karstic lands

The factors *affecting pedogenesis in karstic lands are as follows:*

The position of the crack structure and stratification system, thickness of the layers, and chemical composition of the limestone, especially the amount of the clay and climatic condition determine the soil formation and its physical and chemical properties in karstic lands.

3.1 Crack structure of limestone

Crack structure is a very important factor for soil formation in the Taurus mountains. In fact, weathering and dissolution processes take place along the thin cracks. Also some kind of lapiés develops along the vertical cracks (Fig. 1).

The extent of the crack is mainly dependent on the chemical composition and age of the limestone. As a general rule, the cracks in limestones were mostly produced by tectonic movements. The hard and pure limestones which were subject to tectonic movements were dissected by cracks. For this reason, the extent of cracking in sandy and pure limestone is much more than in clayey limestone or marl. For example, Paleozoic and Mesozoic limestones contain more abundant cracks than the clayey or marly limestones belonging to Tertiary, in general (Atalay 1987b).

The limestones which were dissected by cracks are richer in terms of soil content than the less dissected one (Atalay 1973, 1987 a, 1987 b, 1988, 1989 and 1991).

In the Taurus Mountains, Red Mediterranean soils are found in the cracked limestone because of the fact that soil has formed along the cracks (Figure 1).

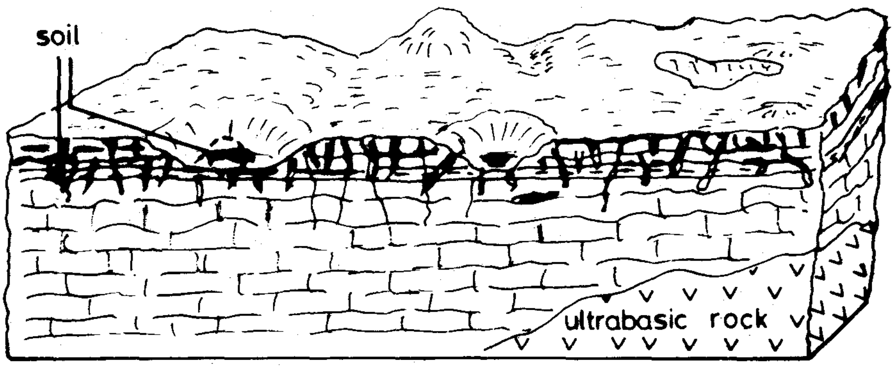

Figure 1. Soil formation along the cracks. This figure represents the Mesozoic hard limestones (location 2 and 6 in Table 1), in the western part of Taurus Mountains.

3.2 Chemical composition of limestone

Pure limestone dissolves more quickly than clayey limestone. That is why, if limestone contains more residue such as silicious sand and clay, the degree of solution decreases. When limestone has been completely dissolved, the clay-sized residues are left behind. Although the residual clay content of the limestone is less, rich soils are found on this type of limestone (Site 2 from

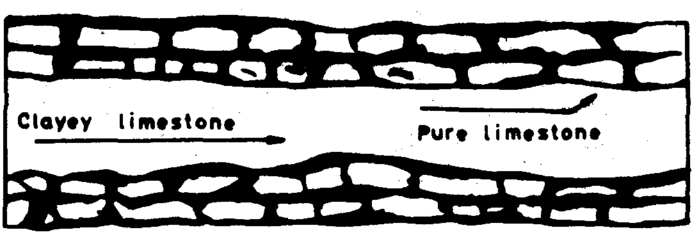

Figure 2. The differences between marl and cracked limestones. Black places show red soils. This figure is prepared from the Karaburun Peninsula, Western part of the Aegean region.

table 1, and Fig. 2). Sandy limestones produce sandy soils which are widespread on the Taşeli plateau, Middle Taurus. Soft limestone form Rendzina soils.

In the Taurus Mountains the thick and abundant soils occur on the rather pure limestones belonging to Lower Miocene and Mesozoic which are common in the Middle and the western part of the Taurus Mountains, especially the Davras and Dedegöl Mountains. The thin and stony soils are seen on the limestones containing $MgCO_3$, hard and crystalized limestone; sandy soils are found on the sandy limestones.

3.3 Stratification properties of limestones

When the clayey, marly and sandy layers lie alternately, in karstic lands the water is mostly held along the bedding and/or weak surfaces. Therefore soil formation generally has been developed between the bedding surfaces. On the other hand, there is no considerable difference among the soils which are found along the bedding surfaces. But, clayey loam textures are dominant in the soils which are developed both on the surface and along the cracks, while the texture is clay in the bedding surfaces (Table 1, site 2 and Fig. 3).

Our observations showed that soil formation is more active in the thin bedded limestone formation, while the soil-forming process may be slow in the

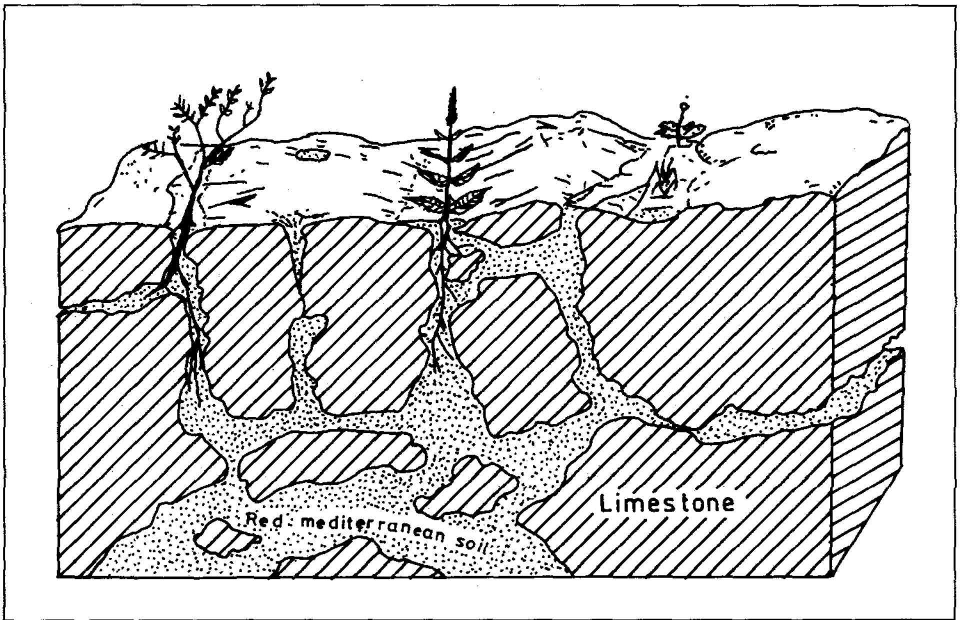

Figure 3. The relationships between soil formtion and stratification. Black places show the reddish soils. This figure is drawn in the vicinity of Akseki, western part of the Middle Taurus.

thick or massive limestones which may be more widespread. However, soils are found along the cracks within the blueish and hard limestones representing Mesozoic in the western part of the Taurus Mountains, Çeşme and Karaburun peninsulas in the Aegean region, western part of Turkey. Thin and stony reddish soils are only common at the bottom of the "V" shaped dolines. The inclination of the layer determines the soil formation as shown in Fig. 3 (Sites 1 and 2 in table 1). In the horizontal and thin-bedded or stratified areas, soil layers resemble a wall built by bricks. Soil follows the weathered zones or layers (Atalay et al 1988, 1990).

3. 4 Relationships between karstification and soil formation

There is a close relationship between soil formation and karstification events. Karstification processes occur in cracked limestones, because of the fact that dissolution events continue along the crack (Jennings 1985, Atalay

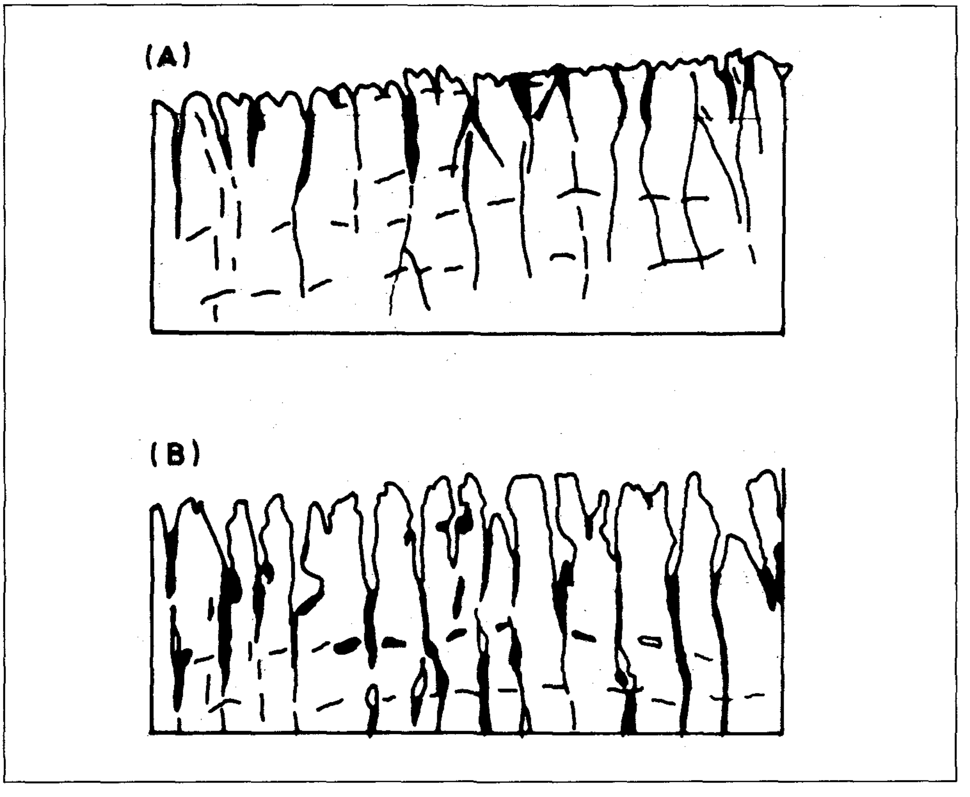

Figure 4. (A) Soil developed along the cracks, and (B) vertical transport of the soil with the widening of cracks. This figure represents Gidengelmez Mountains, made up of Mesozoic limestone and extending between Seydişehir and Manavgat towns, western part of Middle Taurus Mountains.

1989). The dissolution of limestone along the cracks leads to the widening of the cracks. Soils which have been developed along the cracks are transported further down by the widening of the cracks. This shows that the soil mass may be moved from the upper zones towards the lower in the vertical direction. Such soils are found in the rather pure limestones of the Gidengelmez mountains in the western part of the middle Taurus Mountains (Fig. 4). This position explains why the soil is found in the deeper section of karstic lands (Sari et al, 1986; Atalay, 1988, 1989).

While the clay and clayey layers may prevent the karstification activities, especially in horizontal formations, soil formations may be rapid in this material. In the horizontal structure areas, the bottom of the karstic depressions such as dolines and poljes is generally composed of clay and/or a clayey layer on which a thick soil can be found (Atalay 1989) These soils are common in the poljes of the middle and eastern parts of the Taurus Mountains, especially Taşeli plateau (Table 1, sites 4 and 5)

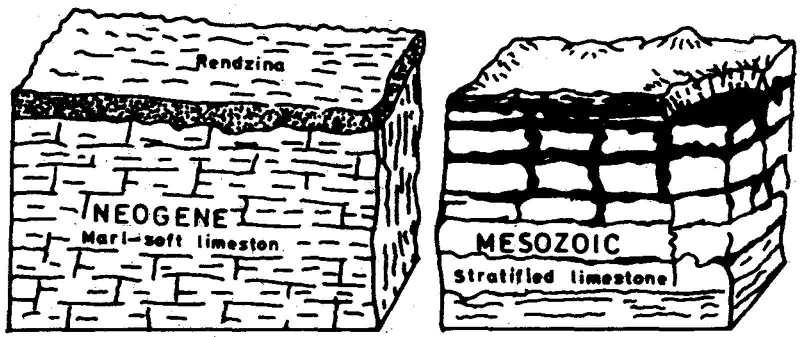

Figure 5. The prevention of soil forming process on the marl layer in the some polje areas. This figure represents Taşeli plateau composed of clayey and limestone layers lying in horizontal structure.

A rocky appearance is generally dominant in the places where intense karstification events have occured. In the Taşeli (Rocky country) plateau, in the middle part of the Taurus Mountains, soils are common along the weak zones in which they have been formed (Fig. 5 and 6).

3.5 Physical and chemical properties of karstic soils

The clay content of karstic soils is generally much more than that of other soils. For example, soils which have been developed on the gneiss are of sandy loam texture; the soils occurring on the marl are generally loam and clayey loam; and the soils which have developed on the peridotite are of clayey loam. But karstic soils are of clay and rarely clayey loam texture, because, the materials remaining on karstic land are of clay, in general. As it is known that bauxite deposits have developed by a dissolving of the limestones and accumulation of the clay.

Site and parent material, elevation (m)	Hor.	Texture	pH	$CaCO_3$ (%)	CEC (cmolc kg^{-1})
İzmir-Çeşme road,	A	C	8.0	1.5	36.2
limestone, 400	A	C	7.8	-	34.2
Karaburun peninsula					
W of Aegean region,					
limestone cracks		Cl	7.0	1.5	31.5
Bedding surfaces		C	8.2	1.5	31.3
Top soil, 20 m		Cl	7.6	-	40.7
Davraz Mountain, W					
of Taurus in doline areas	A	Cl	7.0	0.4	-
Middle Taurus, 1600 m					
Dümbelek düzü, Middle	A	Si C	6.6	0.0	43.5
Taurus, 2300 m	B	C	7.5	3.0	46.0
Başkonuş dağı	A1	C	7.7	2.8	41.3
E of Taurus,	A3	C	6.5	2.4	47.7
1300 m	B1	C	7.5	0.8	45.5
near doline	B3	C	7.3	0.2	53.1
Beydağı (W.of Taurus)	A	C	7.4	1.6	52.1
Çığlıkara, 1600 m	B	C	7.1	1.2	50.2
Gazipaşa (Middle of	A	C	7.2	0.8	48.5
Taurus), Karatepe,	B	C	7.2	0.8	53.2
1700 m					

Abbreviate: C: Clay, Si: Silty, SiC: Silty clayey Cl: Clayey

Table 1: Physical and chemical properties of the red mediterranean soils

In addition to this, the clay content of the B horizon is more than horizon A due to illuviation process. The amount of the rounded silt particles in horizon A is generally more than in horizon B. This may be responsible for the eolian accumulation. Indeed, during the last glacial period under the dry and cold climate, eolian materials coming from the Arabian-Syrian and Sahara deserts accumulated on the soils. These soil samples are found in the eastern part of the Bornova Plain and the eastern part of Karaburun peninsula, in the western part of Turkey (Atalay, 1992).

Under the humid mediterranean climate, $CaCO_3$ is completely leached out from the solum of the mature mediterranean soils. But the formation of secondary carbonates may be found in the downslope areas.

The reaction of these soils found in karstic areas changes from slightly acid to alkaline (pH 6.1 to 7.7), and it has generally neutral reaction. But under the same climatic regime the soils which have been developed on the marl have an alkaline reaction.

The CEC of the karstic soils varies between 25 and 40 me/100 g, supporting that they contain a substaintial amount of smectites. These values are less than in the soils developed on the peridotite and gneiss and quartzite which seem to have more smectite in them (Atalay et al. 1990).

4. ECOLOGICAL PROPERTIES OF KARSTIC LANDS

Although the surfaces of the karstic lands are of stony and rocky appearance, in general all plants grow on the karstic land. Besides, some plant communities grow very well and some relic communities are found in the karst. As mentioned before, the runoff does not occur on the cracked limestone in the slope areas due the fact that its infiltration capacity is very high. Most atmospheric water is absorbed by the soils which are found in the pockets, cracks and bedding surfaces. Meanwhile capilllary action does not occur due to the crack structure. The reflection of the sun's radiation is higher than with some materials such as basalt, gneiss and andesite. These pecularities produce a somewhat more humid habitat than that of the other parent materials. Indeed, the roots of plants easily develop and penetrate along the cracks. In other words, karstic lands produce a suitable habitat for plants that have deep root systems. It can be said that karstic lands form a suitable habitat for some trees and shrubs such as *Quercus coccifera, Pistacia lentiscus, Ceratonia siliqua, Arbutus andrachne* having vertical extension of the root system. For this reason, the plants with deep root grow easily in karstic terrains because of the fact that there is mostly sufficient water for the plants from the soils found in cracks and pockets.

Stony and/or rocky karstic lands prevent the growth of the herb vegetation due to the fact that adequate water is very low in the surface. In other words, the plants with finely dense lateral root systems quickly develop but dry up in the short time because the water holding capacity of the surface is very low. For that reason the herb vegetation density of the karstic lands is generally very low in the Taurus Mountains. But the seeds of conifer trees come rapidly to generate on the bare surfaces due to the fact that this surfaces gets the required radiation for the seeds to germinate. The seeds germinate on the soils which are found in the crack or pockets, providing adequate water. Indeed, cedar *(Cedrus libani)* seeds easily germinate on karstic lands, especially protected from grazing. Thus the karstic lands, in the Taurus Mountains are extensively covered by cedar plants because cedar roots easily penetrate and develop along the cracks. The root lenght is measured to be 80-90 cm in one year old cedar plants.

Karstic depressions and canyon valleys present a special habitat for the growth of some hydrophytic vegetation and provide a refuge or shelter areas for relic species. According to our observation, dolines which are found in the oro-mediterranean belt are the main refuge areas of the relic species belonging to Euro-Siberian elements. For example, *Tilia rubra* (basswood), *Fagus orientalis* (beech), *Sorbus torminalis, Euonymus latifolius, Buxus sempervirens* are found in the doline areas, because these plants obtain adequate water

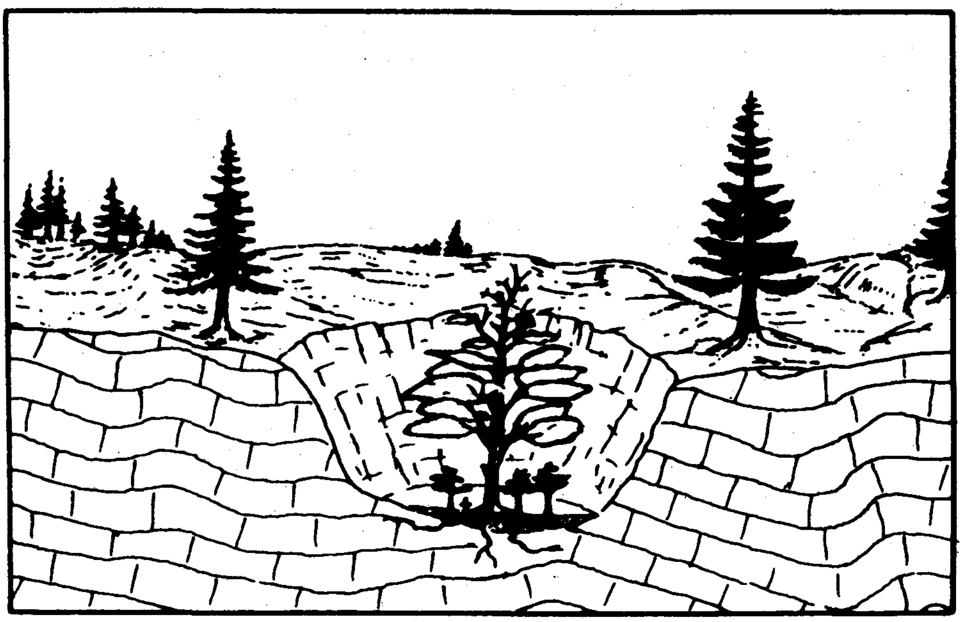

Fig. 6. Dolines provide a favourable habitat for the growth of hygrophytic and endemic plants. In this figure, Quercus vulcanica, an endemic oak species, grows only within doline, Davras Mountain, western part of Taurus.

from the deep soils found in the bottom of the dolines. In addition to this, doline walls protect them against the cold and severe winds. The best example may be given as *Quercus vulcanica,* being both endemic and relic oaks. This oak only grows in the doline areas in the Davras Mountains, W of Lake Egirdir (Fig. 6).

On the other hand, *Celtis australis* stands only occur in the deeply opened valley. One can come across *Celtis australis* clusters in the karstic depressions NW of Maraş province, E of Taurus. Canyon valleys are also rich in terms of hydrophytic vegetation. Such vegetation appears in the canyon valleys extending in the Taurus Mountain. For example *Taxus baccata, Cornus mas, Corylus avellana* belonging to Euro-Siberian or Black Sea phytogeographical region are found in the Cehennem valley in the Taşeli plateau in middle Taurus. At the same time, small karstic depressions can be termed as a treasure of distinct plants. These areas protect the plants against the destruction activities of human beings and cold and severe winds. That is why, special vegetation including relic and endemic plants grow in such areas. For example, the memorial trees which are composed of *Cornus colurna, Buxus sempervirens, Acer,* and *Tilia* are found in the karstic areas of the Black Sea region. These trees also indicate the natural paleoenvironmetal conditions.

One of the most important aspects of the karstic areas is to maintain the growth of climax and subclimax vegetation. Because even if maquis vegetation is completely destroyed, its roots remain in cracks and again the natural reproduction occurs via stool shoot. Indeed, since climax trees and shrubs growing on the soft soil and other parent material are destroyed they are replaced by different ones. But in the karstic lands, destroyed vegetation may again regain the natural habitat.

The negative effects of the karstic lands in terms of vegetation is to convert into bare rocky habitats after the natural vegetation has been completely destroyed. Once vegetation cover has been completely removed in karstic land, the stony and rocky surfaces emerge. In these areas reforestation activities are very hard or sometime impossible because of the fact that natural equilibrium is destroyed and it is very hard to find a suitable soil for the plants.

5. CONCLUSIONS

Soils are not found on the steep slopes of karstic lands, except along the cracks and bedding surfaces or between the layers.

Soil has been developed along thin cracks and between the layers. Thin cracks and bedding surfaces are favourable places for holding water. So weathering or soil forming processes take place where there is water. Clay illuviation and the transportation of the soil particles in a vertical direction only occur as a result of the widening of the lapiés. With the progres of karstification, vertical material transport occurs through the enlargement of cracks. Thus, in the karstic areas which are deeply dissected by the lapiés soil is not found on the surfaces but in the deeper sections.

Clay is the main impurity within the limestone and this is the reason why the soils in the karstic lands often are clay or of clayey texture. The cracks in the limestone provides a favourable conditions for oxidation so that Fe becomes oxidized and soils attain reddish colour, and at the same time roots of trees easily penetrate into the deeper part of the area through the cracks.

Rich and thick soils are common in places where thin bedded stratigraphic sequence are present. Because pure limestones contain many more cracks than the clayey limestones, soil forming process in karstic lands takes a long time and the depth of the soils is mostly thin.

Soil erosion activities generally do not occur on the surfaces of karstic lands because runoff is very low due to high infiltration capacity. In these areas chemical erosion is dominant.

Karstic areas provide a suitable habitat for the growth of some distinct shrubs and trees. Karstic canyon valleys and small depressions such as doline are the main refuge areas for some relic and endemic species. That is why karstic land is generally rich in terms of relic and endemic species showing past climatic conditions.

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REFERENCES

ATALAY, I. (1973): Karstification and soil formation in the Taurus mountains: Turkish, summmary in English). Bulettin of Geomorphology , 5: 135-143.

ATALAY, I. (1987): The ecological conditions of the natural occurrence areas of cedar (Cedrus libani A. Rich.) and regioning of seed transfer of cedar in Turkey: General Dir. of Forest Pub Nu.: 661/63, Ankara, 167 p.

ATALAY, I. (1987) : Introduction to Geomorphology of Turkey (in Turkish). Ege University, Faculty of Letters Pub. Nu: 9, 454 p, İzmir.

ATALAY, I. (1988): Karstification and the ecology of the karstic land in the Taurus mountains (Summary in english), Bulettin of Geomorphology, 16: 1-8.

ATALAY, I. (1989): Soil formation of the karstic lands of the Taurus Mountain (in Turkish). Papers of 10th of Soil Scientific Meeting, Soil Science Union, Pub Nu: 5, 18.1-13.

ATALAY, I. (1989): Soil Geography (in Turkish). Ege Univ. Faculty of Letters Pub. Nu: 8, 450 p., İzmir.

ATALAY, I. (1991): Soil formation in the karstic land in Turkey. Proceedings of the International First Regional Conference of Geomorphology, Special Issue, 19, Bulettin of Geomorphology, 19: 139-144.

ATALAY, I. (1992): The ecology of beech (Fagus orientalis Lipsky) forests and their regioning in terms of seed transfers. Pub. of the Directory of Forest Trees and Seeds Improvement, Nu. 5, 209p., Ankara.

ATALAY, I. (1993): Red Mediterranean soils in the karstic land of Turkey: 2nd International symposium on the Red Mediterranean Soils, May, 1993, Adana, Turkey.

ATALAY, I. (1994): Vegetation geography of Turkey,Ege Univ Press, ISBN: 975 95527 8 7, Izmir, 352 p.

GERRARD, A. S. (1981): Soils and Lardforms. George Allen and Unwin. ISBN 0045510492, 219 p.

JENNINGS, J. N. (1985) : Karst geomorphology. Basil Blackwell Ltd, ISBN: 0-631- 14032-8, 293 p.

SARI, M., DINÇ, U., SENOL, S., and KAPUR, S. (1986): Karstik topraklarin oluşu, önemli fiziksel, kimyasal ve mineralojik özellikleri ile siniflandirilmisi, The formation of karstic soils and their main physical, chemical and mineralogic properties and classification (in Turkish), Papers of 9th of Scientific Meeting, Turkish Soil Science Union Pub. Nu:4, 6.1-6.9, Ankara.

PEDOGENEZA IN EKOLOGIJA KRASA V TURČIJI

Povzetek

Z vidika pedogeneze in ekologije je kraški svet jugozahodne in zahodne Turčije posebno pomemben. Za to študijo so bile izbrane različne lokacije. Ker prsti nastajajo v kamninskih sistemih, so upoštevane tudi fizikalne in kemijske lastnosti apnencev.

Splošno pravilo je, da se na strmih kraških pobočjih prsti ne morejo ohraniti, pač pa so v razpokah in plastnih razpokah na krasu, tako na mediteranskem kot tudi na egejskem področju. Ko voda prenika v razpoke in dalje v sedimentne plasti, se prično procesi lokalnega razpadanja. Rezultat tega je nastajanje prsti in situ, vzdolž razpok ter plasti, in ni nujno vezano na transport delcev prsti iz višjih leg.

Fizikalne in kemijske lastnosti apnencev so tudi pomemben dejavnik, ki vpliva na lastnosti prsti. Prsti na masivnih in manj razpokanih apnencih so običajno plitve in kamnite, medtem ko so na gosto prepokanem apnencu, še posebej, če so vmes laporne in peščeno-meljaste plasti, bolj globoke.

Delci prsti potujejo proti globljim delom apnenca kot posledica večanja škrapelj, ki običajno nastajajo vzdolž razpok. Na takih področjih poteka transport delcev prsti v navpični smeri.

Procesi oksidacije oziroma barvanje prsti v rdeče potekajo na apnencih veliko hitreje, kot na drugih matičnih kamninah, saj prepokana struktura *apnencev omogoča dobro kroženje vode in zraka. Prisotnost pirita v apnencih* lahko ta proces močno pospeši. Večina rdečih prsti na krasu se je morda razvila tekom teciarja ter v vročih in vlažnih obdobjih kvartarja. Debele plasti prsti na apnencih jasno odsevajo paleoklimatske značilnosti. Za nastajanje prsti in razvoj koreninskega sistema so v gostih gozdnih združbah v Taurusu zelo dobri pogoji.

ACIDIFICATION AND OTHER KARST SOIL PROCESSES IN HUNGARY

ZAKISLJEVANJE IN DRUGI PROCESI V KRAŠKI PRSTI NA MADŽARSKEM

I. BÁRÁNY-KEVEI & L. MUCSI

Izvleček UDK 631.415:551.44(439)

I. Bárány-Kevei & L. Mucsi: Zakisljevanje in drugi procesi v kraški prsti na Madžarskem

Vzrok zakisljevanja rjave gozdne prsti je v temnosivem skrilavcu, proces pa pospešuje tudi kisli dež. Ker je plast skrilavca vedno tanjša, se veča delež kalcija v prsti, s tem pa tudi puferska kapaciteta. Ta je dovolj dobra na kamnitih prsteh in črnih rendzinah, toda vedno več anionov absorbirajo površine koloidov.

Ključne besede: krasoslovje, pedologija, kraška prst, zakisljevanje, mikroklima, procesi v prsti, korozija

Abstract UDC 631.415:551.44(439)

I. Bárány-Kevei & L. Mucsi: Acidification and other karst soil processes in Hungary

The cause of the acidification in brown forest soil is the dark grey shale, and this process is made stronger by the acid rain. Thickness of the shale decreased and calcium content and the buffer capacity increased. The buffer capacity of rocky soil and of the black rendzina is good enough, but more and more anions are absorbed on the colloid surfaces.

Key words: karstology, pedology, karst soil, acidification, microclimate, soil process, corrosion

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INTRODUCTION

On hidden opened karst areas (the karstic rock covered by soil, Bárány-Kevei - Jakucs 1984.) the effects of microclimate and plant cover success through the soil. The thickness of the soil layer, its permeability, as well as the physical and chemical properties take a significant part in the subsoil corrosion.

DISCUSSION

The content of the water soluble anions and cations has important effect on the chemical properties of the soil, therefore their investigation is indispensable from the point of view of subsoil corrosion.

Fig. 1-2 shows the content of water soluble anions and cations in the soil of dolines and karst surfaces in Bükk Mountains and we present some data of soil type of Dinaric Karst. We can find low anion and cation content in the soil of dolines in Bükk, especially if we compare them with the data of Dinaric Karst.

The soil as a horizon of the activity of biogene factors also takes an important part in the process of karst corrosion. Apart from the fact that the roots of macroflora emit carbon dioxide during the root respiration, millions of microorganisms appear in the soil, producing carbon dioxide during the decay of organic materials. At the same time, they modify the chemical properties of the soil and have an influence on the aggressivity of the soluble water. The microbiotic activity is very effective in 0.5-1 m depth, which results in significant carbon dioxide emission. In the deeper soil layers, the activity of microorganisms decreases, then becomes strong again on the soil-rock boundary. The density of the bacterium population is in close connection with the soil moisture and pH value.

These exogenic ecologic factors can modify the process of weathering in a favourable or unfavourable direction. In this level, there may be some possibilities for intervention to decrease the unfavourable (for example the environmental pollution) effects.

The properties of infiltrating soluble water cannot be modified if it reaches the deeper rock layers the reactions are unreversable, such as

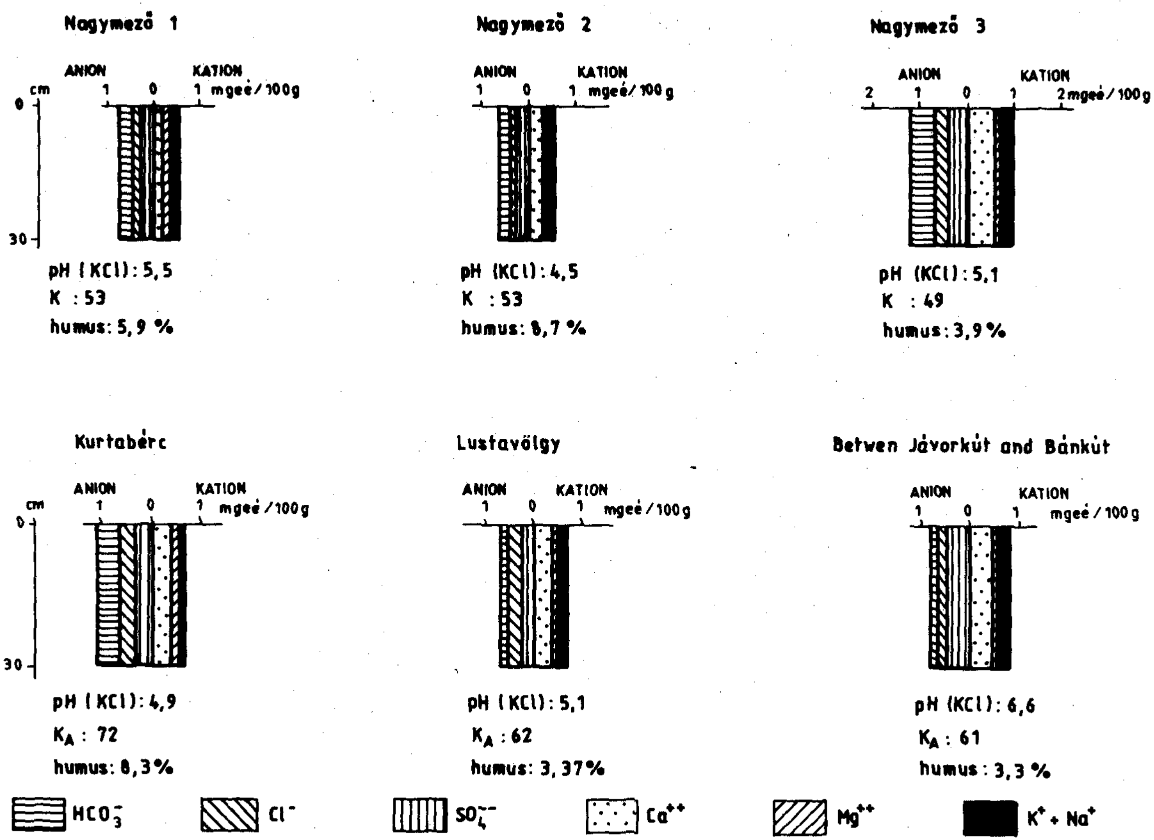

Fig. 1 WATER SOLUBLE ANIONS AND KATIONS IN THE BOTTOM OF DOLINA (Bükk Montain, Hungary)

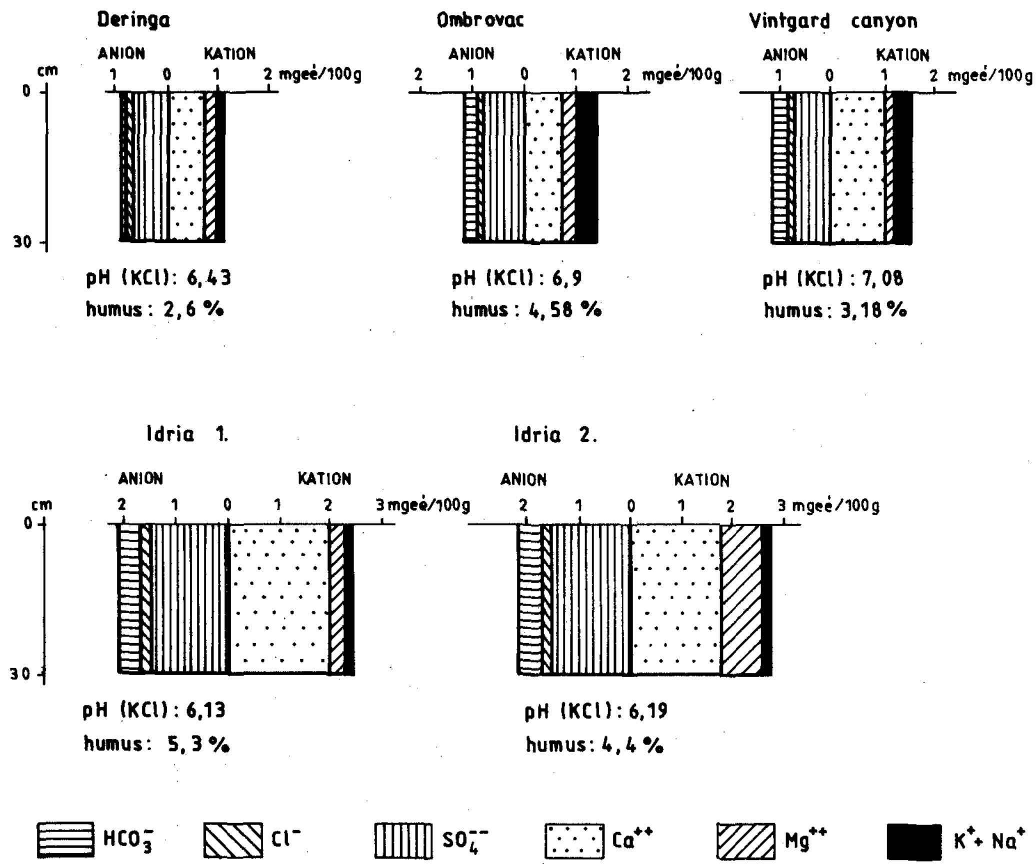

Fig. 2 WATER SOLUBLE ANIONS AND KATIONS IN A KARST SOIL IN A DINARIC KARST

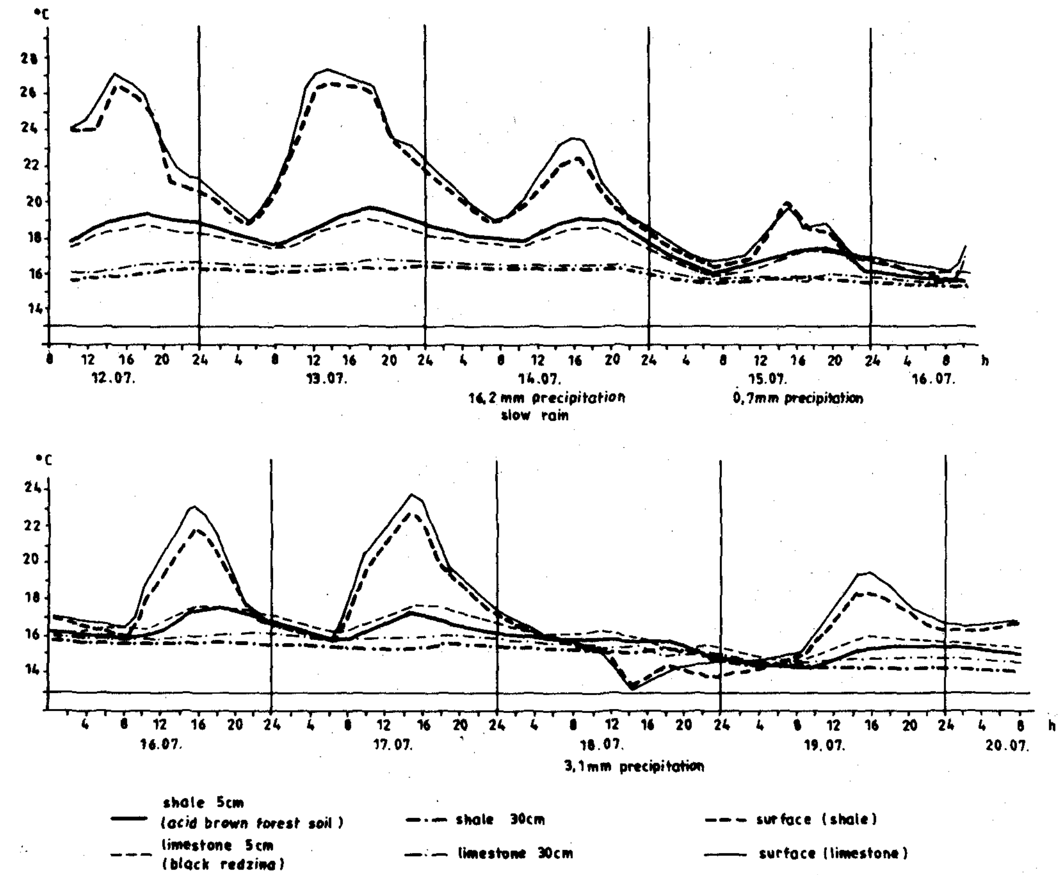

Fig. 3 SOIL AND AIR TEMPERATURES IN JULY 1991 (acid brown forest soil and black rendzina)

dripstone degradation in the European caves recognized by us. The effect of the polluting materials is similar to this process when they reach the karst water system, getting through the limestone layers and appearing in the karst springs.

The climate is the one of the most important ecological factor of karst processes. Amongst the climatical factors, the rain and temperature have very strong influence on the intensity of karst processes. The microclimate could effect the microkarst processes such as development of solution forms. Differences in microclimate can be the causes of the formation of asymmetrical solution dolines (Bárány-Kevei, I.-Mezősi, G.1991).

Maximum and minimum temperature measured in the dolines show a considerable extreme values. The extreme values of temperature in karstic soil show considerable large differences on various slopes and various levels of soils (Bárány-Kevei, 1985., Mucsi L. 1992. Fig. 3).

In 0.5-1.0 m deep soil zone, the microbial activity results in a huge amount carbon dioxide production. On the soil-rock boundary, increased bacterial activity could be observed (Table 1). Our previous investigations carried out on the surface near dolines as well as the presented results suggest that the bacterial activity is the most important factor in the upper soil layer and on the soil-rock boundary. Further investigations should be focused in

depth (m)	aerob (10^6/g soil)	anaerob (10^6/g soil)
0.2	2.1	7.0
0.5	1.2	10.5
1.0	0.2	5.0
1.5	0.08	1.2
2.0	0.002	-
2.5	0.008	0.05
3.0	0.023	0.05
3.5	0.006	0.25
4.0	0.194	0.55
4.5	0.06	0.6
5.0	0.06	0.6
5.5	0.133	0.3
6.0	0.53	0.3
6.5	0.126	0.05
7.0	0.001	0.2
soil-rock boundary	0.256	0.3
crumled remnants	1.04	8.5
rock surface	3.86	2300.0

Table 1. Numbers of aerobic and anaerobic bacteria in soil samples of doline:

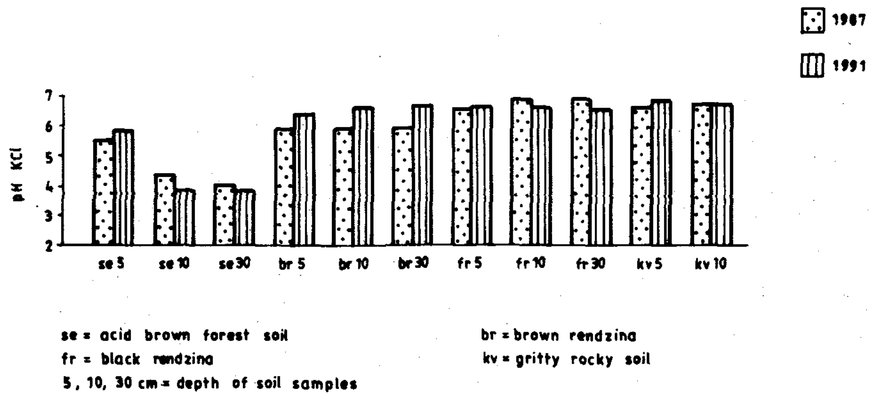

Fig. 4 pH (KCl) VALUES IN DIFFERENT SOIL TYPES ON ODORVÁR IN 1987 AND 1991

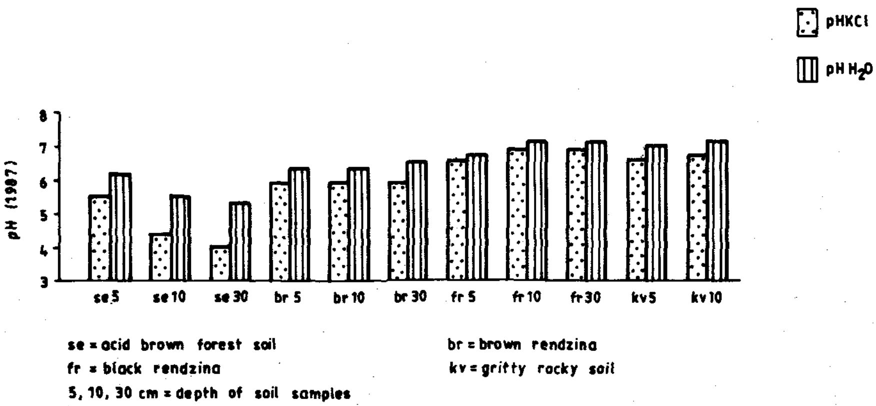

Fig. 5 pH VALUES (KCl and H_2O) IN DIFFERENT SOIL TYPES ON ODORVÁR (1987)

these zones (Bárány-Kevei, I. - Zámbó, L. 1988) .

During the investigation of genetic soil-types on the area of Odorvár (Bükk Mountains) we recognized different processes connected with soil acidification. The most important factors in the acidification are

- pH of the precipitation
- buffer capacity of the soil
- chemical and physical properties of the base rock.

We have drawn patterns from 4 different soil-types in 1987 and in 1991 and have investigated their physical and chemical properties in connection with changes in acid properties.

Acidification in acid, non podzolic brown forest soil

The acidification in brown forest soil is natural, non anthropogenic process. This soil type is formed on shale, phyllite, porphyrite and hydroandesite. It contains clay minerals formed before the beginning of soil formation. These minerals lose in their colloid properties significantly. The brownish-black illuvial layer is rich in humus, its structure is crumbled and grained. The pH value ranges from 3.5 to 4.5. We can always find aluminium and iron ions among the changeable cations. In the alluvial layer the acidification is a significant process as well (Stefanovits, P. 1981).

The acid property of brown forest soil is traceable quality of disintegrated remnants of dark grey shale, which is the base of the soil formation. The remnants of rocks which are poor in basic materials can be reduced in these components and this process produces favourable conditions for acidification (Máté, F. 1987).

We examined the changes in pH values in 1987 and in 1991. Figure 4 shows the pH values in three layers (5, 10 and 30 cm depth). The pH (H_2O) values were 6.2, 5.5 and 5.3, while the pH (KCl) values were 5.5, 4.4 and 4.0. If the difference of distinctive pH value (e.g. pH (H_2O)-pH (KCl)=1.3 in 30 cm) is greater than 1 in a special layer, it indicates to intensive acidification (Fig. 5).

The acidification in brown forest soil is basicly formed by the chemical properties of dark grey shale, but this process may become harder due to the imission of acid materials of the atmosphere. Therefore we have investigated the sulphate and nitrate ion contents in distinctive soil-types. These materials are imitted onto the Earth's surface by dry and wet imission and they are washed down into the lower soil layers by precipitation. In connection with the buffer capacity of the soil we have found lower nitrate content in the lower layers, while the distribution of sulphate ions was more uniform in the whole soil profile. In 1987 the nitrate contents in different soil layers were 8.3, 2.3 and 1.5 ppm, while in 1991 the ion contents were 8 times greater than four years before (64.7, 11.5 and 4.8 ppm). The sulphate content also increased, but not so significantly. In 1987 the sulphate content was 10.8, 11 and 25.4 ppm, while in 1991 it was 18.6, 16.6 and 22.1 ppm (Fig.6).

The development of acid brown forest soil shows that the acid rainfall makes stronger the process of soil acidification. Due to the low buffer capacity, this tendency will continue.

Process of acidification in soil types formed on limestone

Besides the geologic composition of the area of Odorvár, the acidification is being modified by climatic conditions. Basic materials are washed out from the upper soil layer by the seeping precipitation. The most soluble ions of alkaline metals and later their hydrocarbonates are carried away in the first stage.

During the changing of cations (calcium, magnesium cations and ions of metals found in soil) are the deputy of hydrogen ions of acids. Minerals are dissolved in precipitation and groundwater, which contain carbon dioxide. Positive ions of metals are carried away together with anions and negative bicarbonate ions by seeping water down to the lower soil layers. If later the sulphuric acid gets into the soil then magnesium and calcium ions are carried away by sulphate ions. While the sulphate solution transport the cations, hydrogen ions remain in the soil and these are the cause of the acidity of the soil (Mohnen, V. 1988).

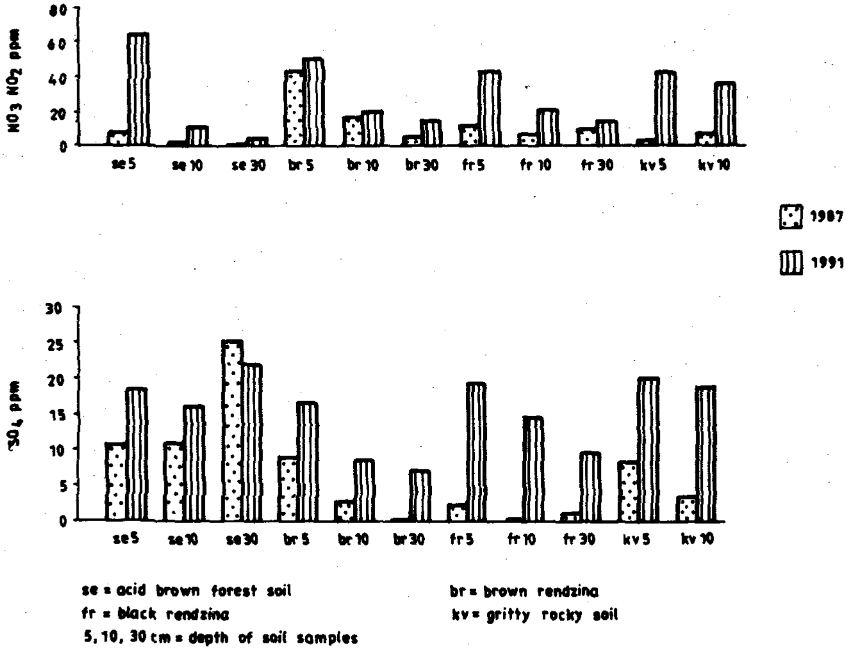

Fig. 6 NO_3, NO_2 AND SO_4 ION CONTENT IN DIFFERENT SOIL TYPES ON ODORVÁR IN 1987 AND 1991

The seeping water contains organic acids formed during the microbiological decomposition of plant residues, which are taking very important role in the acidification (biogenic factor). Acid organic materials arisen from the formation of humus combine with calcium ions into salt and calcium humate, if there is sufficient calcium carbonate in the soil. The chemical reaction of the soil solution does not change by acid and basic influences than that of the distilled water, because of the buffer capacity of the soil.

Different soil-types were formed on limestone on the area of Odorvár. The gritty, rocky soil is the erosional residue of black rendzina. The fragments of limestone and the calcium ion content of seeping water are the cause of the high buffer capacity of this soil-type. The surplus hydrogen ions are absorbed in the soil containing calcium and magnesium carbonates and chemical reaction of the soil layer is regulated by the

$$CaCO_3 - Ca(HCO_3)_2 - H_2CO_3$$

buffer system in accordance with the following chemical reaction (Filep, Gy. 1988.).

$$CaCO_3 + (H^+ + HCO_3^-)_2 \rightleftharpoons Ca^{++} + 2HCO_3^-$$

$$(H^+ + HCO_3^-)_2 \rightleftharpoons CO_2 + H_2O$$

Therefore, the pH value of the soil solution does not decrease, while there are sufficient calcium and magnesium carbonates in the solid phase of the system. Calcium and magnesium ions can be washed out by seeping water if they are in solution.

Gritty, rocky soil does not cover the limestone surface continuously on the eastern, southeastern and southern slopes of Odorvár. The precipitation reaching the covered and uncovered surfaces can be a considerably acid solution.

The pH of the precipitation, because of the absorbed free carbon dioxide content of the air, is about 5.6, but the pH value can be 4.5 or lower if it dissolves air pollution emitted by industry (Mészáros, E.-Horváth, L. 1980.). Dissolution of limestone by runoff is started in spite of the high water velocity of the sinking water (rillen karren). If the sinking water is not saturated then it is able to absorb further calcium ions in the fractures of the limestone or in the soil. The process is made stronger by humus acids created by the decomposition of organic materials. The humus content of black rendzina ranges from 5.5% to 10% (Fig. 7).

The most important factor in the soil acidification is the acid rain. We have found enormous differences between the sulphate and nitrate contents in soil sample gathered in 1987 and 1991. The sulphate contents was 8.4 and 3.5 ppm in 1987. We could pick up samples from two layers because this soil-type is strongly eroded by external forces. The sum of nitrate and nitrite ion content was 2.9 and 6.6 ppm. In 1991 the sulphate content was 20.4 and 19.2 ppm in the samples, while the sum of nitrate and nitrite ions was 42.5 and 5.5 ppm. The distribution of these anions shows that this very thin soil layer can absorb the acid factors of precipitation by its hard buffer capacity. The increasing sulphate and nitrate content proves that more and more anions are being absorbed on the colloid surfaces. If the sulphate and nitrate content of the precipitation does not decrease then the buffer capacity of the soil will become impoverished. If it ensues then the seeping water will not be saturated and it can dissolve the dripstones formed in the caves. On the area

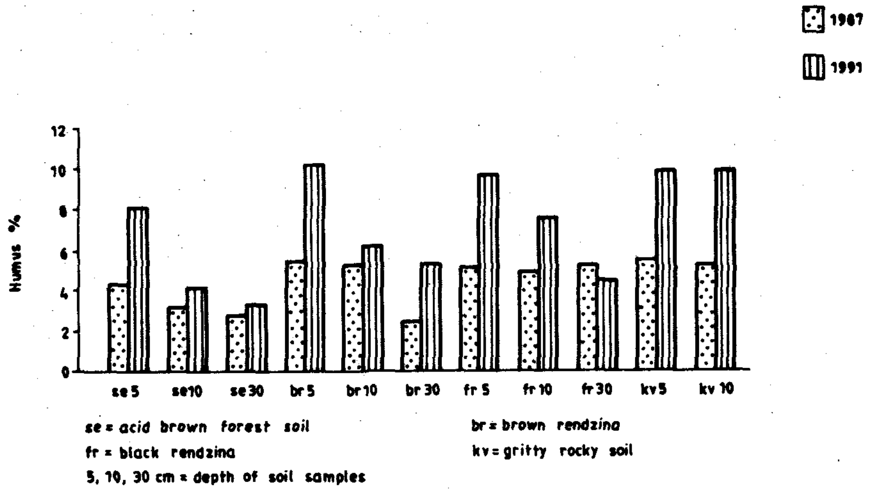

Fig. 7 HUMUS CONTENT IN DIFFERENT SOIL TYPES ON ODORVÁR IN 1987 AND 1991

of Odorvár, we can find very thin limestone layer over the Giant-chamber of Hajnóczy-cave. The degradation of dripstone phenomena can be traced back to other two reasons besides the effects of aggressive seeping water:

a, there is lower relative humidity (80-85 % than in other chambers, therefore the dripstone layers are broken off from the stalagmites (physical process),

b, the other reason for degradation is the guano of bats living in the cave. The dropping water is sinking through the guano, which can be 10 cm thick, and the seeping water becomes aggressive again.

RESULTS

1. The cause of the acidification in brown forest soil is the chemical property of dark grey shale, and this process is made stronger by the acid rain.
2. The dark grey shale is eroded by the external forces, its thickness is decreased and calcium content and the buffer capacity of the soil are increased.
3. The buffer capacity of gritty, rocky soil and that of the black rendzina is good enough, but more and more anions are absorbed on the colloid surfaces.
4. Acidification in soil-types formed on limestone is made stronger by acid rains.

REFERENCES

BÁRÁNY, I. 1980. Some data about the physical and chemical properties of the soil of karst dolines. Acta Geogr. Szegediensis pp. 37-49.

BÁRÁNY, I. 1985. Ökologische Untersuchung der Karstdolinen unter besonderer Berücksichtigung des Mikroklimas. Acta Geogr. Szegediensis Tom. XXV. pp. 109-130.

BÁRÁNY-KEVEI, I - MEZŐSI,G. 1991. Further morphometrical data from some important Hungarian karst area. Proceedings of the Int. Conf. on Environmental Changes in Karst Areas. Italy, 15-27 sept. 1991. pp. 137-142.

BÁRÁNY-KEVEI, I. - ZÁMBÓ, L. 1988. Study of the relationship between bacteria activity in karstic soils and corrosion. Ann. Univ. Scient.Budapestiensis de R.Eötvös Nom.Sectio Geographica. Tom. XX-XXI. pp.325-334. Geographica. Tom. XX-XXI. pp.325-334.

BOHN, H. L. - McNEAL, B. L. - O CONNOR, G.A. 1985. Talajkémia. Mezőgazdasági Kiadó - Gondolat Kiadó Bp. 270 p.

FILEP GY. 1988. Talajkémia - Akadémiai Kiadó Bp. 293 p.

MÁTÉ F. 1987. Talajsavanyodás - környezetsavanyodás. Term. Vil. 5.sz. p. 146-148.

MÉSZÁROS E. - HORVÁTH L. 1980. A levegő regionális háttér-szennyezetsége

Magyarországon - Időjárás 84. p. 135-142.
MOHNEN, V.A. 1988. A savas eső - Tudomány, p. 10-18.
MUCSI L. 1989. Karsztalajvizsgálatok Odorvár környékén Szakdolgozat - Szeged p. 1-76.
MUCSI L. 1989. Connection between different soil-types and seeping water system in the cave-Hajnóczy, Budapest X. International Speleological Congress II. Proceeding. p. 226-228.
STEFANOVITS P. 1981. Talajtan - Mezógazdasági Kiadó Bp. p.380.

ZAKISLJEVANJE IN DRUGI PROCESI V KRAŠKI PRSTI NA MADŽARSKEM

Povzetek

Na pokritem odprtem krasu (na kraški kamnini, pokriti s prstjo) (Bárány-Kevei & Jakucs 1984) segajo vplivi mikroklime in rastlinskega pokrova skozi prst. Debelina prsti, njena prepustnost, kot tudi njene kemijske in fizikalne značilnosti so pomembni dejavniki subkutane korozije.

Vzrok zakisljevanja rjave gozdne prsti je temnosivi skrilavec, proces pa podpira tudi kisli dež.

Temnosive skrilavce erodirajo eksogene sile, zato so vedno tanjši, obenem pa se povečuje v prsti vsebnost kalcija in se veča puferska kapaciteta. Ta je v kamniti prsti in v črni rendzini dovolj dobra, toda vedno več anionov absorbirajo površine koloidov. Zakisljevanje tipov prsti na apnencih pa pospešuje tudi kisli dež.

TERRITORIAL STRUCTURE OF THE KARST GEOSYSTEMS AND THE INTERPRETATION OF NEGATIVE ANTHROPOGENIC INTERVENTIONS

TERITORIALNA STRUKTURA KRAŠKIH GEOSISTEMOV IN INTERPRETACIJA NEGATIVNIH ANTROPOGENIH VPLIVOV

PAVEL BELLA

Izvleček UDK 504.05:551.44

Pavel Bella: Teritorialna struktura kraških geosistemov in interpretacija negativnih antropogenih vplivov

V članku avtor predstavi značilnosti geosistemov in posebnosti kraških geosistemov, njihovo kompleksno strukturo ter strukturno stabilnost v okviru pokrajinskih sistemov. Neustrezna izraba kraške pokrajine povzroča primarne in sekundarne negativne pojave, ki se pojavljajo izven samega območja osnovnega onesnaževanja. Te sekundarne negativne pojave avtor razlaga na osnovi horizontalnih geosistemskih struktur. Tako nekraško ozemlje močno vpliva na alogeni kras s pomočjo vodnih tokov, kar je eden izmed najpomembnejših dejavnikov razširjanja onesnaževanja preko kraškega ozemlja.

Ključne besede: krasoslovje. človekov vpliv na kras, kraški geosistem, onesnaževanje krasa

Abstract UDC 504.05:551.44

Pavel Bella: Territorial structure of the karst geosystems and the interpretation of negative anthropogenic interventions

Characteristic of geosystems, karst geosystems, their complex structure and structure stability in the landscape system are presented in the paper. Disproportional exploitation of the karst landscape produces primary and secondary negative phenomena which occur outside the source of contamination. The negative secondary phenomena are interpreted on the basis of horizontal geosystem structures. The allogeneous karst teritory is strongly influenced by the non karst territory through water streams which are one of the main factors of contamination spreading in the karst.

Key words: karstology, man's impact on karst, karst geosystem, karst pollution

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The karst landscape represents a specific geosystem. The karst process is the main factor at its forming. Besides the inevitable presence of karstic rocks this process is limited by the geographic position of geosystem. Morphogenesis is also influenced by tectonic movements.

Karst forming process is the complex of morphogenetic processes connected with corrosive and corrosive-erosive water activity and other morphogenetic processes, influenced by initial karstic form, that created a chronological system of individual generic states of georelief in the area built by karstic rocks.

Individuality of geomorphological forms of karst landscape is also pointed up by the presence of underground forms of georelief. Permeability and solubility of karstic rocks make rapid infiltration of atmospheric water. Surface water flows run into underground also by swallow holes. Karstic hydrogeological structures are marked by specific hydraulic conditions of water flow with the low filtering capability and specific regime of underground water stores draining. Calciferous soils have a shallow profile. Character of biotic components is determined by the abiotic components' properties. The main distinctive factor in the landscape is the georelief. Climatic and vegetation inversions occur in the depressed areas. Specific conditions of cave environment cause the presence of the relative independent underground geosystems but underground and surface parts of karst geosystem are strongly interdependent.

Landscape is the part of the geosphere consisting of its components - the upper part of lithosphere with georelief, lower part of atmosphere, hydrosphere, pedosphere, biosphere, and socioeconomic sphere. In the point of view of system interpretation the most important are the relations between individual geospheres. Geosystems are divided into geographic dimensions according to their size. Geosphere is not a static formation and it is exposed to evolution process. Within geosystems we can distinguish the space (vertical and horizontal) structure and chronological structure.

VERTICAL INTERCOMPONENT SYNERGETIC STRUCTURE

The structure is formed by the interrelations between the geographic sphere components or their parts. The interrelations are studied using monosysteme model. Geosystems of topic dimension are separated on the base of this model. Geotopes are the smallest elementary physical-geographic and cartographic units, quasi homogeneous concerning the individual components' properties. Abiogenetic and biogenetic parts of geotope form the physiotope that does not include the sociogenetic block. Partial quasi homogeneous physic-geographical units can be separated (lithotope, morphotope, hydrotope, climatotope, pedotope and biotope).

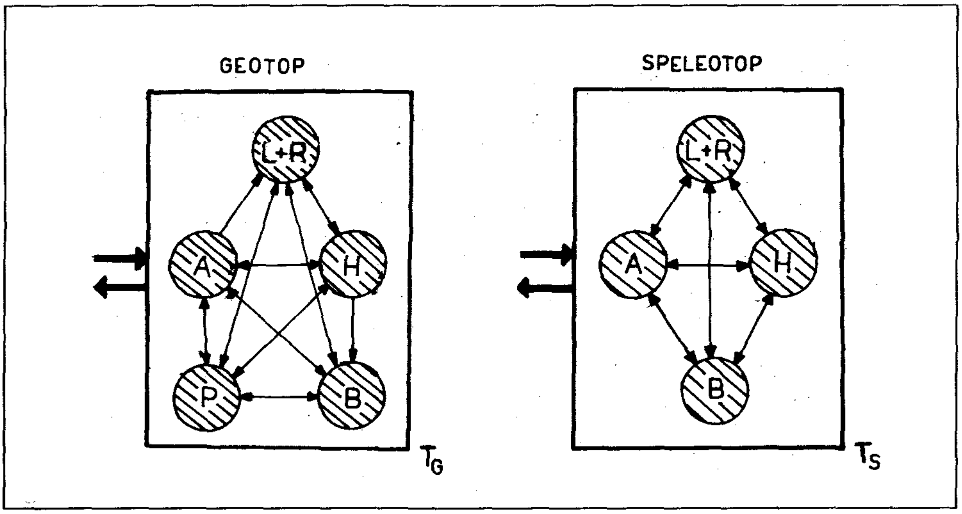

Fig. 1. Monosysteme model of geotope and speleotope (L + R - litosphere with georelief, A - atmosphere, H - hydrosphere, P - pedosphere, B - biosphere)

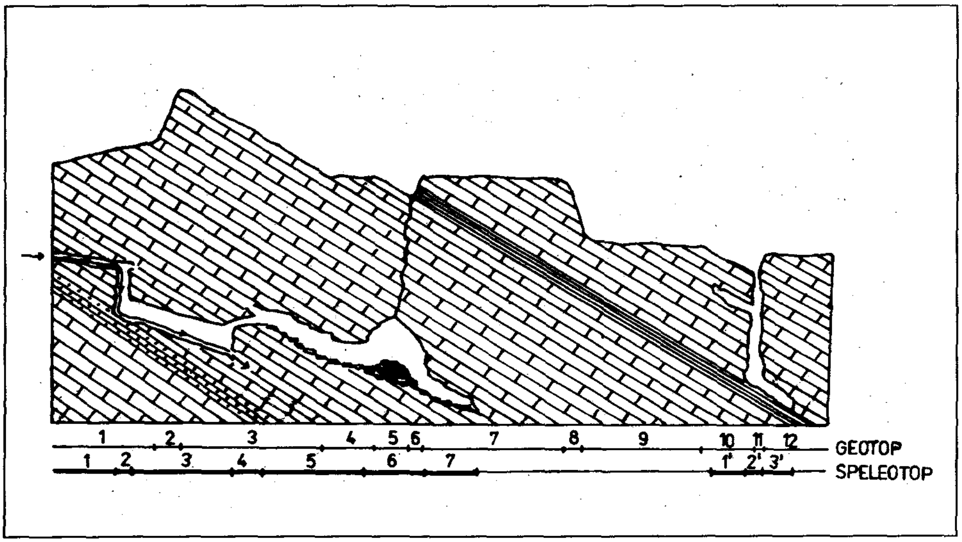

Fig. 2. Examples of geotopes and speleotopes selection

Speleotopes can be taken into account in the underground open space on the analogy of geotopes separation in the surface part of landscape. The speleotopes represent the complex quasi-homogeneous and cartographic units of cave environment with nearly equal lithological, texture-tectonic, morphological, morphometric, microclimatic, hydrological and biospeleological conditions (P. BELLA, 1991). Soil cover is not present in the underground space (B. A. GERGEDAVA, 1983). Overburden thickness and properties influence the grade of geotope and speleotope difference and interconnections of surface and underground. Overburden rocks suppressing karst forming process are significant by barrier effect. The surface boundaries of geotopes are often different from the boundaries of underground speleotopes. Speleotopes are often of the line character.

Ideas of component determination and separation are not uniform. V. N. SOLNCEV (1981) distinguishes massive and contact components. Ľ. MIČIAN (in Ľ. MIČIAN - F. ZATKALÍK, 1984) consider material and energetic components consisting of elements based on representative geographic publications of numerous German and Russian authors. N. L. VERUČAŠVILI (1986) uses the terms "geomass" and "geohorizons". Components do not enter the interaction "en bloc" but just by mediation of some their properties or parts (E. MAZÚR - J. DRDOŠ - J. URBÁNEK, 1983).

VERTICAL INTERCOMPLEX STRUCTURE

Underground forms of cave georelief determine specific physiognomic features, space organization and mass and energy flow in the underground space as an independent geosystem. This geosystem is characterized by specific features of biocomponent, microclimate and water as a part of hydrosphere and lithosphere in the zone of hypergenesis as well as by absence of pedogenetic processes and photosyntesis. The course of physical and chemical variable characteristics of components straightens with the closeness of georelief forms. Interaction increases in the underground space related to overburden part of lithosphere. Numerous authors deal with the reason of the idea of underground space as the individual geosystem (B. A. GERGEDAVA, 1983; A. G. ČIKIŠEV, 1987 and others).

Underground space is fully or prevailingly surrounded by underground form of georelief. The bearer of form is the rock environment. Boundary outside underground form is determinated on the base of geosphere discontinuity resulting from different surface and subsurface conditions (P. BELLA, 1989).

Presence of individual subsurface geosystems determines the existence of intercomplex vertical structure (besides intercomponent) that is of great importance considering dynamics, stability and other properties of karst geosystems. Strong vertical linkage between surface landscape and subsurface space creates the unique paradynamic systems (L. I. VOROPAJ - V. N. ANDREJČUK, 1985). Vertical structure of karst geosystems with caves is characterized by "mirror" structure and according to V. N. ANDREJČUK (1991a) consists of two subsystems of surface and subsurface part with their own component structure. As they together create greater geosystem, they represent two geosystems of lower hierarchic level.

Relation of intercommunicating geotope and speleotope is noted for vertical paradynamic relations from initial stage of underground geosystem evolution. In case of intercommunicating geotope and extracommunicating speleotope (flow of allochtonous submerged water, etc.) the vertical dynamic relations are topical just at more advanced stage of underground geosystem evolution. It causes certain autonomy of underground space evolution in initial stage.

Vertical intercomplex structure of karst geosystems as a component of geosphere refers to exokarst floor of karstosphere in sense of V. N. ANDREJČUK (1991b) formed in hypergenesis. This author also specified the endokarst floor of karstosphere that is however out of reach of exogene processes. Boundary of exogene energy influence forms the marked discontinuity. Therefore the endokarst floor of karstosphere surpasses the limit of geosphere.

The existence of subsurface caverns often occurring at several cave levels

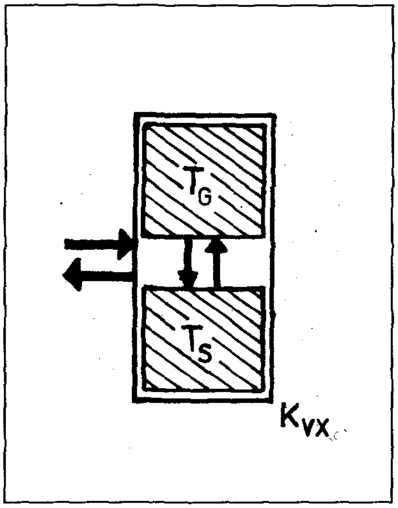

Fig. 3. Vertical intercomplex structure of karst geosystem

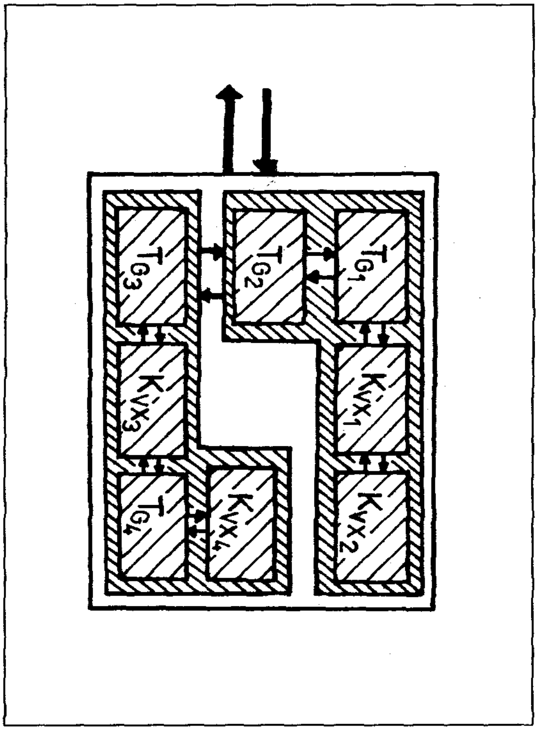

Fig. 4. Polysystem model of karst geosysteme

forces to think of vertical intercomplex structure with spatial relations and acquires character of chorologic system. This fact corresponds with including of vertical relations into the term "speleostructure" determined by V. N. ANDREJČUK (1987).

HORIZONTAL CHOROLOGIC STRUCTURE

Large territorial units consist of smaller territorial units of different vertical synergic structure. Their interrelations form the horizontal chorologic structure studied by polysystem model. Its hierarchic settlement results from various geographic dimensions influencing the degree of distinctive level, methods of study, ways of display, etc. Terminology of geographic dimensions is not uniform. In the German geographic literature the choric, regional and planetary dimensions are quoted besides topic dimension laying stress upon spatial aspect.

At the study of geosystem structures the attention is devoted to geosystems representing the base of larger landscape units. In frame of chorologic systems the units of choric dimension (nanochore, microchore, mezochore and macrochore) are the point in question. Nanochore has the simplest structure consisting of several physiotopes that are very similar or functionally complement. They are regularly settled into groups in space in consequence of the influence of landscape processes. The set of nanochores, created based on certain criteria (hillside, plane, etc.), represent the microchore. The remaining hierarchically

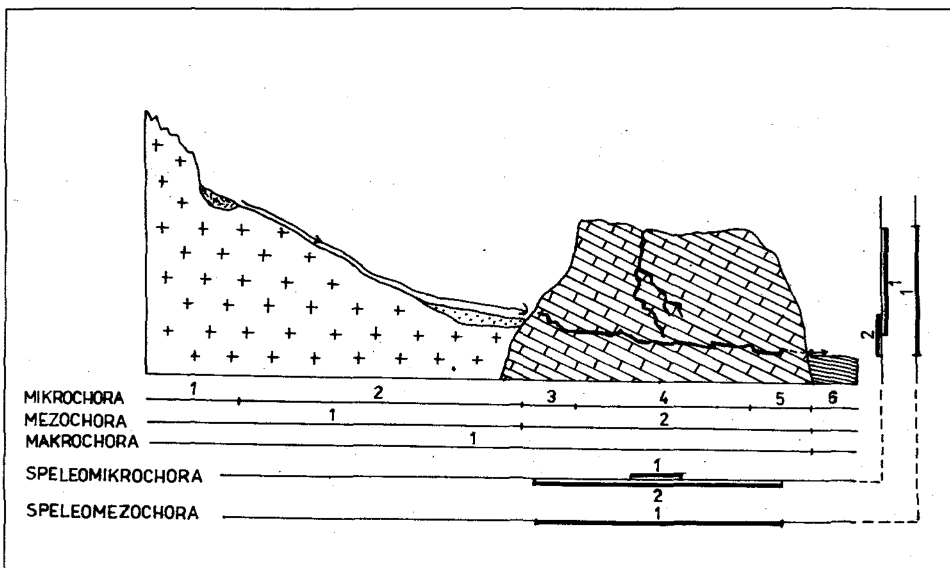

Fig. 5. Examples of larger choric units selection

higher choric units are determined based on certain logic context.

The georelief plays the important role at the determination of boundaries between individual geosystems as it directs the flow of matter and energy within the geosphere. The lithological and structure-tectonic predisposition are also important in case of underground karst geosystems. Morphologic contrast is typical to karst landscape georelief that reflects to its horizontal structure. Subsurface caverns are marked by considerable spatial differentiation too. Allogene karst is an example of outer chorologic relations of karst geosystem with hydrologicaly tending nonkarstic area.

Mediations of greater spatial units separation exist too. However it is necessary to comprehend the structure of karstosphere - karstic levels, karstogenetic environment and karstogenetic situations (V. N. ANDREJČUK, 1991b) in context with hierarchic geosystem levels of higher choric, regional and planetary dimension. The largest landscape geosystem is the whole geosphere. That is why the definition of terms "karstosphere" and "speleosphere" as specific parts of lithosphere must accept spatial integrity and hierarchy structure of geosphere in frame of exokarst stage.

Besides quasihomogeneous geocomplexes (units of topic dimension) and relative homogeneous geocomplexes (units of other dimensions) it is possible to distinguish paradynamic complexes as the systems of spatially neighboring contrast units interconnected by horizontal ties realized by the flow of matter and energy (F. N. MIL'KOV, 1981). Paragenetic complexes are the special case of paradynamic complexes. They also correspond with the terms "geochemical landscape" (A. I. PEREL'MAN, 1975) and "katena" (CH. OPP, 1983 in L'. MIČIAN - F. ZATKALÍK, 1984).

DYNAMICS AND STABILITY OF KARST GEOSYSTEM

System as the certain quantity of elements and their relations is determined mainly by processes, its conditions and behavior. Vertical synergic relations between components of karst geosystem are marked by higher dependence as in most non-karst areas. Considerable greater volume of mass flow between surface and underground arises. The energy of chemical reactions plays important role. Hydrologic activity determines markedly the course of karst morphogenetic processes. Zonal location of territory and tectonic movement need to be taken into account at the geosystem dynamic evaluation.

According to L. I. VOROPAJ and V. N. ANDREJČUK (1985) the importance of self-evaluation in karst geosystem increases. They lay stress upon less capability of its evolution control by outer mass and energy interferences. Asynchrone evolution of surface and underground parts of karst geosystem results from their different location related to outer creating and stabilizing factors of evolution of its balance.

The evolution of geosystems is interpreted by chronological structure including individual conditions and causal relations. Each evolution state is related to synergic or chorologic structure of geosystem. It is possible to distinguish cyclic, reverse and non-reverse sequences of states. V. B. SOČAVA (1978) determines the terms of "evolution" (evolution process in geologic time scale and invariants' alternation) and "dynamics" (alternation of variable states of geosystem subordinated to one invariant). E. NEEF, H. RICHTER, H. BARSCH and G. HAASE (1973) determine the term "regime, rhytmics" (seasonal changes dependent upon changes of seasons of the year). The behavior of geosystems with seasonal rhytmics analyzes N. L. VERUČAŠVILI (1986) in detail.

Stability of landscape structure indicates the stability of relations in the landscape system as a system of processes. Within the anthropocentric research it expresses the ability of landscape structure to resist to human activity (E. MAZÚR - J. DRDOŠ in E. MAZÚR et al., 1985). Karst landscape represents very unstable geosystem. It is disproportionately more complicated to maintain its balance than in most non-karst landscape systems. Unstability results from its well-organized character (J. JAKÁL, 1991). The fossil structure is marked by low stability. Inconvenient anthropogenic interferences into natural structure of karst geosystem result in its immediate affection. Regeneration ability of karst landscape is low and in some cases impossible.

SPATIAL RELATIONS AND INTERPRETATION OF NEGATIVE ANTHROPOGENIC INTERVENTIONS ON EXAMPLE OF KARST REGIONS OF WESTERN CARPATHIANS

Optimum and rational landuse require anthropogenic interventions respecting regularity of the landscape nature structure. Recently can be in many cases observed the disproportions between its exploitation and potential. E. MAZÚR and J. DRDOŠ (in E. MAZÚR et al., 1985) understand potential as the condition for performing the functions demanded by man without the affection of landscape structure stability.

Knowledge of recent reliefmorphic process, water movement and hydrological regime in the landscape can help to border the landscape units endangered by the negative anthropogenic activity. Flowing water with its erosive energy and material transport ability is the mediate of many kind of landscape devastation and contamination. It often leads to the depreciation of natural water sources - underground water resources, soil cover and biotic component. This fact shows up in the geosystems of choric dimension mainly. Research of these geosystems is of the extraordinary importance for social practice as many important kinds of human activity are realized within them (Ľ. MIČIAN in Ľ. MIČIAN - F. ZATKALÍK, 1984). The choric aspect shows up at harmful materials spreading not only by allochthonous position, mainly hydrological processes but also by air masses movement (contamination of precipitation with industrial exhalations, dust emission).

Improper location of farmyard manure near the swallow holes in Ponický kras in Zvolenská kotlina basin caused eutrophication of Oravecká vyvieračka karst spring. Inconvenient management of fields in the area of water dipping caused flooding of Domica cave in Slovenský kras including ablation of soil sediments with agrochemicals. Agricultural activity threatens the underground water quality in hydrological systems Suché doly - Teplica in Muránska planina plateau, Jašteričie jazero lake - Čierna a Biela vyvieračka karst springs in Silická planina plateau in Slovenský kras, Priepadlá - Teplica in Važecký karst and elsewhere. Water contamined by agriculture in Šumiacky karst in Horehronské podolie valley leaks into flood plane of the river. Contamination of karst hydrogeological structure threatens from the deposition of petrochemical industry wastes near Predajná in Lopejská kotlina in Horehronské podolie valley in Nízke Tatry mountains. The sewerage is constructed in alogene karst area that drains wastewater from higher situated recreation centre in non-karst area. This sewerage protects the water source of Demänovka submerged stream for Liptovský Mikuláš water conduit. Throwing down of perished animals and pouring waste into abysses and depressed areas of georelief in the karst hydrogeological structures have the negative influence of spatially wider signification. The changes of air mass movement in subsurface caverns influence the creation of sinter and ice filling.

Removing and damaging of vegetation cover, improper use of agrochemicals, ploughing in the slope course and other inconvenient anthropogene interferences markedly affects natural synergic relations between individual components in topic geosystems. Surface mining influences geotopes, nanochores and microchores.

From the point of view of intercomplex structure the affection of hydrologic regime of percolating atmospheric water into subsurface caverns arises that negative affects the sinter filling creation. Part of the plate above Važecká jaskyòa cave at the border of Kozie chrbty mountains was aforested for nature protection reasons. Seepage of agrochemicaly contamined atmospheric water causes the chemical decomposition of sinter filling. At the cave opening-up the affection of roof stone stability can arise.

Man with its activities enters natural processes, often speeds up their development (accelerated erosion and corrosion, acceleration of seepage and outflow, etc.). It affects the landscape structure stability. P. BELLA (1992) worked up the classification of negative anthropogene interferences into the karst landscape in Slovakia.

RESULTS

Landscape diagnosis consisting of gnozeologic part (knowledge of natural and anthropogene structure), evaluation part (knowledge of landscape potential and its limiting values) and comparative part (analysis of relations between landuse and landscape potential) forms the presumes of optimal anthropogene interventions into natural geosystems. As the knowledge of natural landscape structure is the primary condition of the diagnosis, we point at the need of geosystem interpretation that strongly influences the complexity of this recently actual problem solution. Disproportional exploitation of the landscape produces both accompanying negative phenomena "in situ" and secondary negative phenomena which occur outside the contamination source as a result of emissions and contamined materials transport by regions belong to the most valuable landscape units and that is why it is necessary to devote the adequate attention to their protection.

LITERATURE

Andrejčuk, V. N.: Speleosfera, speleostruktura i speleoresursy territorii. Problemy izučenija, ekologii i ochrany peščer, Tezisy dokladov, Kiev 1987, 8-9

Andrejčuk, V. N.: Opredelenie antropogennogo karsta. Sverdlovsk 1991a

Andrejčuk, V. N.: Obstanovki razvitija karsta. Obstanovki karstogeneza: glubinnyj karst, endokarst, gidrotermokarst, Tezisy dokladov, Kungur 1991b, 92-100

Bella, P.: Geografický výskum krasovej krajiny a jej ochrana. Pamiatky - Príroda, 19, 4, Bratislava 1988, 32-34

Bella, P.: Teoretické aspekty stanovenia hraníc medzi povrchovými a podzemnými formami reliéfu. Slovenský kras, 27, Martin 1989, 153-165

Bella, P.: Poslanie a návrh základnej koncepcie geoinformačného systému o jaskyniach. Slovenský kras, 29, Martin 1991, 83-105

Bella, P.: Klasifikácia negatívnych antropogénnych zásahov v krasovej krajine na Slovensku. Slovenský kras, 30, Martin 1992, 57-73

Čikišev, A. G.: Problemy sistemnogo issledovanija karstovych komplexov. Voprosy obščego i regional'nogo karstovedenija, Moskva 1977, 25-35

Čikišev, A. G.: Podzemnye karstovye landšafty kak osobye prirodnye kompleksy. Problemy izučenija, ekologii i ochrany peščer, Tezisy dokladov, Kiev 1987, 6-7

Daoxian, Y.: Karst Environmental Systems. Resource Management in Limestone Landscape, Sydney 1988, 149-163

Demek, J.: Úvod do štúdia teoretickej geografie. Bratislava 1987

Drgoňa, V.: Formovanie základných chorických štruktúr: geoekologické prístupy. Geografický časopis, 35, 4, Bratislava 1983, 353-373

Gergedava, B. A.: Podzemnye landšafty. Tbilisy 1983

Jakál, J.: Problémy ochrany krasových oblastí Slovenska. Životné prosteredie, 18, 1, Bratislava 1984, 10-13

Jakál, J.: Krasová krajina ako špecifický prírodný geosystém. Slovenský kras, 24, Martin 1986, 3-26

Jakál, J.: Natural Resource of a Karst Landscape and Possibilities of their Utilization. Slovenský kras, 29, Martin 1991, 3-29

Jakál, J. - Bella, P.: Karst of the Demänovské vrchy Mountains; Morphology, Contemporaneous Processes and Human Impact. Studia Carsologica, 4, Brno 1991, 15-28

Mazúr, E. a kol.: Krajinná syntéza oblasti Tatranskej Lomnice. Bratislava 1985

Mazúr, E. - Drdoš, J. - Urbánek, J.: Krajinné sysntézy - ich východiská a smerovanie. Geografický časopis, 35, 1, Bratislava 1983, 3-19

Mičian, Ľ. - Zatkalík, F.: Náuka o krajine a starostlivos· o životné prostredie. PvF UK, Bratislava 1984

Miklós, L. - O·ahel, J.: Model výskumu fyziotopu. Geografický časopis, 30, 1, Bratislava 1978, 42-56

Mil'kov, F. N.: Fizičeskaja geografija: sovremennoe sostojanie, zakonomernosti, problemy. Voronež 1981

Neef, E. - Richter, H. - Barsch, H. - Haase, G.: Beitrage zur Klärung der Terminologie in der Landschaftsforschung. Leipzig 1973

Perel'man, A. I.: Geochimija landšafta. Moskva 1975

Preobrazhensky, V. S.: A System Orientation of Landscape Research in Geography and its Present-day Realization. Landscape Synthesis, Bratislava 1983, 31-36

Sočava, V. B.: Vvedenije v učenije o geosistemoch. Novosibirsk 1978

Solncev, N. A.: Sistemnaja organizacija landšaftov. Moskva 1981

Veručašvili, N. L.: Četyre izmerenija landšafta. Moskva 1986

Voropaj, L. I. - Andrejčuk, V. N.: Osobennosti karstovych landšaftov kak geosistem. Černovcy 1985

TERITORIALNA STRUKTURA KRAŠKIH GEOSISTEMOV IN INTERPRETACIJA NEGATIVNIH ANTROPOGENIH VPLIVOV

Povzetek

Kraški svet je poseben geosistem. Prispevek podrobneje razlaga strukture geosistemov kot tudi njihovo strukturno stabilnost v okviru pokrajinskih sistemov. Posebej seznanja bralca z vertikalno interkomponentno sinergetsko strukturo (v podzemlju je to speleotop, ki odgovarja geotopu na površju), z vertikalno interkompleksno strukturo (taka struktura je značilna za speleotope) in s horizontalno horološko strukturo. Na koncu splošnega dela govori o dinamičnosti in stabilnosti kraških geosistemov. Praktični primer preučevanja kraškega ozemlja s pomočjo prej navedenih struktur je obdelan v poglavju o prostorskih odnosih in interpretaciji negativnih antropogenih vplivov, na primeru kraških regij v Zahodnih Karpatih.

Analiza pokrajine, ki sestoji iz gnozeološkega dela, iz ovrednotenja in iz primerjalnega dela, lahko predvidi optimalne antropogene vplive na naravni geosistem. Poznavanje naravnih pokrajinskih struktur je torej prvi pogoj za diagnozo in zato je potrebna interpretacija geosistemov, ki imajo močan vpliv na celotni kompleks. Neenakomerno izkoriščanje pokrajine povzroča tako negativne pojave "in situ" kot tudi sekundarne negativne pojave, ki nastopijo izven območja vira kontaminacije, s pomočjo prenosa kontaminiranega materiala.

BRACKISH KARST SPRING PANTAN (CROATIA)

ZASLANJENI KRAŠKI IZVIR PANTAN (HRVAŠKA)

OGNJEN BONACCI

Izvleček UDK 556.36(497.13)"1979"

Ognjen Bonacci: Zaslanjeni kraški izvir Pantan (Hrvaška)

V prispevku je predstavljena hidrološka analiza zaslanjenega kraškega izvira Pantan (Hrvaška). Avtor je imel na voljo hidrološke podatke devetmesečnih meritev v l. 1979. V skladu z meritvami je bila napravljena pretočna krivulja za sladko vodo v izviru in okvirno določena velikost zaledja. Preučil je tudi odnos med višino talne vode v zaledju in slanostjo izvira.

Ključne besede: hidrologija krasa, kraški zaslanjeni izvir, hidrološka analiza, odnos talne vode in zaslanjenosti, Hrvaška, Dalmacija, izvir Pantan.

Abstract UDC 556.36(497.13)"1979"

Ognjen Bonacci: Brackish karst spring Pantan (Croatia)

The paper presents the hydrological analysis of a brackish karst spring Pantan (Croatia). The available hydrological measurement data cover the period of nine months in 1979. The discharge curve for the spring fresh water and the approximate catchment area has been defined according to these measurements. The relationship between the groundwater levels in the catchment and the salinity of the spring water have also been studied.

Key words: karst hydrology, brackish karst spring, hydrologic analysis, relationship between ground water and salinity, Croatia, Dalmatia, Pantan spring

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INTRODUCTION

The brackish karst spring Pantan is located in the vicinity of the city of Split. It is a permanent and abundant coastal spring of the ascending type, with the opening at 2.6 m a.s.l. In its close vicinity there is a temporary spring Slanac and two vruljes Arbanija and Slatina. They represent part of the groundwater from a unique hydrogeological collector, through which a large area covered by rough, bare Dalmatian karst is drained. The catchment area is formed of highly permeable limestone rocks. The karstification process has been developed down to the depth of 40-50 m below the sea level. The opening of the spring is located in the contact zone between the limestone and flysch layers, about 200 m distant from the sea shore. The hydrological measurements at the spring have not been numerous. The discharge varies from 0.5 to 10 $m^3\ s^{-1}$, and the water temperature ranges from 11.5 to 16.0 °C. The salinity varies from 90 to 10,000 mg l^{-1}, with an unfavourable distribution during the year. During the wet winter period, when the water quantities in the region are abundant, the salinity is exceedingly low. In the dry period the situation is the reverse.

ANALYSIS AND INTERPRETATION OF DATA MEASURED IN 1979

Figure 1 presents 5-day averages data for the following hydrological, hydrogeological, climatological and chemical parameters:

1 Precipitation **P** in the catchment expressed in mm,
2 Water level **H** in piezometer expressed in m a.s.l.,
3 Total discharge of all the water from the Pantan spring **Q** expressed in m^3s^{-1},
4 Concentration of chlorides **c** 1in the brackish water of the Pantan spring expressed in mg 1 .

Other available data are:

5 Discharge of sea water $\mathbf{Q_s}$ sucked from the sea and appearing at the Pantan spring expressed in $m^3\ s^{-1}$,
6 Discharge of fresh water of the Pantan spring $\mathbf{Q_p}$ expressed in $m^3\ s^{-1}$,
7 Air temperature **T** expressed in °C.

However, these data cannot be used to analyse the possible influence of tide on the capacity and salinity of the Pantan spring.

The discharge of the salty and fresh water was defined according to the following expression:

$$\mathbf{Q_s} = \frac{(\mathbf{Q_s} + \mathbf{Q_p})}{\mathbf{K}}\ \mathbf{c} \qquad (1)$$

where $\mathbf{Q_s}$ is discharge of the sea water intake in $m^3\ s^{-1}$, **K** is concentration of the chlorides in the sea water (taken to be 20,000 mg l^{-1}), $\mathbf{Q_p}$ is fresh water discharge from the Pantan spring $m^3\ s^{-1}$, **c** is measured concentration of chlorides in the water of the Pantan spring in mg l^{-1} . According to this relatively simple relation it was possible to define the discharge quantities of the fresh and sea water in the total discharge of the brackish water of the Pantan spring. This is an approximation, particularly due to the fact that the analysis is performed always with the same concentration of chlorides in the sea water.

Table I presents the matrix of the coefficients of the linear correlation, *calculated for the seven climatological, hydrological, hydrogeological and chemical*

TABLE I
Matrix of the coefficients of the linear correlation calculated for seven parameters

r_{ij}	P [mm]	H [m a.s.l.]	Q [m^3s^{-1}]	Q_s [m^3s^{-1}]	Q_p [m^3s^{-1}]	c [mg l^{-1}]	T [°C]
P	1	.117	.140	-.059	.131	-.050	-.148
H		1	.912	-.771	.925	-.818	-.842
Q			1	-.727	.991	-.851	-.778
Q_s				1	-.811	.917	.807
Q_p					1	-.901	-.817
c						1	.717
T							1

parameters of the average five days values measured during the period from 1 January to 30 September 1979. The review of the results presented in Table I makes it possible to draw several conclusions. The first conclusion is related to the relationship between the rainfall and other parameters. The time increments of five days are not very suitable for the study of this relationship. The groundwater level in the piezometer is evidently the most important parameter for the explanation of the outflow process from the Pantan spring.

Very high values of the coefficient of the linear correlation with all the already studied parameters except rainfall, evidently show the predominant influence of the groundwater levels in the hinterland of the spring upon the outflow processes and the capacity of the spring. The most of the analysed relations between the parameters are not linear, but slightly nonlinear. Consequently, the analysed relations are even stronger than shown by the mentioned linear correlation coefficients. Most of these relations can be clearly explained from the physical standpoint. The relation between the total discharge and the groundwater levels is quite strong, as well as the interdependence (with negative sign) between the groundwater levels and the sea discharge as well as the concentration of chlorides in the brackish water of the Pantan spring. The appropriatness of separating the fresh water from the sea water can be proved, to a certain extent, by the high coefficient of the linear correlation between the discharge of the fresh water and the total spring discharge. It is particularly important to note the relatively high values of the coefficient of the linear correlation between the air temperature and all the other analysed parameters except precipitation. High values of the coefficients (both positive and negative) can be explained by the fact that temperature represents a climatic characteristic with the clearly marked seasonal features. In the summer warm period of the year the concentration of chlorides and the sea water discharge are high at the spring and thus there is a strong positive correlation between them, whereas the relation with the groundwater levels, total discharge and the fresh water discharge, is negative. The presented facts also show the main problem of the spring Pantan water exploitation for drinking and possibly for other technological demands. In the cold period, when the capacity of the spring is high, the water is practically fresh and it could be directly used. At that time the other springs supply the region with sufficient quantities of water so there is no special interest to use the water from the Pantan spring. In the warm summer period the situation is just the reverse, and the water demand increases greatly due to tourism. At that time the Pantan water is so salty that it cannot be used as drinking water. During the last few years there have been frequent droughts in the winter period of the year. Since there were no actual measurements for the situation, it can be supposed with certainty that the salinity of the water depends upon the groundwater levels in the hinterland and hence upon the discharge of the Pantan spring. Consequently, the salt content in the water of the Pantan spring will increase even in the cold period of the year. Table II presents the coefficients of the linear correlation between various parameters. As opposed to Table I this table deals with the strength of the links between time lags series. The index **(t-1)** represents the series moved five days back compared with the index **(t)**. In this case the analysis does not refer to all possible combinations, but only to those which have some physical sense. The review of the results presented in Table II entirely confirms the conclusions drawn after discussing the results from Table I, and proves the strong interior chronological link of the parameters.

TABLE II
Coefficient of the linear correlation for the time lag series parameters

r_{ij}	$Q_{(t)}$	$Q_{s(t)}$	$Q_{p(t)}$	$C_{(t)}$	$H_{(t)}$
$H_{(t-1)}$	.846	-.797	.873	-.822	----
$Q_{(t-1)}$	.934	-.732	.934	-.842	.899
$Q_{s(t-1)}$	-.722	----	----	----	----
$Q_{p(t-1)}$	.936	----	----	----	.908
$C_{(t-1)}$	-.836	----	----	----	-.792
$T_{(t-1)}$	-.787	----	----	----	-.847

DISCHARGE CURVE FOR THE FRESH WATER OF THE PANTAN SPRING

The essential problem of all hydrological analyses is to define reliable discharge curves. The data obtained by measurements in 1979 made it possible to define this curve for the Pantan spring. Evidently, the only way to define the discharge curve for the Pantan spring is to determine the dependence between the spring outflow discharges and the groundwater levels measured in the spring hinterland. The groundwater measurements obtained by piezometer, which is located in the hinterland about 500 m distant from the spring, are the best, since they actually represent the general and dominant state of the aquifer which essentially affects the spring capacity.,

Figure 2 presents the definition of two analytical expressions which can be used as discharge curves of the fresh water from the Pantan spring. The first expression:

$$Q_p = 1.266 \ (H\text{-}2.75)^{0.613} \qquad (2)$$

was defined exclusively according to the principles of the least squares theory, whereas the second expression:

$$Q_p = 1.496 \ (H - 2.60)^{0.5} \qquad (3)$$

was also defined according to the least squares theory, but considering the flow in a fully rough zone, which is reflected by the value of the exponent of 0.5 and by taking the level of the spring opening to be at 2.60 m a.s.l. If these two expressions are compared analytically and graphically, it can be stated that the difference between them is insignificant. According to the previously stated facts, a hypothetical statement can be reached. The outflow from the Pantan spring occurs through a karst pipe (conditionally speaking), which is under pressure. According to the expression 3, the following general equation for the discharge curve of the Pantan spring can be written:

$$Q = a \ (2g \ (H - Z))^{0.5} \qquad (4)$$
$$a = A * \alpha \qquad (5)$$

where **A** is the hydraulic measurement cross section area of the hypothetical karst pipe, α is discharge coefficient, **g** is the acceleration of gravity, and **Z** is the level of the outflow opening. If we take the value of the flow coefficient α to be 0.6, it follows that the dimensions of the diameter of the hypothetical pipe is 0.75 m. Since it is evident that coefficient α can be both higher and lower, and it is difficult to assume it is actually a pipe, the dimensions of the analysed conduit are probably different and more irregular along the conduit. The mentioned dimensions of 0.75 m is only the order of magnitude, which has strong supportive arguments. According to the past measurements it is not possible to put forward any hypotheses on the position of the conduit pipe system in space. This is probably an ascending siphon flow caused by geological factors and primarily by the lower sea level in the Pleistocene.

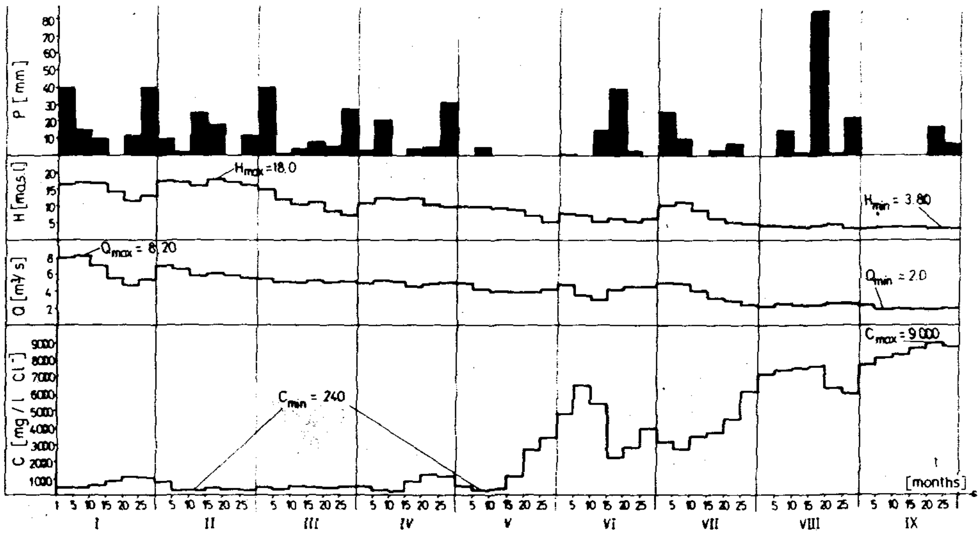

Figure 1

TIME SERIES OF THE GROUNDWATER LEVEL (H) , DISCHARGE (Q) AND SALINITY (C) OF THE PANTAN SPRING AND 5 DAYS PRECIPITATION (P) ON ITS CATCHMENT AREA (H, Q, C - 5 DAYS AVERAGE DATA)

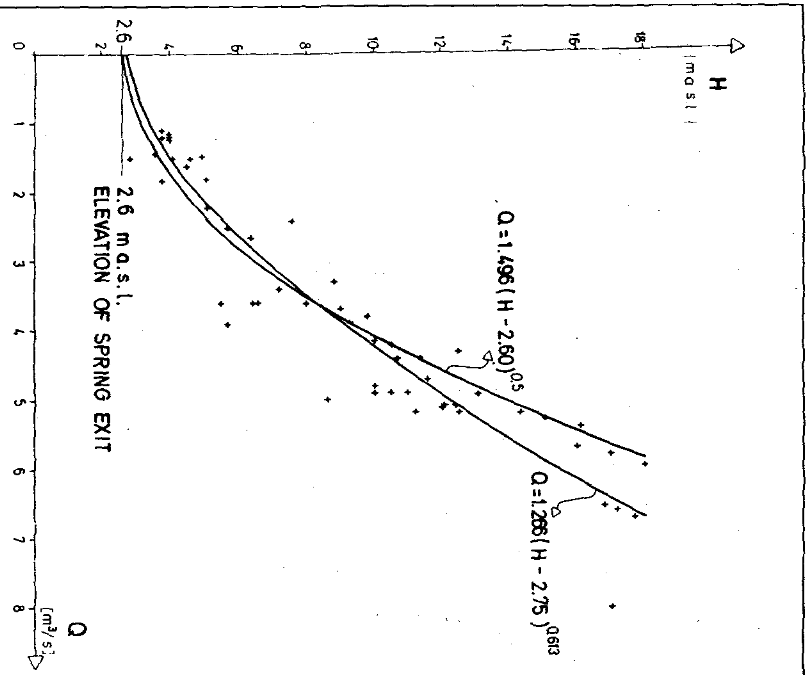

Figure 2

DISCHARGE CURVES OF THE PANTAN SPRING

DETERMINATION OF THE CATCHMENT AREA OF THE PANTAN SPRING

The catchment area of the Pantan spring cannot be reliably determined, due to the insufficient data. It is possible only to define approximately the hypothetical catchment area. The method of the outflow coefficient was used in order to achieve this. The outflow coefficient for the Dinaric Karst, for one year as a time unit, ranges in values from 0.5 to 0.7. The basic period for the definition of the outflow coefficient was the period covering nine months measurements of the discharges of the fresh water from the Pantan spring. Since the catchment area was not known, the calculations of the precipitation volume were performed with a number of alternatives for different catchment areas. Realistic results for the outflow coefficient were obtained only for the assumed areas covering 200 to 260 km², which can be seen from the results shown in Table III. Obviously, this simplified approach cannot guarantee

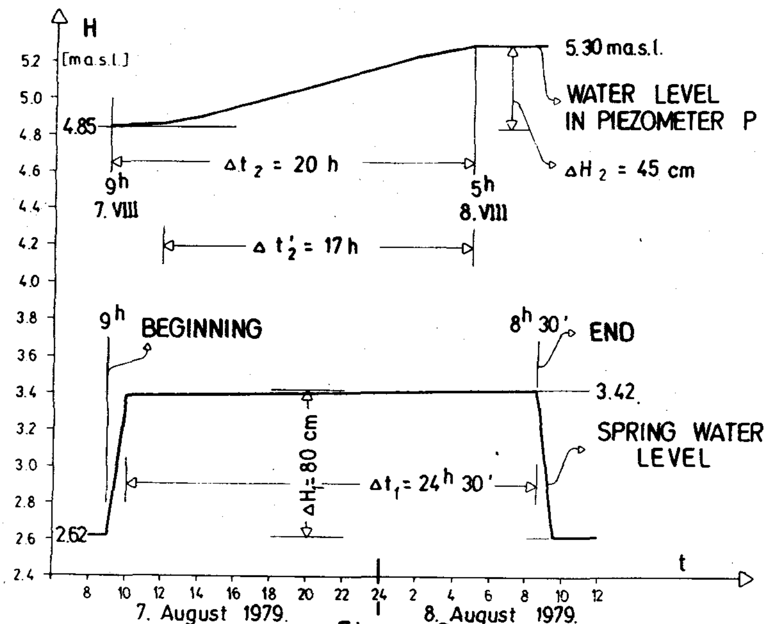

Figure 3
WATER LEVEL HYDROGRAPH AT PANTAN SPRING AND PIEZOMETAR P DURING RAISING

reliable results, but it is also certain that it makes it possible to define the order of magnitude catchment area of the Pantan spring.

TABLE III
Outflow coefficient of the Pantan spring for various assumed catchment areas calculated for the period Jan.-Sept. 1979

Catchment area [km²]	180	200	220	240	260
Outflov coefficient	0.722	0.650	0.590	0.541	0.500

CONCLUSION

According to the analysis of the climatological, hydrological, hydrogeological and chemical parameters, measured in the catchment of the Pantan spring in the period from January to September 1979, several relevant conclusions were reached in this paper regarding the functioning of the spring. According to the reliability of the measured and processed data the obtained results can be evaluated as preliminary. Nevertheless, these results are logical and acceptable from the hydrology and hydrogeology standpoints. The connection of the groundwater with the spring Pantan water is direct and very clear. According to the additional interdisciplinary analyses and measurements it will be possible to obtain clearer and more direct relations. The catchment area of the Pantan spring ranges from about 200 to 260 km^2, which represents the first approximation of the real state.

ZASLANJENI KRAŠKI IZVIR PANTAN (HRVAŠKA)

Povzetek

Zaslanjeni kraški izvir Pantan je v bližini Splita. To je stalni in obilni kraški izvir 2,6 m nad morjem. V njegovi neposredni bližini so presihajoči izvir in dve vrulji. Zaledje grade dobro prepustni apnenci, zakraseli do globine 40 - 50 m pod morsko gladino. Izvir je na stiku s flišnimi plastmi, okoli 200 m od obale. Pretok se spreminja med 0,5 - 10 m^3 s^{-1}, temperatura med 11,5 - 16,0^{0}C, slanost pa od 90 - 10000 mg l^{-1}. Pozimi, ko je povsod v regiji dovolj vode, je slanost izredno nizka, ob suši pa je obratno.

V prispevku je več zaključkov o delovanju tega izvira, glede na analize klimatoloških, hidroloških, hidrogeoloških in kemijskih parametrov (januar - september 1979). Zveza med talno vodo in izvirom je tesna in očitna. Zaledje izvira obsega 200 - 260 km^2, kar je prvi približek resničnemu stanju.

PALEOKARST OF THE BOHEMIAN MASSIF IN THE CZECH REPUBLIC: SHORT REVIEW

PALEOKRAS ČEŠKEGA MASIVA (ČEŠKA REPUBLIKA): KRATEK PREGLED

PAVEL BOSÁK

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Izvleček UDK

Pavel Bosák: Paleokras Češkega masiva (Češka republika): kratek pregled

Paleokras Češkega masiva (Češka republika) je razvit v poligenetskih in policikličnih oblikah z večimi fazami fosilizacije in pomlajevanja, glede na tektonske faze in globino kemičnega preperevanja. Za paleotektonske dobe (v glavnem pred permijem) je značilen razvoj relativno majhnih področij sinsedimentnega in lokalnega paleokrasa. V neotektonski dobi (platforma, po permu) so bila daljša obdobja razvoja interregionalnega paleokrasa v več ali manj ločenih fazah zakrasevanja.

Ključne besede: paleokras, kraške dobe, faze zakrasevanja, fosilizacija, pomlajevanje, kemično razpadanje, diageneza karbonatov, Češki masiv, Češka republika

Abstract UDC

Pavel Bosák: Paleokarst of the Bohemian Massif in the Czech Republic: Short review

Paleokarst of the Bohemian Massif on the territory of the Czech Republic developed as polygenetic and polycyclic forms with several phases of fossilization and rejuvenation depending on tectonic phases and deep chemical weathering. Paleotectonic period (pre-Permian in general) was characterized by evolution of relatively minor depositional and local paleokarsts. Neotectonic (platform) period (post-Permian) favoured the prolonged karst evolution of interregional paleokarst in several more or less distinctly separated karst phases.

Key words: paleokarst, karst periods, karst phases, fossilization, rejuvenation, chemical weathering, carbonate diagenesis, Bohemian Massif, Czech Republic

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INTRODUCTION

The Bohemian Massif is known by landforms that have been intricately and unequally developed during many periods and phases of changing climate and of tectonic activity in the geological past. This very complex form of the karst and paleokarst, with relict, fossil, recent, active or rejuvenated features and in periglacial conditions transformed karst, led Panoš (1964) to define it as the Central European Type of polycyclic karst. The polycyclic and polygenetic nature of karsts and paleokarst represents the specific characteristics for karst evolution of the whole Bohemian Massif. The general review of paleokarsts of the Bohemian Massif was presented by Bosák, Horáček and Panoš (1989).

THE GEOLOGICAL BACKROUND

The Bohemian Massif represents the epi-Variscan platform consisting of two major blocks, i.e. the Bohemian Massif proper in the west and partly subducted promontory of the East European Platform - Brunovistulicum (Dudek 1980) - in the east. The eastern and southeastern slopes of the Massif are covered by the Carpathians as a consequence of Alpine nappe overthrusting over the epi-Variscan platform in the foreland of Alpine - Carpathian chain (Grecula and Roth 1978)

Three structural levels can be distinguished in the Massif (e.g. Suk et al. 1984): (1) Precambrian (Cadomian) basement composed dominantly of metamorphites and plutonites. Crystalline limestones and dolostones occur only locally and no paleokarst forms habe been known; (2) Variscan (Paleozoic) level with development of sedimentary and sedimentary-volcanic sequences, dominantly of marine origin, in places metamorphosed and intruded by plutonites. Carbonate rocks of Upper Silurian (Přídolian) to Lower Carboniferous (Tournaisian) occur. Abundant evolution of relatively minor paleokarsts is known, and (3) Platform (post-Variscan) level composed dominantly of sediments (continental and marine) separated by important unconformities. Very broad developments of paleokarsts is known.

Paleotectonic period, prior to the consolidation of the epi-Variscan platform, is characterized by high mobility and resulted in a great changes in facies development. The neotectonic period is more quiet with only several important marine transgressions covering larger extent od the Massif (Upper Jurassic, Cenomanian, Middle Miocene). The evolution of eastern and south-eastern margins of the Massif (majority of Brunovistulicum) facing the Tethys realm as passive continetal margins was especially strongly influenced by the Alpine Orogeny as being submerged under thick pile of flysh nappes and molasse deposits. The neotectonic stage was strongly influenced by single phases of Alpine Orogeny (cf. Malkovský 1979).

TERMINOLOGY

The terminological problems appeared as the reflectance of the complexity of the problem in our geological and geomorphological environment. Therefore *paleokarst* is refered to phenomena defined by Bosák, Ford and Glazek (1989) with the application of the *fossil karst* in the strict sense (forms completely originated in the past, entirely fossilized and loosing its hydrological characteristics without any traces of present development). Stratigraphy of paleokarst is defined here according to definitons of Bosák, Ford and Glazek (1989) using *karstification periods* and *karstification phases.* The application of *interregional, local* nad *depositional paleokarst* is here based on sense and definitions of Choquette and James (1988) and is assumed to be very usefull.

PALEOKARST PERIODS AND PHASES

The evolution of paleokarst can be connected with Variscan and platform stages of the evolution of the Bohemian Massif. The majority of forms developed in Devonian limestones, now buried or uncovered, which were also highly metamorphosed by Variscan Orogeny, in places. Some forms developed in Proterozoic carbonates and a limited number has been known from Upper Jurassic carbonate sequence deeply submerged on eastern margins of the Massif.

The evolution of paleokarst, its origin, development, fossilization and rejuvenation have been affected by numerous lithological and structural conditions. In general, three types of paleokarsts could be distinguished.

Depositional paleokarst was typical by low relief, freshwater vadose and phreatic and mixing freshwater/ marine diagenesis. Its evolution followed cyclic nature of deposition without tectonic influence and the Milankovich cycles of the 5th to 4th orders. The role of freshwater/marine mixing diagenesis was substantial. Its evolution was connected with the evolution and accretion of Devonian carbonate sequences.

Local paleokarst was product of longer emersion caused by regressions in individual blocks. Karst relief was developed up to first hundreds of metres (shafts, dolines, caves) with well defined hydrological zonation. The evolution followed tectonic movements of individual, even very small, tectonic blocks together in the combination with cyclic events or sea level changes (unconformities of the 3rd and the 2th orders). Biozone to stage is missing. Effect of drowned platforms followed the polarity of orogenic movemets from W to E within the Brunovistulicum. Results of the local paleokarstification can substantially differ place to place owing to the altitudinal position of emerged carbonate surface. Low altitudinal position led to undeveloped paleokarsts similar to depositional paleokarst forms even through longer hiatus, while high altitudes of distinct elevations created mature paleokarsts. Its evolution was connected with the evolution of sedimentary basins during Lower/Middle Devonian in the Barrandian and Middle Devonian/Lower Carboniferous in Brunovistulicum. Some of Jurassic carbonates suffered also by this kind of evolution.

Interregional paleokarst was product of long-lasting erosion and karstification connected with deep weathering and formation of planation surfaces. There was developed substantial karst relief and deep groundwater circulation. There was a close connection to individual tectonic phases reflecting major impacts of the Alpine Orogeny leading to the rejuvenation of relief and the acceleration of karstification. There was the clear relation to marine transgressions/regressions separating individual karst phases within karst periods or to periods of mass continental deposition. This evolution was typical for post-Upper Carboniferous evolution of the whole Massif.

There are several typical conditions affecting the evolution of the interregional paleokarst in the Massif: (1) the prevalence of a continental regime since the Permian; (2) relatively short-lasting marine transgressions in Upper Jurassic, Late Cretaceous and Middle Miocene times; (3) increasing tectonic activity since the Late Paleogene as impacts of the Alpine Orogeny; (4) evolution of the Paratethys sea on the eastern margins of the Massif; (5) increasing relief dynamics resulting in a considerable increase of erosion rates exhuming and rejuvenating old planation surfaces and karst forms, and (6) a continual fall of the base level following stabilisation of the river system in the Pliocene (Bosák and Horáček 1981). Nevertheless, the phases of accelerated erosion were interrupted by relatively long-lasting quiet periods with stabilized conditions favouring the development of subsurface karst forms (Bosák, Cílek and Tipková 1992).

Lower Devonian - Pragian. Local paleokarst related to freshwater vadose and phreatic karstification (diagenesis) of the Koněprusy Reef (central Bohemia) was connected with tectonic uplift and major sea level changes. Deep neptunic dikes developed associated with the system of vuggy to cavern macroporosity filled with lithologically variable internal sediment.

Climate was tropical, wet and hot. Correlate sediments are proved in overlying Dalejan to Eifelian limestones content of iron oxides derived from lateritic weathering of mainland

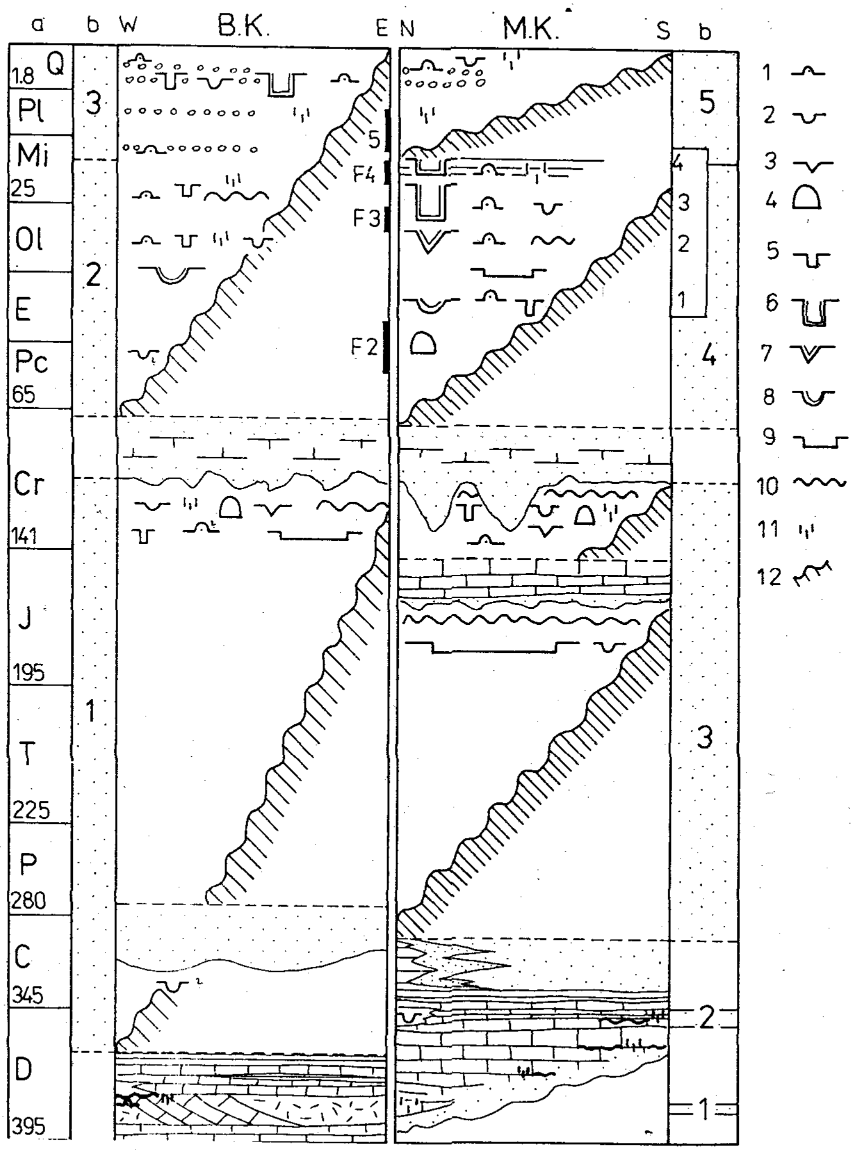

Fig. 1 - Distribution of paleokarst within the geological history of the Bohemian Karst (B.K.) and Moravian Karst (M.K.).
a. periods; numbers indicate the age of the period base in Ma; b. karstification periods and phases; 1. caves, 2. dolines, 3. deep corrosional organs (geological organs, pockets), 4. karst cones, towers and inselbergs, 5. shafts, 6.-8. valleys and canyons (shape is indicated), 9. poljes and large depressions, 10. corrosional surfaces, 11. karren, 12. periods of paleorelief evolution, F1-F5 - planation phases (modified from Bosák, Horáček and Panoš 1989).

Middle Devonian - Eifelian/Givetian. Depositional freshwater vadose and phreatic karstification (diagenesis) of limestone cycles in Old Red complex in the Moravian Karst and Carpathian foredeep The evolution was connected with minor cyclic sea level change (Milankovich's cycles).

Climate was hot, seasonally dry and wet. Correlate sediments are represented by red beds of the basal clastics themselves.

Upper Devonian to Lower Carboniferous - Fammenian to Upper Viséan. Local paleokarst, sometimes with substantial relief and developed shafts, sinkholes, depressions and caves in Upper Devonian limestones in the Moravian Karst (pre-Upper Tournaisian), the Tišnov area (pre-lower Visean), the Ostrava area (pre-upper Viséan). Emergence caused by the tectonic uplifts and tilting of individual blocks combined with 2nd-3rd order of sea level changes. Paradox of drowned platforms is often developed, as karstified shallow marine carbonates are overlain by relatively deep water facies.

Climate was subtropical to tropical. Correlate sediments are represented by variocoloured pelitic matrix of the Křtiny nodular Limestone (Upper Frasnian to Tournaisian) and of the Jedovnice breccia (Fammenian to Tournaisian) derived from lateritic weathering of the mainland, lateritic material and phosphorites in the Ostrov Shales (Tournaisian)

Upper Carboniferous - Westphalian/Stephanian. The *interregional paleokarst* proved by pebbles of karstified Devonian limestones and speleothems in red beds of the Mšeno Basin (Upper Stephanian). The karst phase caused by the tectonic uplift as a consequence of Variscan Orogeny and emplacement of plutonic bodies.

Climate was dry, seasonally wet, warm (subtropical). Correlate sediments are represented by kaolinization of the Plzeň - Podbořany group of deposits (west Bohemia)

Permian to Upper Jurassic. Extensive interregional paleokarst developed. The macroform of the Moravian Karst completed prior the Callovian transgression In the Hranice Karst (north Moravia) some Permian to Paleogene karstification has been supposed without identified extent and in the Bohemian Karst without identified karstification.

Climate has no direct evidence on the Bohemian Massif. Correlate sediments represent kaolinic clastics of the Bohdašín Formation (Bundsandstein, north Bohemia), lateritic material in the Kimmeridgian breccia finishing the sequence of Upper Jurassic in the Moravian Karst and no correlate sediments in the Bohemian Karst.

Lower Cretaceous (post-Kimmeridgian - pre-Cenomanian). The interregional paleokarst developed in regionally widespread karstification phase which products are preserved mostly thanks to overburden of the Upper Cretaceous (?Albian - Cenomaian - Santonian) platform cover. Known in the Bohemian Karst (narrow depressions with kaolinic sands and clays), in the Moravian Karst (the Rudice Formation, i.e. kaolinic sands and clays, quartzose sands, kaolins, filling extensive corrosional depressions, cone karst), in the Vratíkov - Němčice Karst (central Moravia, mogotes, iron ores in caves, relics of the Rudice Formation), in the Tišnov Karst (relics of sands and clays in sinkholes), and nearby of Kunštát and Olešnice (both in central Moravia, terrae calcis and lateritic weathering products in fissures of crystalline limestones), in Moravský Krumlov (south Moravia, the Rudice Formation in sinkholes), in the Carpathian Foredeep (inselbergs on Jurassic limestones), on the Turold Hill (Mikulov, south Moravia, tectonic clippe, planated surface with depressions and Fe-Mn incrustations on upper Jurassic limestones covered by Turonian flysh).

Depositional paleokarst developed in authochthonous Mesozoic cover of eastern margins of the Bohemian Massif. Known at the Kotouč Hill (Štramberk, north Moravia) in two karstification phases in Upper Valanginian and Upper Hauterivian to Aptian related too oscillating sea level (3th to 4th order cycles).

Climate was tropical, wet and hot, at the end temperate. Correlate sediments are widespread as weathering profiles under the Upper Cretaceous platform cover are widespread, e.g. laterites on basic to ultramafic rocks, kaolins on acidic rocks, weathering profiles with paleosols, kaolinization of some deposits in west Bohemia, the Rudice Formation and the Amberg Ore Formation (NE Bavaria, FRG) etc.

Paleogene to Lower Miocene. Interregional paleokarst developed during widespread karst period without possibilities of precise dating of phases and sites (general absence of paleontologically dated localities). The period is characterized by the main phase of cave formation in the Bohemian Massif with origin of largest karst systems in the Bohemian, Moravian, Javoříčko Karsts and smaller karst regions also in crystalline complexes (Bližná, south Bohemia). Karst surfaces with depressions and conical hills developed (Tišnov (?pre-Badenian), Lažánky (pre-Karpatian), Hranice (pre-Karpatian and pre-Badenian), Branná, Vápenná, Supíkovice, karst of the Drahany Upland - Mladeč, Červenka, Javoříčko, Hvozdečko). Numerous sites in the Carpathian Foredeep on Devonian and Jurassic limestones is known covered under thick Miocene siliciclastics and covered by overthrusted flysh nappes.

Climate in Paleocene to Eocene was tropical, wet and hot. During Oligocene-Lower Miocene oscillations from tropical to Mediterranean type occurred. Correlate sediments are reprezented by kaolins of Vidnava (north Moravian) and Znojmo (south Moravia, pre-Eggenburgian), Lažánky (central Moravia, pre-Karpatian), Hranice (pre-Karpatian kaolinic and lateritic weathering products), kaolinic clays of Vížina (central Bohemia). Quartzose to quartzitic conglomerates and sandstones of the Staré Sedlo Formation (Upper Eocene - Oligocene) and pre-Oligocene kaolinitization occur in North Bohemian Coal Basins.

FOSILIZATION AND REJUVENATION

Karst becomes fossil or inactive when it loses its hydrological function. The general cause for this are changes of local or regional geotectonic conditions or of global sea level. Fossilization can be a result of uplift or of subsidence, of marine transgression or of mass continental deposition. Continental drift (plate motion) may change the latitudinal position of karst areas in different geologic stages resulting in climatic changes, i.e. to arid or to humid, which may contribute to fossilization or rejuvenation (Bosák 1981, 1989, Zhang 1986).

Fossilization of karst forms in the Bohemian Massif are closely related to above mentioned factors. But the polycyclic and polygenetic nature of karsts and paleokarst represents the specific characteristics for karst evolution of the whole Bohemian Massif, and leads to the presence of polycyclic and polygenetic features attributed to paleokarst also within the present landscape. They sometimes form a great part of present objects of the speleological interest. To distinguish what is ancient and what can be remodeled at the present time is therefore very difficult. In such terrane, the substantial role was played by the change of hydrological circulation loosing its hydraulic head, at least partially, when not covered by younger deposits. Such evolution is typical e.g. for the Koněprusy region of the Barrandian following the development of river network entrenching since Upper Miocene times. Caves were partially or completely filled with Sarmatian and Lower Pliocene deposits disappearing its hydrological function completely. Paleokarst contains, by such way, a lot of evidence missing on the baren surface and represents true conservers of the geological and environmental past and sometimes also the missing link in regional and global chronostratigraphy.

The rejuvenation of karst making the conserved fossil record degraded and unreadable is caused by numerous factors generally leading to the renewal of the hydrological function of the karst and of karst water circulation. It is typical for periods of introduction of energy to the whole karst/relief system. It is contradictory to the fossilization. The new creative and destructive karst and landform processes, deposition and redeposition, exhumation and weathering disturb the paleokarst content. The rejuvenation processes are very typical for karsts of the Bohemian Massif. The most striking example is represented by polyphase evolution of karst levels in the Moravian Karst since Lower/Middle Miocene times with several repeated filling and exhumation of karst canyons and cave horizons, and creation of inserted cave levels and subvertical invasion vadose connections. Low levels of Miocene caves are now serving as phreatic conduits.

PALEOKARST, PLANATION SURFACES AND DEEP CHEMICAL WEATHERING

The evolution of paleokarsts are often linked with the formation of planation surfaces, as the result of the uniform process of relief-forming agents. Planation surfaces are proved to be very often connected with periods of deep chemical weathering. The evolution of surfaces is connected with prolonged periods of tectonic stability, so they originated inbetween impacts of orogenic phases. Such conditions are also favourable for the origin of mature endokarst.

To correlate periods of karstification and of formation of weathering crusts in the Bohemian Massif is relatively complex owing to the lack of well defined chronostratigraphic horizons within long periods of nondeposition and continental regime. The foreland and flanks of the Massif are covered by complex sucession of marine formations, sometimes of high thicknesses (e.g. Alpine and Carpathian Foredeeps, pre-Sudetes block). In the centre of the Massif, marine formations younger than Lower Carboniferous (except of Cenomanian to Turonian) are rare and preserved in very small areas (topmost Doggerian to Kimmeridgian, Badenian). Also the extent of continental deposits of post-Variscan age is limited to certain regional geological units. Such formations do not cover the whole time span of hiatuses between marine transgresion - regression cycles, but offer paleogeographic and paleoclimatic data enabling to roughly date periods of karstification.

The best link between periods of intensive chemical weathering and karstification can be stated for two periods. During topmost Jurassic and Lower Cretaceous (or pre-Cenomanian), large karst forms of tropical paleokarst are preserved under thick kaolinitic (-lateritic) weathering crusts in the Moravian Karst and some adjacent areas including Carpathian-Alpine Foredeeps; similar situation can be stated in the Bohemian Karst (weathering crusts are thinner). These phenomena can be correlated e.g. with identical forms and sediments of the northeastern Bavaria (Amberg Ore Unit). The Paleogene to Lower Miocene karstification (i.e. the main phase of cave formation) can be correlate with Paleogene-Miocene weathering period. The origin of caves was iniciated under the cover of Upper Cretaceous rocks. Surface paleokarst of identical or somewhat younger age (Miocene) is also relatively abundant, sometimes containing kaolinic fill (Lažánky near Tišnov), variegated and other weathering products (Bohemian, Hranice and other karsts). Indications of simultaneous weathering and karstification exist for Upper Carboniferous (Stephanian). Pebbles of limestones and speleothems were found in molasse red beds in central Bohemia. The karstification occured in the same time-span in which some of large kaoline deposits in west Bohemia were formed (e.g. Kaznějov).

The link between periods of intensive chemical weathering/origin of planation surfaces and karstification is evident in the Bohemian Massif. Both the intensive chemical weathering (lateritization, kaolinization) and evolution of planation surfaces, and the karstification are linked rather with prolonged periods of relative tectonic stability. The link between intesive weathering and karstification is important indicator for prospection of economic mineral deposits in paleokarst terrains.

REFERENCES

Bosák P. (1981): Fosilní a paleokrasové jevy -terminologie. - Abs. Pracov. Semin. k otázkám Českého krasu u příležitosti 100. výročí narození Jaroslava Petrboka, Stalagmit, Příl. 4: 7. Praha.

Bosák P. (1989): Problems of the origin and fossilization of karst forms.- in P. Bosák, D.C. Ford, J. Glazek, I. Horáček (Eds.): Paleokarst. A Systematic and Regional Review: 577 -598. Elsevier-Academia. Amsterdam -Praha.

Bosák P., Cílek V., Tipková J. (1992): Le Karst de Boheme au Tertiaire. - in J.-N. Salomon et R. Maire (Eds.): Karsts et évolutions climatiques: 401-410. Presses Universitaires de Bordeaux. Talence.

Bosák P., Ford D.C., Glazek J. (1989): Terminology. - in P. Bosák, D.C. Ford, J. Glazek, I. Horáček (Eds.): Paleokarst. A Systematic and Regional Review: 25-32. Elsevier-Academia. Amsterdam-Praha.

Bosák P., Horáček I. (1981): The investigation of old karst phenomena of the Bohemian Massif in Czechoslovakia. A preliminary regional evaluation. - Proc. 8th. Int. Speleo. Congr., Bowling Green, I: 167-169.

Choquette P.W., James N.P. (1988): Introduction. - in N.P. James and P.W. Choquette (Eds.): Paleokarst: 1-21. Springer, New York.

Dudek A. (1980): The crystalline basement block of the Outer Carpathians in Moravia: Bruno-vistulicum. - Rozpr. Čes. akad. věd, Ř. matem. přír. věd., 90(8): 1-85. Praha.

Grecula P., Roth Z. (1978): The kinematic model of West Carpathians in complex section. - Sbor. geol. V_d., 32: 49-73. Praha.

Malkovský M. (1979): Tektogeneze platformního pokryvu Českého masívu. - Knih. Úst_. úst. geol., 53" 1-176. Praha.

Panoš V. (1964): Der Urkarst in Ostflügel der Böhmischen Masse. - Z. Geomorphol., N.F., 8(2): 105-162.

Suk M. et al. (1984): Geological History of the Territory of the Czech Socialist Republic. - Ústř. úst. geol.: 1-400. Praha.

Zhang S. (1986): On paleoenvironment of karst development and plate tectonics. - Com 9. Congr. Int. Espeleol., 1: 223-226. Barcelona.

PALEOKRAS ČEŠKEGA MASIVA (ČEŠKA REPUBLIKA): KRATEK PREGLED

Povzetek

Češki masiv je znan po policiklični in poligenetski naravi krasa in paleokrasa (srednjeevropskega tipa), razvitega na posameznih, manjših kraških področjih. Matične kamnine so predvsem devonski apnenci (deloma metamorfozirani), ponekod pa jurske karbonatne kamnine. Matična kamnina je bila vključena v strukturo epi-varističnih platform, kjer je mogoče razmejiti paleotektonsko od neotektonske dobe z mejo v permiju. Za paleotektonsko dobo je značilna velika mobilnost, zaradi česar so velike spremembe v razvoju faciesov, posledica tega pa je nastanek zgolj sinsedimentnega in lokalnega paleokrasa. Neotektonska doba (platforma) je bila bolj umirjena, le z nekaj pomembnimi morskimi transgresijami, ki so zajele velik del češkega masiva. Nanj so tudi močno vplivale posamezne faze alpidske orogeneze. Razvila so se obsežna interregionalna paleokraška področja v večih, med seboj bolj ali manj ločenih fazah.

Spodnjedevonska in spodnjekarbonska faza zakrasevanja sta bili povezani z lokalnimi tektonskimi dviganji in regionalnimi regresijskimi oziroma transgresijskimi cikli 3. reda ter z osciliranjem morske gladine 4. in 5. reda. Sinsedimentni in celo zreli lokalni paleokras se je razvil v pragiju, na meji eifelij - givetij in od famennija do zgornjega viseija. Za razlago razvoja tega krasa lahko uporabimo karibski model, kjer je zelo pomembno mešanje sladke vadozne in freatične vode ter prepletanje sladkovodnih in morskih diagenetskih faciesov.

Razvoj paleokrasa v zgornjem karbonu in med permijem ter zgornjo juro je navzgor omejen s callovijsko morsko transgresijo. Spodnjo mejo predstavljajo zaključne faze variskične orogeneze z odlaganjem obsežnih rdečih molasnih sedimentov. Interregionalni tip krasa se je razvijal izključno v kontinentalnem okolju. Pred zgornjim juro je bilo površje močno uravnano.

Spodnjekredna faza zakrasevanja se je končala s cenomanijsko transgresijo. S številnih krajev so znani primeri dobro razvitega interregionalnega paleokrasa, za katerega so značilne globoke oziroma visoke oblike s pisanimi produkti kemičnega preperevanja.

Paleogena do spodnjemiocenska faza zakrasevanja se je končala z mlado alpsko tektonsko fazo, ko je badenijsko morje deloma preplavilo vzhodne robove masiva. Interregionalni paleokras je nastajal v fazi zakrasevanja, ki je obsegala zelo široko področje, vendar posameznih faz in regij ni mogoče natančno določiti (zaradi splošnega pomanjkanja paleontološko datiranih nahajališč). To je glavna faza nastajanja jam v Češkem masivu, vključno nastanek največjih kraških sistemov v večini najobsežnejših kraških ozemelj. Znani so številni primeri iz karpatskega jarka v devonskih in jurskih apnencih, kjer so pod apnenci kremenčevi klastiti, nad njimi pa flišni narivni pokrovi. Čas od srednjega miocena do kvartarja je bolj čas fosilizacije kot pa masovnega

nastajanja kraških oblik.

Povezava med periodami intenzivnega kemičnega razpadanja oziroma nastajanjem uravnav in zakrasevanjem je vidna v Češkem masivu. Tako intenzivno kemično razpadanje (lateritizacija, kaolinizacija) kot razvoj uravnav in zakrasevanje so v povezavi s podaljšanimi periodami relativne tektonske stabilnosti. Zveza med intenzivnim razpadanjem in zakrasevanjem je pomemben pokazatelj za odkrivanje ekonomsko pomembnih nahajališč mineralov v paleokraških ozemljih.

CAVE ENTRANCES SHOWN IN THE ORIGINAL SKETCHES OF VALVASOR

JAMSKI VHODI NA ORIGINALNIH VALVASORJEVIH SKICAH

VLADO BOŽIĆ

Izvleček UDK 551.44:74.021(091)

Vlado Božić: Jamski vhodi na originalnih Valvasorjevih skicah

Avtor opisuje devet Valvasorjevih skic, shranjenih v metropolitskem oddelku univerzitetne knjižnice v Zagrebu. Večina skic je bila osnova za bakroreze v Valvasorjevem delu Die Ehre dess Herzogthums Crain (1689). Skice, opisane v prispevku, prikazujejo vhode v jame, kraške izvire in ponore in so zato zanimive za krasoslovje.

Ključne besede: speleologija, zgodovina speleologije, Valvasor

Abstract UDC 551.44:74.021(091)

Vlado Božić: Cave entrances shown in the original sketches of Valvasor

The author described nine Valvasor's sketches kept in the Metropolitana Department in the University Library at Zagreb. Most of them were the base for copperplate engravings for his work Die Ehre dess Herzogthums Crain (1689). The sketches described in the article show entrances to caves, karst springs, and ponors and are therefore of karstological interest.

Key words: speleology, history of speleology, Valvasor

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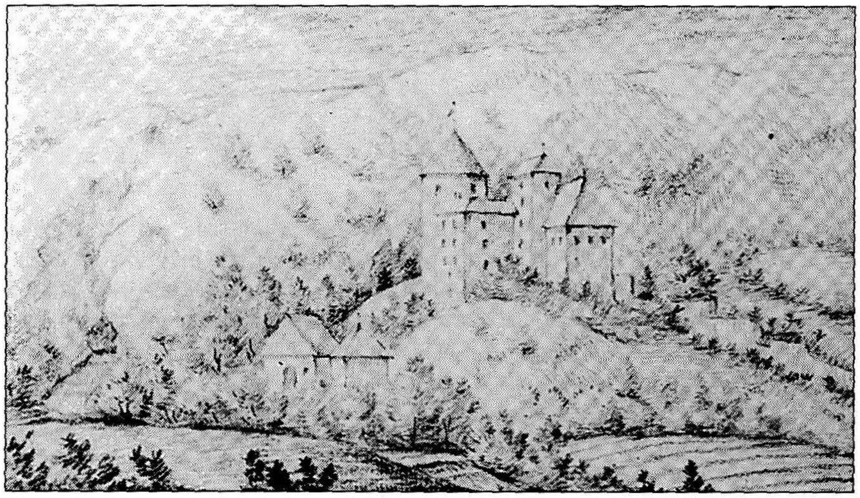
Much has been written about Ivan Vajkard Valvasor, especially on the occasion of the 300th anniversary of the publication of his book "Die Ehre dess Herzogthums Crain" in 1689. Nevertheless, new information is still being found among the wealth of documents on his exploration and scientific activities.

It is known that Baron Valvasor, who was descended from a distinguished Ljubljana family, received his education over a long period and in several different places. He was taught rhetoric by Jesuits in Ljubljana. Then in 1659 he studied in Germany and from 1669 to 1672 in Italy, France, Switzerland and Africa. His studies included not only history, geography, archaeology, mathematics and theology, but also alchemy and magic. Once back from his foreign travels he explored the whole of Carniola and neighbouring lands parts of including Croatia.

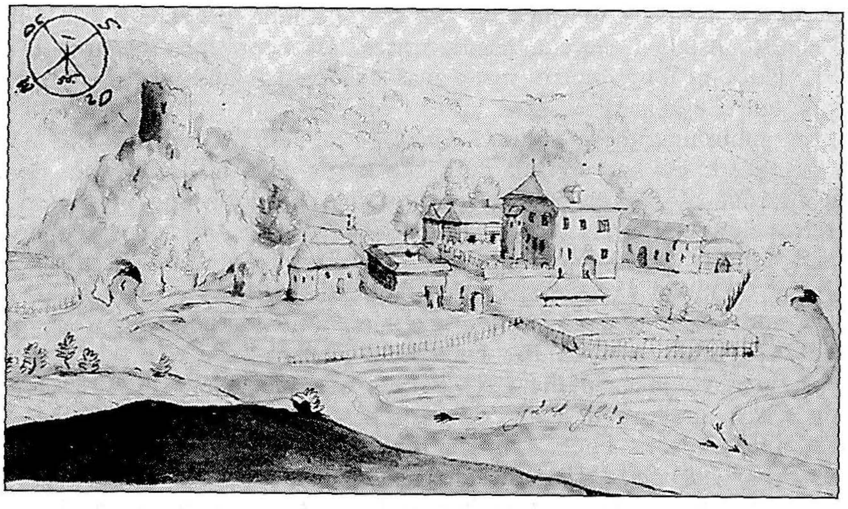
In the course of these travels he made extensive notes and sketches of all he found of interest, so he accumulated an enormous amount of material in readiness for his books. It was because of this that he bought Bogensperk Castle near Litije and made it a kind of museum or academy where he brought many scientists to work on the material and prepare it for publication. He also installed there a printing press for copperplate engravings. So, in 1689, his big four-volume book was completed and was published in Nürnberg and Ljubljana.

But in publishing these volumes he used up all his wealth, and a little before his death he had to sell both the castle and his collections. Bishop Ignacije Mikulić of Zagreb bought some of the collection and presented it to the Metropolitana Library there. Later some books were passed to the University Library in Zagreb, most of the volumes of ecclesiastical sketches went to the Graphics Collection of the Croatian Academy of Science and Art (HAZU), and three volumes of other sketches went to the strongroom of the Metropolitana department in the University Library.

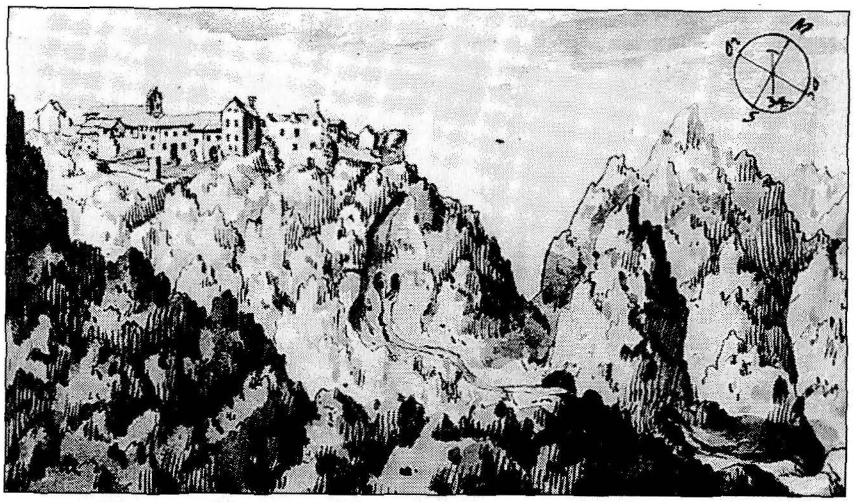
These three volumes in the strongroom have the title: Sketches of towns in Crain (Skice gradova u Kranjskoj). In the first Volume are sketches later published in Valvasor's books, and in the other two volumes under the call numbers MR 198 and MR 199 are sketches till now unpublished. Each Volume is hard bound with about hundred sketches, drawn by pencil, ink or some kind of water colour. On the borders there are no inscriptions or titles, only stickers with numbers. Every sketch has a title in German, and maybe some other words, and a number in the sketch near the frame, and also a



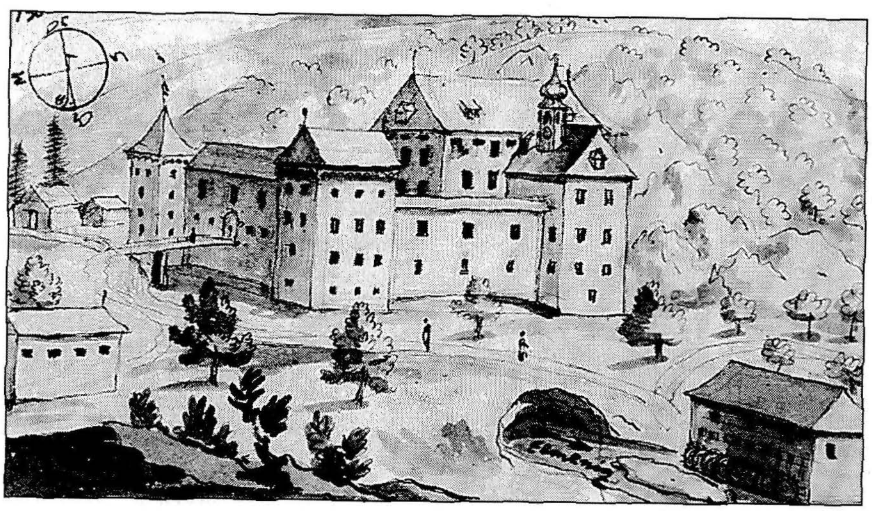
1. Title: GURCKH, Kërka (Vrhkrka, Gradiček) No. 85 (near the frame) and No. 14 and 23 (near the margin of the sketch), presents the sources of two rivers in two caves (Krška jama), on one is written "görk flus" (= river Krka) (Ehre III/ 420) (Roman number is the volume and Arab number the page where the picture is published in the Valvasor's Die Ehre dess Herzogthums Crain, 1689).



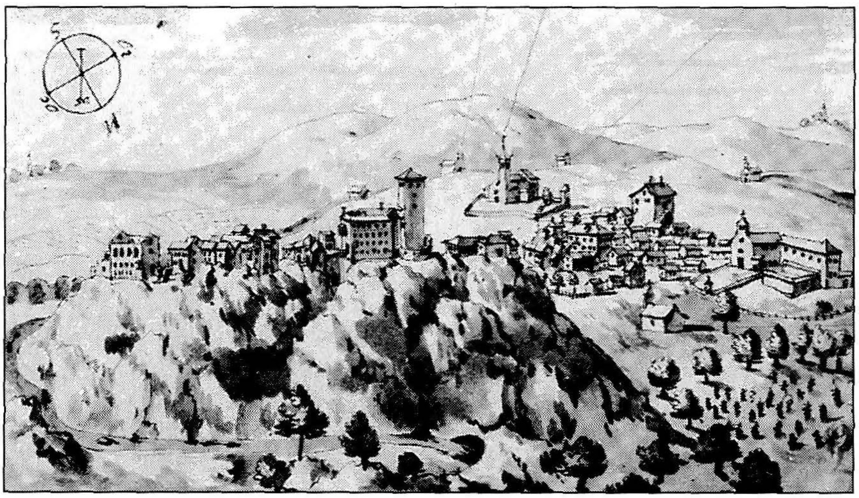
2. Title: KLAINHEISEL, Klajnhejsel (Mali grad, Planina), No. 130 (outside frame), presents a castle and the source in the cave; on the river is written "unz VNZ flus" (Unica river) (Ehre III/309).



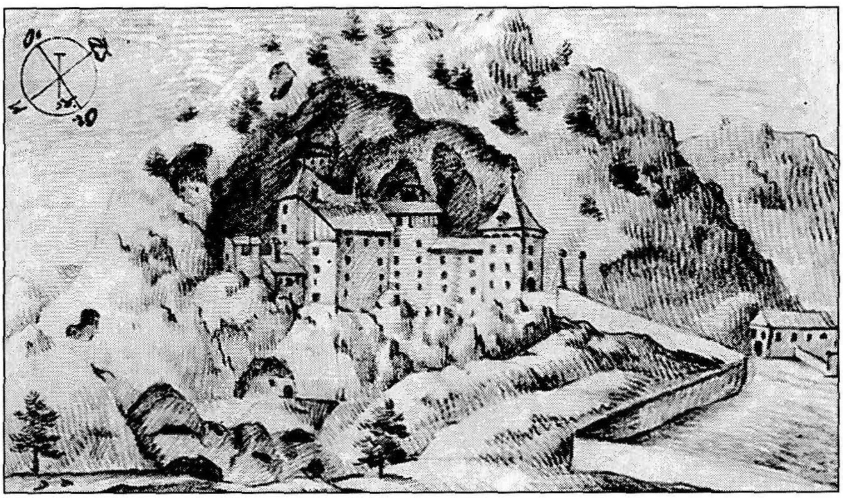
3. Title: ST. KAZIAN (Škocjan), No. 35 and 142 (outside the frame), present a village on the cliff and a river Reka going out of the caves (Škocjanske jame), entering a ponor-cave, again going out of the cave and once more entering a ponor-cave (Ehre I/276).



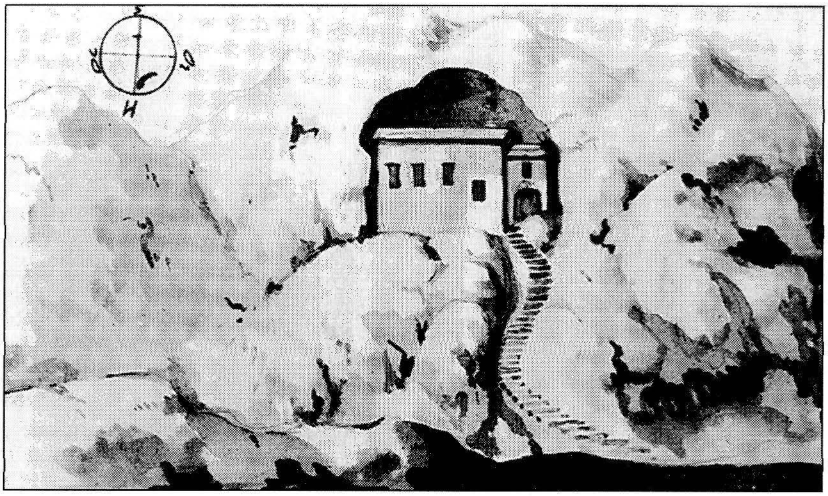
4. Title: LVEG, Luknya, No. 135 (in the picture) and No. 157 (outside the frame), presents a castle and under it a river Temeniz (Temenica) going out of the cave (Luknja) (Ehre III/349).



5. Title: LUEG in der poig, No. 158 (outside the frame), presents a castle (Predjamski grad) in the cave (Jama) and a river (Lokva) entering a ponor-cave; under this place is written "Die grotten". (Ehre I./521).

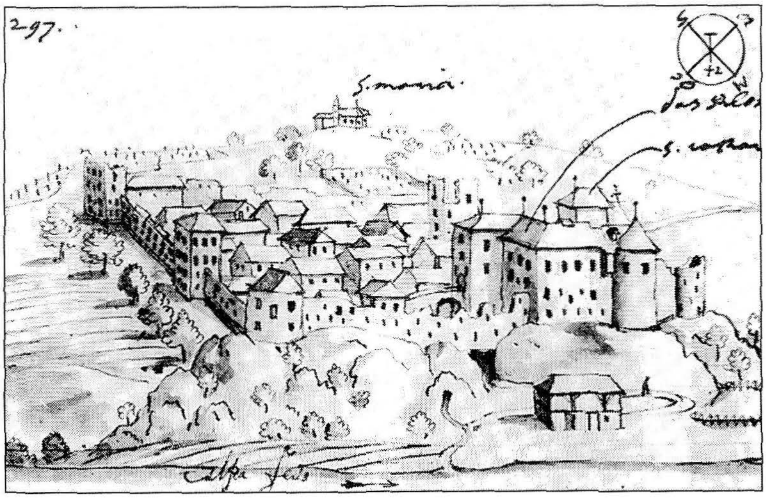


6. Title: Mittelburg, Statt MITTERBVRG (Pazin), No. 173 (outside the frame), presents a big town and a river entering a ponor-cave (Fojba) (Ehre III/374).



7. Title: PODIAMO (Tabor, Grad), No. 221 (outside the frame), presents a building in the cave (Ehre I/282).

8. Title: St. Serff, St. SERFF (Socerb), No. 362 (outside the frame), presents a group of building on the cliff, steps going to the cave entrance (maybe artificial ?), and an other entrance to the cave near a church where is written "die grotta des St" (Sveta jama) (Ehre III/525).



9. Title: WEINITZ, Vinica, No. 297 (in the picture) and No. 338 (outside the frame), presents a village Vinica and a river (on the river is written "Culpa flus") (Kolpa river), with a brook going out of two caves (Ehre III/640).

number added later in pencil outside the frame of the sketch. There are no explanations with the sketches.

Every sketch shows a castle, city, town, village or a building, and its surroundings. These surroundings are of great interest, especially for speleologist, because cave entrances are drawn in several sketches. In the Volume No. MR 199 alone, there are 9 sketches with speleological contents.

The other sketches are first-class documents too, because they show the state at that time of towns and their surroundings known today. Among many such towns there are Mošćenice, Kastav, Rijeka, Kraljevica, Novigrad, Škrljevo, Žumberak, Brinje, etc. (in Croatia); and Kočevje, Velika vas, Mala vas, Ljubljana, Lož, Pleterje, Višnja gora, Idrija, etc. (in Slovenia); and Trieste (in Italy). These sketches will be of interest not only to naturalists but also to historians of architecture and town planning.

JAMSKI VHODI NA ORIGINALNIH VALVASORJEVIH SKICAH

Povzetek

Avtor opisuje devet Valvasorjevih skic, ki so shranjene v metropolitskem oddelku univerzitetne knjižnice v Zagrebu. Večina teh skic je bila osnova za bakroreze v Valvasorjevem delu Die Ehre dess Herzogthums Crain (1689). Te skice, opisane v prispevku, prikazujejo vhode v jame, kraške izvire in ponore in so zato zanimive za krasoslovje. Prikazujejo naslednje kraje: Vrhkrko pri Gradičku (s Krško jamo), Mali grad pri Planini (s Planinsko jamo), Škocjanske jame pri Divači, grad Luknjo pri Novem mestu (z izvirom Temenice), Predjamski grad in Jamo, Pazin s Fojbo v Istri (Hrvaška), jamo Tabor (Grad) pri Šembijah nad Knežakom, grad Socerb s Sveto jamo in Vinico ob Kolpi s kraškim izvirom. V zbirki so še številne druge skice, prav tako zanimive ne samo za naravoslovce, ampak tudi za zgodovinarje, arhitekte in planerje.

THE KARST AREA OF PIETRASECCA (ABRUZZO, ITALY): A PROJECT FOR ITS PRESERVATION AND TOURISTIC DEVELOPMENT

KRAŠKO PODROČJE PIETRASECCA (ABRUZZI, ITALIJA): PROJEKT ZA NJEGOVO OHRANITEV IN TURISTIČNI RAZVOJ

EZIO BURRI & PAOLO FORTI

Izvleček

UDK 504.05:551.44(450)

Ezio Burri & Paolo Forti: Kraško področje Pietrasecca (Abruzzi, Italija): projekt za njegovo ohranitev in turistični razvoj

Kraško področje Pietrasecca je na apnenčevem hrbtu v gorah Carseolani. Med jamami sta po velikosti in obliki najpomembnejši Ovita in Grotta Grande del Cervo. Zato, da bi zavarovala to pomembno kraško okolje, ga je regionalna vlada Abruzzov razglasila za naravni rezervat. Italijanski speleološki inštitut je skupaj z oddelki nekaterih univerz v zadnjih treh letih izdelal več interdisciplinarnih študij o Pietrasecci. Najpomembnejši je morda projekt o turističnem razvoju, ki je popolnoma vsklajen s strogimi varstvenimi zakoni, kot jih ima naravni rezervat. V tem prispevku so predstavljene geografske in geomorfološke značilnosti Pietrasecce ter projekt o turizmu, v zvezi z varovanjem in ohranjanjem narave.

Ključne besede: krasoslovje, geografija krasa, geomorfologija krasa, varstvo narave, turizem na krasu.

Abstract

UDC 504.05:551.44(450)

Ezio Burri[2] & Paolo Forti[3] The Karst area of Pietrasecca (Abruzzo, Italy): A project for its preservation and touristic development[1]

The karst basin of Pietrasecca is located on the limestone ridge of the Carseolani mountains. Several caves are hosted in this area, the Ovito and the Grotta Grande del Cervo being the most important for size and morphology. Therefore the Abruzzi Regional Government transformed this area into a natural reserve, in order to protect its important karst environment. A multifinalized study on the Pietrasecca basin was carried out in the last three years by the Italian Insitute of Speleology together with several University Departments. Perhaps the most important achieved result is a project for the touristic development, which is completely compatible with the strict preservation laws of the area, as imposed by Natural Reserve. In the present paper the geografic and geomorphological settlement of the Pietrasecca basin is briefly outlined and the touristic project is presented and discussed with regards to protection and preservation.

Key words: karstology, karst geography, karst geomorphology, nature protection, karst tourism.

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INTRODUCTION

The karst area of Pietrasecca has been known of a long time due to the presence of the Ovito sinkhole at the bottom of a large blind valley, as testified by a geographic map of the XVIII century.

But the first speleological investigations and the first partial topography of the Ovito cave were only made by the Circolo Speleologico Romano between 1925-30.

During the 1984 the Gruppo Speleologico CAI Roma dug an old landslide, thus entering for the first time into the Grotta Grande del Cervo (The Big Stag cave).

This new cavity presented a wide range of scientific interest: archaeological, paleontological, morphological and seismic being the most important ones. Therefore several studies started inside this cave: the last of which was a multifinalized study organized by the Italian Speleological Institute, co-ordined by the Karst section of the CNR National Group "Physical Geography and Geomorphology" and researched by scientists from about 10 different Universities.

In the mean time, the inhabitants of the surroundings strongly supported the idea of transforming the Grotta Grande del Cervo into a show cave due to the quantity of beautiful speleothems and the easy internal path in the first part of the cavity. Initially the local governments promoted this idea in order to improve the presently lack of economy of the Pietrasecca thus slowing down its depopulation.

In the 1992 the Abruzzo regional government transformed all the karst area of Pietrasecca in a "Natural Reserve" (regional law n.19 , 31.03.92) in order 1- to allow the completion of the researches still developing; 2- to avoid an unbalanced touristic use, which might even destroy the relevant natural values of the area, which must be mantained.

Among the researches promoted by the regional law, one was devoted to prepare a project for the cultural and touristic use of the Pietrasecca karst, which was able to blend the preservation of the natural properties, as requested by scientsts and cavers, together with the touristic and social expectations of the inhabitants.

In the present paper a short geographical, geological and geomorphological outline of the karst area is presented and then the proposed touristic poject is discussed.

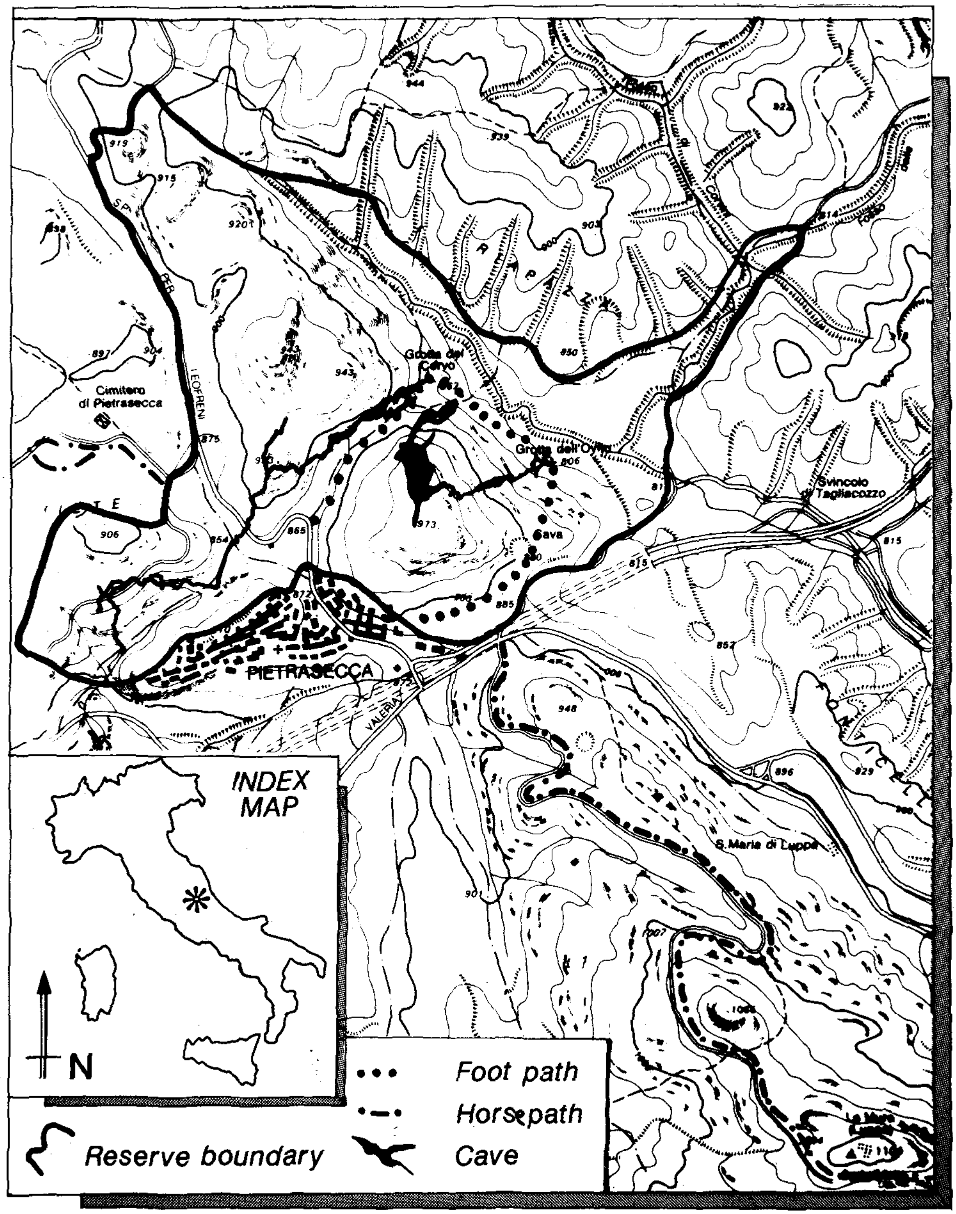

Fig. 1. Map of the Pietrasecca Natural Reserve

GEOGRAPHICAL, GEOLOGICAL, GEOMORPHOLOGICAL AND KARST SETTLEMENT OF THE AREA

The karst outcrop of Pietrasecca is located in the south-western ridge of the Carseolani Mountains (Carsoli, Abruzzo) and consists of about 9 square km just around the small village of Pietrasecca.

In its north-eastern part there is the large Ovito blind valley (13 square km), whose waters are totally drained by the sinkhole in the mouth of the cave of the same name. The risings are south-westward from the village and a small brook flows from them into the wide St. Martino valley.

The Pietrasecca karst has a temperate Mediterranean climate, characterized by hot and dry summers and cold wet winters, the mean rainfall being about 1200 mm/yr (FREDI P., PUGLIESE F., 1993).

The structural geological settlement of this area is well known (AGOSTINI, 1993): the stratigraphic sequence starts with well stratified limestones of Upper Cretaceous (about 25 m thick) over which transgressive limestones and magnesian limestones of the Middle Miocene (100-120 m thick) were deposited in conformable geometry. The deposition of calcarenites followed by marls and planctonic clays and finally by pelitic sandstones close the Pietrasecca sequence.

The object of the present paper is the portion of the ridge just where the Pietrasecca village was built: it consists of an asymmetrical anticline cut by several normal and cross faults, which caused the evolution of a subvertical slope with several escarpments.

If the structural settlement of the area was important in shaping some external morphologies, its control over the deep karst was almost complete, as the excellent fitting between structural lineations and spatial development of cave branches (CUCCHI & ULCIGRAI, 1993) testifies.

Moreover some large breakdowns and the volcanic intrusion inside the Grotta Grande del Cervo (BERTOLANI et Al., 1993) are all located just in the crosspoint of different faults, which is also the limit of some of the steps in the south-western wall of the fold.

The detailed geomorphologic analysis shown that the evolved surface forms were mainly controlled by the substratum lithology (AGNESI et al., 1993).

On the limestone ridge the structural settlement deeply influenced the landscape, which in turn was greatly modified by karst processes. Several open basins may be observed: probably they are the remains of an older karst period than the present one and their opening was induced by fluviokarst processes.

Some small subcircular dissolution dolines and rare micro-forms, mainly karren, are also present in the studied area.

The paleo-valley crossing NE-SW the ridge is worth mentioning: it seems to be related to a paleo-drainage active in the period before the opening of the Ovito and Grotta Grande del Cervo sinkholes.

In the Tortonian flysch the hydrogaphic network is well developed and channel-flow erosions are widespread: among them the small V shaped valleys and the erosional escarpments along the terraced surfaces are the most common.

The presence of several, presently inactive, forms suggest that the hydrographic network alternates static to active deepening stages.

The whole area is actually a single hydrogeological basin (BONO & CAPELLI, 1993),which is drained by the Ovito sinkhole to the Pietrasecca spring: both the two dye tracing experiments, made during a flood and in a base flow period, experienced a very high flow rate with very low dilution, thus showing the absence of storage capacity inside the limestone karst aquifer. Anyway the karst water resources may be regarded as emergency sources for drinking water supply for the Pietrasecca Village and therefore they must be adequately preserved.

But the most important scientific interest of this area is related to the deep karst (AGOSTINI & PICCINI, 1993), which is well developed. Beside some small cavities, it consists of the Ovito - Grotta Grande del Cervo-Pietrasecca rising system, which is a classical example of a hydrogeologic tunnel developed for over 3 km.

Actually the Ovito cave is an active sinkhole, while the Grotta Grande del Cervo is fossilized: the water sinks and then flows inside the first part of the Ovito, from which it is collected in the deeper part of the Grotta Grande del Cervo, then reaching the Pietrasecca rising. Anyway, in the past, both the caves were simultaneously active sinks for the waters coming from the flysch, which was in that time subdivided into two sub-basins.

The morphology of these three caves shows a noticeable structural control on the speleogenesis thus inducing a rapid evolution of the system with hydraulic gradient similar to the actual one.

Forms developed in aereate conditions dominate and testify to an enhanced erosion caused by a large stream with a high solid transport, which in turn is responsible for the widespread deposition of very thick (up to 20 m) sediments and of the complete obliteration of the Grotta Grande del Cervo, which occurred during a long period (AGOSTINI et al., 1993). All the sediments along the systems seem to be actively eroded, anyway they are still massively present in the deeper part of the system (final galleries of the Grotta Grande del Cervo).

Speleothem evolution was noticeable mainly inside the Grotta Grande del Cervo, which therefore is one of the most scenic of the whole Abruzzi. Moreover some of the speleothems are peculiar to this karst system: the permanent wind controlled coralloids of the Ovito and the interbed drainage tubes of the Grotta Grande del Cervo (FORTI, 1993).

The first part of the Grotta Grande del Cervo is characterized by a noticeable amount of speleothem breakdowns, which developed in the last 400.000 years: thanks to a new method of analysis it was possible for the first time in the world to prove that some macroseismic periods were responsible for these breakdowns. The oldest recognized paleoseismic period occurred over 350.000 years B.P., while the youngest one was identified with the 1456 earthquake, which hit all the central and southern Italy (AGOSTINI et al., 1993).

Finally the presence of important paleontological and archaeological remains inside the first gallery of the Grotta Grande del Cervo (AGOSTINI & GIZZI, 1993) have to be mentioned.

MAN'S IMPACT OVER THE NATURAL RESERVE

The Pietrasecca village (BURRI, 1993) is still shaped on the original structure of fortified hamlet, whose features range between XV and XVIII century.

Available historical news about Pietrasecca is very scarce: in fact this village was practicly isolated until present day, mainly due to the distance from the pricipal routes (as the "Tiburtina-Valeria" road existing from the III century B.C.).

Both existing documents on the state of the roads and touristic guides of the beginning of this century confirm that no easy connections existed with the principal regional routes, but only a small and hard mule-road. Therefore the community was more involved with the neighbouring Marsica, developing a weak economy based on non-intensive sheep and cow raising, corn, maize and potato growing, and hunting.

These activities induced an intensive utilization of the few areas suitable for agricultural use, which were obtained from the small blind valleys and dolines even removing from the surface a noticeable amount of boulders, as testified by widespread large rock piles.

The removed limestone boulders were often utilized in the construction of partition walls and terraces, the last created to lower the natural acclivity thus allowing the agricultural use of those lands. Traces of this activity, which lasted several centuries, are quite common around the village and gradually decrease getting away from it: therefore temporary dwelling places are usually absent from the territory.

The inhabitants (a few hundred people) decreased rapidly until 10 years ago due to migrations both inland and abroad. Thus most of the tilled ground was abandoned: now only few fields for fodder and some kitchen gardens close to the village are mantained.

Therefore this area suffered only a small amount of human impact, consisting of the few traditional activities in the land use.

However a noticeable degradation of the landscape was caused by the relalization of the A24 highway, which crosses over the S.Martino Valley with a high and long viaduct just in front of Pietrasecca; as a consequence several burrows were estabilished in the area and a limestone quarry was opened (it is presently unactive).

Pietrasecca inhabitants got no real economic advantages from the existence of this highway, whose main effect was that of lowering the availablility of houses, because several of them were transformed into holiday residences for people living in Rome. At present building activities are limited to a few restorations of old houses, which in turn causes the widespread growth of small illegal waste· disposals.

The caves suffered practically no impact in the past: only the Ovito sinkhole was at intervals utilized as a disposal for slaughtering refuse and a burial ground for dead animals.

Immediatly after its finding, the environment of the Grotta Grande del Cervo was sufficiently damaged: in fact cavers and other visitors brought a lot of mud into the cave, which was smeared over most of the speleothems thus causing a noticeable aesthetic loss. Moreover several cave formations were broken and, in some cases, taken out of the cave. Luckily the Grotta Grande del Cervo was gated a short time after its first exploration and the local authorities restricted the visits to the development of scientific research.

THE TOURISTIC PROJECT

The discovery of the Grotta Grande del Cervo, which hosts an important archaeologic, paleontologic and morphologic patrimony induced the inhabitants of Pietrasecca to associate the possibility of their economic revival to this cavity, thus strongly supporting the idea of transforming it in a show cave on the basis of similar experiences in some other Italian regions (Frasassi cave in Marche, Castellana cave in Apulia, and many others).

In a short time some touristic projects were presented: but the common characteristic of all of them was to suggest a traditional touristic settlement for the whole cavity, without any care for its preservation.

Two facts hindered the realization of such project: the restriction imposed on the cave by the Ministry of Cultural Patrimony due to the presence in the first gallery of peculiar archaelogical remains and the beginning of some scientific research requiring an undisturbed cave environment.

Anyway, the projects were not sufficient to ensure in the near future a permanent protection to the Grotta Grande del Cervo and its natural patrimony; therefore it would be necessary to prepare a general preservation project.

The Regional Government of Abruzzo with a general law (n.61/80) on the Natural Reserves and Parks defined the Natural Integral Reserve as uncontamined natural environment of relevant interest in which only scientific research may be allowed. This definition fits with the "Analogous Reserve" category proposed by the UICN (Union International pour la Conservation de la Nature) and with the "Natural Monument" definition, as used in several countries (BURRI, 1989). The identification of the Ovito and the Grotta Grande del Cervo caves and their karst surroundings as "Integral Natural Reserve" is undoubtedly the best method for their safeguard.

The first problem to be solved was that of delimiting the reserve area, which must be coincident at least with the total extension of the karst basin, from the cave entrances to the risings.

A surface of about 110 hectares was defined (Fig.1), in which disposals of any kind, the use of pesticides and hunting are forbidden. Then a smaller portion of this area, practicly coincident with the cave entrances, was more strictly controlled: in fact inside this any environmental perturbation is forbidden, as for collecting animals or sampling speleothems, fossil remains, etc., and access to the area is controlled.

In Italy the rules existing over a cave entrance are automatically extended to the whole cavity, therefore the restriction imposed over a very small area in reality is sufficient to preserve all the karst system.

The management of the Natural Preserve will be made in co-operation with the Italian Speleological Society, and it will practicly start just after the Regional Government will promulgate the "Management plan", in which the general rules to be followed will be outlined.

The fundamental question to be solved was that of a real compatibility between the need of strict preservation and the request of some touristic development.

A further difficulty in solving this problem was represented by the existence in the same region of other caves, which were transformed in the past into show caves, whose activity may be affected if new cavities will be open to tourism.

Therefore the proposed "management plan" suggested the following program:

- On the surface:

a) Inside the Reserve: the tracing of an educational foot-path (fig. 1) along which the main morphological and anthropic features of the area may be easily seen. Using this path-way the visitor may reach the entrances of the Ovito and Grotta Grande del Cervo, and eventually visit them.

b) Outside the Reserve: the tracing of two horse-routes, mainly along pre-existing mule-roads, which allow a widespread view on the morphological and anthropic peculiarities not only of the Reserve but also of the neighbouring areas.

- Inside the Ovito sinkhole:

A subdivision of the cave paths into three categories characterized by an increase in safeguard and preservation (fig. 2) was made with the same method normally utilized for the Natural Reserve.

A zone: suitable for tourism. In this part a partially artificial foot-path and an emergency lightening fed by solar batteries will be realized keeping the environmental changes to a minimum.

B zone: restricted to semi-free excursion for small groups of tourists controlled by speleological guides. No fixed lights and few and simple artificial fittings to cross over the hardest pathes will be realized.

C zone: wilderness area, restricted to selected wild excursion of cavers with no environmental impact on the caves.

- Inside the Grotta Grande del Cervo:

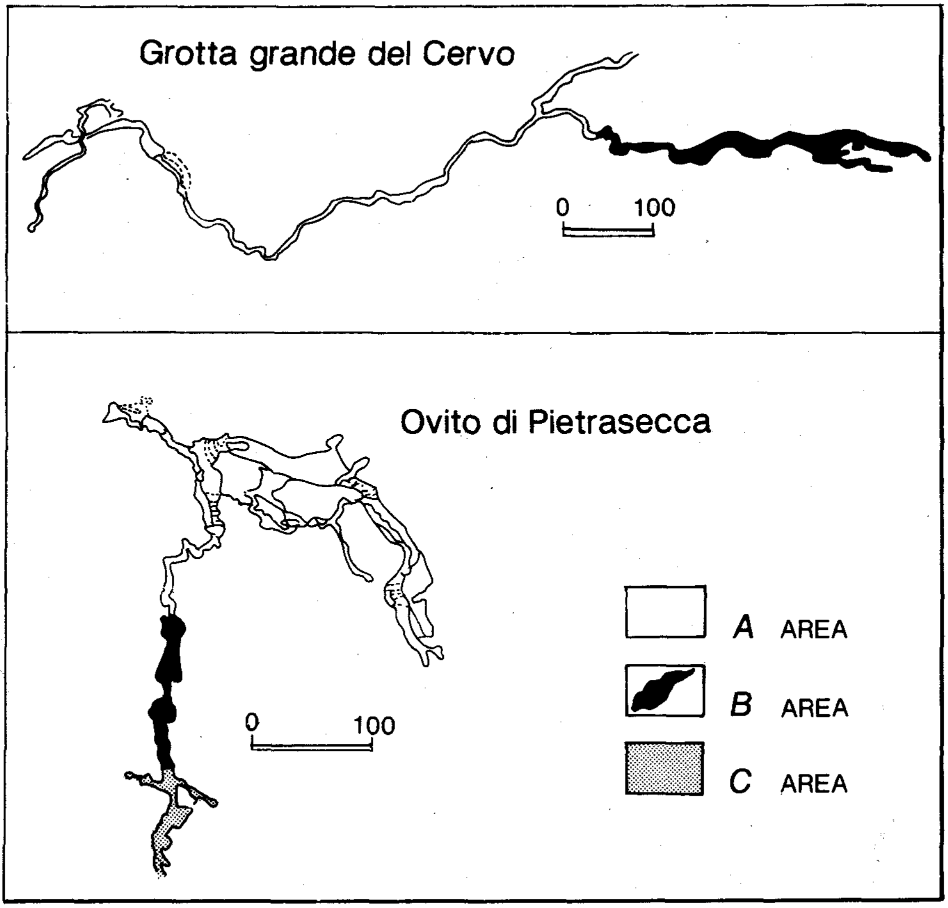

Fig. 2. Maps of the Ovito and Grotta Grande del Cervo caves in which the different areas were evidenced

This cave will not be devoted to tourism but only to educational and scientific uses: therefore no A zone has been proposed (fig. 2). Moreover monitoring of the cave parameters will be done and the allowed number of visitor/day will be determined on the basis of the achieved results (preferance will be given to the students of the primary and secondary schools).

B zone: visitors are restricted inside the signed paths, which will be partially created with artificial elements to prevent any alteration of the cave morphology; no fixed lights will be placed inside. The tours will be always led by an experienced cave guide. In all this area educational panels will be placed in all the points of interest (achaeological, morphological, mineralogical, etc.): it is worth mentioning the idea of replacing a polished vertical section of a big stalagmite, which was used for the paleoseismical study of the cave, in its original place. Finally a restoration of all the area, in which former visitors smeared mud, has been planned in order to clean the flowstones and the stalagmite crusts.

C zone: wilderness zone: admittance to this part of the cave will be decided by a Scientific Commission and it will be allowed only for scientific reserch.

FINAL REMARKS

It is well known that the touristic use of a natural cavity rarely may accomplish also the preservation of its environment. This is particularly true when the cave is characterized by a low level of "energy" (as in the case of the Grotta Grande del Cervo), which correspond to a high level of vulnerability (HEATON, 1986; CIGNA & FORTI, 1989).

In the mean time it was incorrect, in our opinion, completely to refuse the request of the local community looking for the possible touristic exploitation of this karst area as the sole possibility for their social improvement.

The multifinalized studies carried out in this area created the possibility of drawing up a management plan in which both the naturalistic and the touristic requests may be contemporaneously satisfied.

Moreover in this Natural Reserve a new approach to the problem of visiting a cave was introduced and experimented for the first time in Italy: the idea is that to keep lights and fixed structures inside the cave to a minimum and therefore to transform the tourist into a caver at least partially.

We hope that this trend will be enhanced and spread in the future to the management of other natural reserves in karst areas.

REFERENCES

AGOSTINI S., 1993: Caratteri geologici e strutturali dell'alticlinale e del bacino di Pietrasecca, Mem. Ist. It. Spel., Bologna, (in press).
AGOSTINI S., GIZZI E., 1993: Grotta Grande del Cervo : Archeologia e Paleontologia, Mem. Ist. It. Spel., Bologna, (in press).
AGOSTINI S., FORTI P., POSTPISCHL D., 1993: Gli studi sismotettonici e paleosismici effettuati nella Grotta Grande del Cervo di Pietrasecca nel periodo 1987-1991, Mem. Ist. It. Spel., Bologna, (in press).
AGOSTINI S., PICCINI L., 1993: Aspetti geomorfologici ed evolutivi del sistema carsico di Pietrasecca, Mem. Ist. It. Spel., Bologna, (in press).
AGNESI V., FREDI P., MACALUSO T., PUGLIESE F., SANSO' P., SAURO U., 1993: Note illustrative alla carta geomorfologica di Pietrasecca, Mem. Ist. It. Spel., Bologna, (in press).
BERTOLANI M. LUGLI S., ROSSI A., 1993: Studio petrografico delle grotte di attraversamento di Pietrasecca, Mem. Ist. It. Spel., Bologna, (in press).
BONO P., CAPELLI G., 1993: Idrologia sotterranea e di superficie dei monti carseolani (Italia Centrale), Mem. Ist. It. Spel., Bologna, (in press).
BURRI E., 1989: Aree protette a connotazione carsica, in "Problemi di inquinamento e salvaguardia delle aree carsiche", Nuova Editrice Apulia, Bari, pp. 113-133.
BURRI E., 1993: Utilizzazione del territorio ed impatto antropico nell'area limitrofa l'abitato di Pietrasecca (Italia Centrale), Mem. Ist. It. Spel., Bologna, (in press).
CAPASSO BARBATO L., GLIOZZI E., 1993: La fauna pleistocenica della Grotta Grande del Cervo di Pietrasecca (Carsoli - AQ - Italia Centrale), Mem. Ist. It. Spel., Bologna, (in press)
CIGNA A., FORTI P., 1989: I principali agenti del degrado nelle grotte turistiche, in "Problemi di inquinamento e salvaguardia delle aree carsiche", Nuova Editrice Apulia, Bari, pp. 47-60.
CUCCHI F., ULCIGRAI F., 1993: Evoluzione del carsismo ipogeo dell'area di Pietrasecca, Mem. Ist. It. Spel., Bologna, (in press).
FORTI P., 1993: I fenomeni concrezionari nella Grotta Grande del Cervo e dell'Ovito di Pietrassecca, Mem. Ist. It. Spel., Bologna, (in press).
FREDI P., PUGLIESE F., 1993: Inquadramento geografico dell'area carsica di Pietrasecca, Mem. Ist. It. Spel., Bologna, (in press).
HEATON T., 1986: Caves. A tremendous range in energy environments on Earth, Nat. Spel, Soc: News, August, pp. 301-304.

KRAŠKO PODROČJE PIETRASECCA (ABRUZZI, ITALIJA): PROJEKT ZA NJEGOVO OHRANITEV IN TURISTIČNI RAZVOJ

Povzetek

Kraško področje Pietrasecca je že dolgo znano, saj je ponorna jama Ovito označena že na zemljevidu iz 18. stol. 1984 je Gruppo Speleologico CAI Roma odkopalo vhod v Grotta Grande del Cervo, ki se je izkazala zelo pomembna za arheologijo, paleontologijo, morfologijo in seizmiko. Zato so se lotili interdisciplinarnega preučevanja, ki ga je organiziral Italijanski speleološki inštitut pod vodstvom Kraške sekcije CNR nacionalne skupine "Fizična geografija in geomorfologija" in ob sodelovanju znanstvenikov z desetih univerz. 1992 je lokalna vlada razglasila področje Pietrasecce za naravni rezervat.

Kras Pietrasecce je v jugozahodnem hrbtu gorovja Carsoli (Abruzzi) in obsega okoli 9 km^2 ozemlja okoli vasi Pietrasecca, na severovzhodu pa je velika slepa dolina z jamo Ovito. Ta kras grade predvsem zgornjekredni in srednjemiocenski apnenci. Jamski rovi se lepo ujemajo z geološko strukturo. Celotno področje je danes en sam hidrogeološki bazen, ki se drenira proti jami Ovito in predstavlja skupaj z Grotta Grande del Cervo in izviri pod Pietrasecco primer 3 km dolgega "hidrogeološkega tunela".

Za Grotto Grande del Cervo so značilna obsežna rušenja kapnikov pred okoli 400.000 leti. Z novo analitično metodo je bilo mogoče prvič na svetu dokazati, da so bile vzrok temu rušenju močne makroseizmične periode. Najstarejša je nastopila pred več kot 350 000 leti, najmlajša pa je identična s potresom leta 1456.

Vpliv človeka na ta kras je bil tekom zgodovine zelo majhen, saj je bila Pietrasecca majhna, izolirana vas. To se je spremenilo šele z zgraditvijo avtoceste v neposredni bližini.

V zvezi z razglasitvijo naravnega rezervata in turistično izrabo se je pojavilo dvoje temeljnih vprašanj: omejitev področja in sožitje varstva s turizmom. Določenih je bilo več con z različnimi varstvenimi režimi in različnimi možnostmi turistične izrabe.

ASPECTS OF HUMAN IMPACT IN THE MONTE GRAPPA MASSIF (VENETIAN PREALPS, ITALY)

ČLOVEKOV VPLIV V POGORJU MONTE GRAPPA (BENEČIJSKE PREDALPE, ITALIJA)

MONICA CELI

Izvleček UDK 504.05(450)

Monica Celi: Človekov vpliv v pogorju Monte Grappa (Benečijske predalpe, Italija)

Pogorje Monte Grappa pripada Benečijskim predalpam, zgrajenim iz apnencev z dobro razvitimi kraškimi pojavi, vključno pomembne izvire v dnu dolin. Človekov vpliv je vezan na dva glavna dejavnika: na vire in na zgodovinski razvoj. Deforestacija, I. svetovna vojna, paša, turizem, so spremenili naravne ekosisteme in danes je razmerje med človekom in okoljem neuravnovešeno. V primerjavi z drugimi deli Benečijskih predalp Monte Grappa ni tako zelo degradirana, vendar jo je treba zavarovati, preden bodo njeni viri nepopravljivo poškodovani.

Ključne besede: krasoslovje, kraška morfologija, varstvo narave, človekov vpliv na kras, Italija, Benečijske predalpe, Monte Grappa.

Abstract UDC 504.05(450)

Monica Celi: Aspects of human impact in the Monte Grappa Massif (Venetian Prealps, Italy)

The Monte Grappa Massif belongs to the Venetian Prealps. It is of limestone and the karstic phenomenous is well developed, with important springs along valley bottom. The dynamic of human impact are linked to two principal factors: the resources and the historical events. The deforestation, the First World War, grazing, tourism have changed the natural ecosystem and today the equilibrium between man and environment is instable. The Massif is, among the others Venetian Prealps system, not much degraded but needs protection before irreparable damages to the resources.

Key words: karstology, karst morphology, nature protection, man's impact on karst, Italy, Venetian Prealps, Monte Grappa.

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INTRODUCTION

The mountain group of Monte Grappa belongs to the Venetian Prealps with the other groups: Monti Lessini, Altopiano di Asiago and the group of Cansiglio Cavallo (fig.1). Each of these groups presents a different aspect of the human impact evolution. Three principal factors induced these differences: 1) the morphology, which has influenced the possibility for men to penetrate inside the mountain, 2) the resources, 3) the historical events.

The combination of this factors, but in particular of the last two, has been very important to determine the actual situation about the human impact on the Monte Grappa.

SOME NOTES OF GEOLOGY AND GEOMORPHOLOGY

Monte Grappa is bounded by the two river valleys, Brenta and Piave. It presents to the east a morphostructural uniformity with the Altopiano di Asiago, broken only by the Brenta valley. Carbonate rocks of Mesozoic age predominate. From the bottom to the top the massif consists of these formations: Dolomia Principale of Triassic age, Calcari Grigi (grey limestone) of Jurassic age, Rosso Ammonitico (red limestone) of upper Jurassic age, and Biancone (white limestone) of Cretaceous age.

On the upper part scattered till deposits of the quaternary glaciation exist.

The relief of Massiccio is asymmetric, more steep toward the plain (south) and gently sloping to the inner part of the Alpine Chain.

The geomorphology is typical of karstic landscape. The epikarstic forms seem not well developed, but there is no surface flow, only dry valleys, and in the last ten years speleologists have explored more than 380 caves. Eight of the caves exceed in depth 100 m. The Monte Oro cave reaches 500 m in depth and a continuation is possible. The development of the caves is strongly controlled by the tectonic structure. The principal fault directions are two, NNE-SSW and ENE-WSW.

NOTES ON THE KARST HIDROLOGY

Along border valleys of the massif there are many karstic springs. The 20 principal springs with their discharge are indicated in tables 1 and 2. They represent most of the karstic runoff that flows in the massif. Table 3 shows an evaluation of water balance in this system. About the circulation inside the Massif and the structure of the karstic system we can suppose a discontinuous epiphreatic zone. Little basins, influenced by tectonic and local morphological condition determine the localisation and the discharge of the springs. During the rainy periods the Fontanazzi di Solagna spring is the highest discharge one. It is associated with the crossing of the Brenta valley by an important system of faults, along which there are the Monte Oro caves and others, about 7 caves with a mean depth between about 50 and 100 m (fig. 2). A tracing test with fluorescine has indicated a velocity of 34 m/h of flow between the Monte Oro cave and the Fontanazzi di Solagna spring. There has not been dispersion of colorant in the nearest springs. In other sites in the massif the velocity of flow detected was less than 15 m/h.

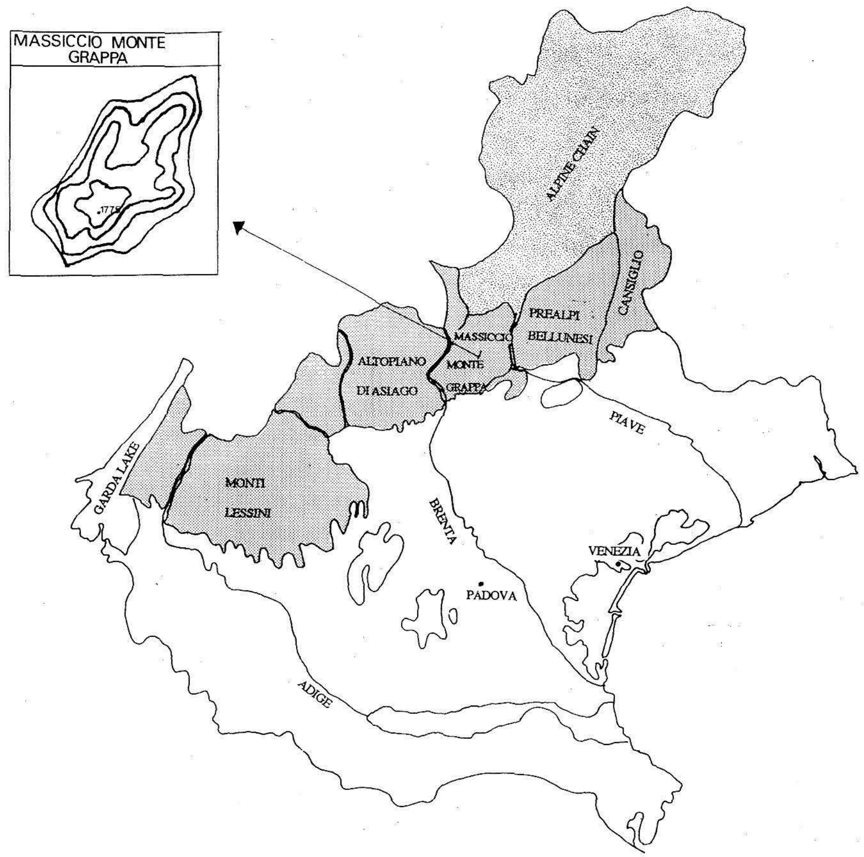

Fig. 1

MAN AND MASSICCIO OF MONTE GRAPPA

The asymmetric relief of Monte Grappa determines an assymmetric disposition of settlements, which reach medium elevations only toward the inner part of Alpine chain, or along the valleys. Differing from the other Venetian Prealps systems in Massiccio of Monte Grappa important settlements never developed. The human impact was thus limitted, but has some effect on the ecosystem.

In general the strongest forms of impact, that in past times and today have partialy degraded the ecosystem of this massif can be summed as:

deforestation and wrong reaforestation, grazing, World Wars, tourism and new settlements.

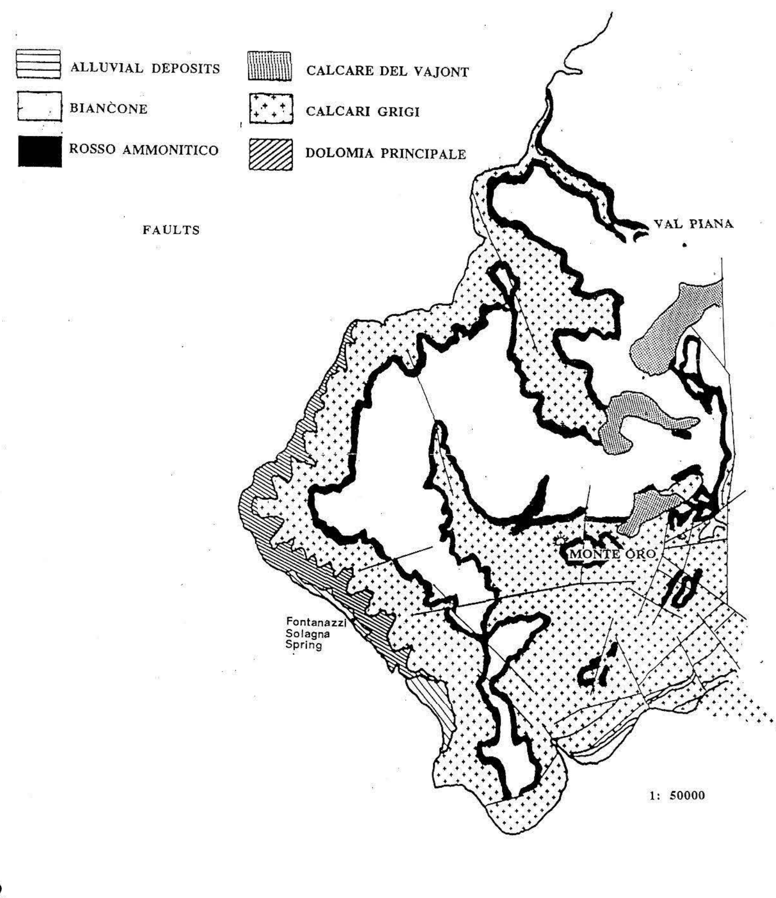

Fig. 2

Table 1
Discarge (lt/sec) of the 20 principal spring present in the Massiccio of Monte Grappa.

SPRING	Q max	Q min	Q mean *
Fener			45
Val Bicadora			26
Valle la Pila			43
Molinon			65
Tegorzo	500	300	360
Val Cauca	3	1.5	2.5
Fontana del Moro	1.5	0.5	1.2
Vallonara	3	1	2.3
Val Carbonaia	1.5	0.5	1.2
Segat			0.1
Lavazè	34	24	27.3
Molino Benvenuto			14
Vallle della Fontana	3.5	1.5	2.9
Fontanazzi Cismon	1200	600	800
Val dei Ponti			5
Rivalta			2
Carpanè			100
Fontanazzi Solagna	1800	300	800
Col Raniero			0.1

* Q mean = 1/3 Q max + 2/3 Q min

Table 2
Year discarge of Monte Grappa springs

SPRING	Q m^3/year
Fener	1419120
Val Bicadora	819936
Valle la Pila	1356048
Molinon	2049840
Tegorzo	11352960
Val Cauca	78840
Fontana del Moro	37843.2
Vallonara	72532.8
Val Carbonaia	37843.2
Segat	34.7
Lavazè	860932.8
Molino Benvenuto	441504
Vallle della Fontana	91545.4
Fontanazzi Cismon	41352960
Val dei Ponti	157680
Rivalta	523497.6
Carpanè	63072
Fontanazzi Solagna	43541952
Col Raniero	3154
TOTAL	107414804.7

Table 3
Evaluation of water balance for the Monte Grappa karstic system

	m^3/year	%
Precipitation	403187500	100
Evapotraspiration	156484000	39
Surface flow	139288696	34
Dow flow	107414804	27

- Deforestation and wrong reaforestation

The natural vegetation up to 1600 m was a beech forest and low elevation sub-Mediterranean forest, with *Abies* and *Picea*, only where the local climate situation was particularly cold. The important deforestation began in 500 A.C., when Teodorico needed wood to build 1000 ships for his fleet. The deforestation continued also during the Venetian Republic, and it was greater than in the others Prealps systems, because this site is nearest to Venice, and the Brenta and Piave rivers can be used for transport. This degraded irremediably the soil, with many problems of hydrogeological deterioration. Another important cause of deforestation was grazing animals. To create area for pasture many woods were cleared. The first World War, had many battles in the massif, transforming the upper part into a desert. Now the situation is no better. The reaforestation in this century did not good results, because instead of the beech, *Abies* and *Picea* were planted. The soil became more acid, and many species of rare plants and flowers have disappeared. The upper part was a refuge area for many species during the glaciations and represents an important and very interesting botanic area. About the karstic areas the capacity of water corrosion is increased by greater concentration of humic acids; the soil had less humidity because of larger density of networks. Studies of the Department of Forest find in this the cause of the very common fires in the massif.

- Grazing

The grazing now is only temporary; in the upper part (about >500 m) there are no stock-farms. In past times it was more developed, and large areas with a lower density of animals were used; today only small areas, well served by roads, are used with problem of overloading. The other areas, often better for grazing, have been abandoned. So an important resource has been wasted, and there are many problems of bacterial pollution of springs due to overloading particularly during the summer time when the precipitations are less.

- The war events

The war events have completely transformed large areas in the massif, particularly near Cima Grappa, the highest summit, where the first line of the Italian army was settled. The consequences of these military actions were complex. The surface acquired different morphology. Aerial ropeways, new roads and muletracks, trench labyrinths were built . The bomb holes today are like dolinas and new fractures were created in the limestone, so the natural karstic processes find a favourable situation (Celi M., 1991). During the retreats and at the end of the wars much war equipement and ammunition was left in caves and fissures, with problems of danger and of heavy metal pollution of karstic system. During the war and at the end, many people emigrated from the valley to the plain, the consequence was the degradation of the pastures and particularly of woods. The artificial but, in that context, good equilibrium between man and the karstic ecosystem was thus irremediably broken.

- New settlements and tourism

Around the settlements in the valleys and at the foot of the massif agricultural activities developed principaly in the last three centuries, that used the mountain upper part for pasture and timber during the summer time. Many houses with stalls, named "malga", were built. Today only a few of these are still used and the others are ruined or are used as inns for tourists.

In Monte Grappa there are only two villages, but many scattered residential houses, and some hotels without infrastructures like drainage or an efficient service of waste collection and disposal. Near these new buildings there are many of the old buildings, now ruins.

The tourism is very different from that in the other Venetian Prealps systems. The winter tourism is limited by the deficiency of facilities. The ski-lift in all the massif are only 8, in the near Altopiano di Asiago are 57. Many roads are closed for snow, and nearly all hotels are closed in winter. There is no tourist centre and so the residential tourism is restricted only to the residential houses or hotels. So particularly the tourism for the young is very limited; in the massif there are no discos, cinemas or swimming-pools or others similar facilities like in the Altopiano di Asiago. This is very important to limit the strong human impact in this ecosystem. But if the impact of the residential tourism is limited, particularly in winter, in the massif is possible to find other types of turists. During summer and autumn there are many sporting tourists: hunters, pickers of mushrooms, excursionists, cyclists with mountain bikes, speleologists, persons with off-road vehicles, pick-nickers, "commemoration" tourists and so on. A big problem is the use of off-road vehicles and mountain-bikes, that have degraded some areas, giving acoustic and chemical lead pollution. These two types of pollution have negative consequences on the fauna, particularly during the reproductive period, when the noises and the lead can disturb the acoustic and chemical signals between animals.

A very particular problem is today the "commemoration" tourism. During the summer time, especialy in August, the parking near the shrine of Cima Grappa is completely full, many cars are parked on the meadow, where the pioneer vegetation is beginning on the desert left from wars. The facilities near this important monument are totally insufficient to support the large quantity of visitors.

FINAL REMARKS

The war events and in general the historical events have been very important to define the actual state of the relation between man and karstic ecosystem of Grappa. This area is partly preserved, but a big problem will be the future. The people will have more free time, and probably also this territory will be strongly colonised. From many years many people and naturalist association work to create a protected area, a park, to defend this particular ecosystem of the Venetian Prealps, but political and economic interests see in this massif a gold quarry for the possibility to build touristic and sport centres. The possibility of having protection for the whole massif appear very remote.

REFERENCES

CARRARO F., GRANDESSO P. and SAURO U. (1990) - Incontri con il Grappa. I segreti della Geologia. Editore Moro. Centro incontri con la natura Don Paolo Chievacci. Crespano del Grappa, 4-125.

CELI M. (1991) - The impact of bombs of World War I on limestone slopes of Monte Grappa. International conference on environmental changes in karst, Proceedings. University of Padova, 279-288.

MIETTO P.and SAURO U. (1989) - Le grotte del Veneto: paesaggi carsici e grotte del Veneto, Regione del Veneto - La Grafica Editrice, 415 pp.

SAURO U. (1987) - The impact of man in the karstic environments of the Venetian Prealps. International symposium on human influences on karst, Proceedings. Postojna, Yugoslavia, 241-254.

SAURO U., MARTELLO G.and FRIGO G. (1991) - Karst environment and human impact in the Sette Comuni Paleau (Venetian Pre-Alps). International conference on environmental changes in karst, Proceedings. University of Padova, 269-278.

SAURO U. (1993) - Human impact on the karst of the Venetian Fore-Alps, Italy. Environmental Geology, Springer International- Verlag, 21: 115-121.

ČLOVEKOV VPLIV V POGORJU MONTE GRAPPA (BENEČIJSKE PREDALPE, ITALIJA)

Povzetek

Pogorje Monte Grappa pripada Benečijskim predalpam in kaže podobne geomorfološke poteze, kot druge predalpske skupine: Altopiano di Asiago, Monti Lessini, itd. Grade ga apnenci z dobro razvitimi kraškimi pojavi, vključno s pomembnimi izviri v dnu dolin. Človekov vpliv je zelo raznolik in njegova dinamika je vezana na dva glavna dejavnika: na preskrbljenost z naravnimi viri in na zgodovinski razvoj oziroma dogodke. Deforestacija z napačno reforestacijo, prva svetovna vojna, pretirana paša, turizem in moderna sekundarna bivališča, so globoko spremenili naravne ekosisteme in danes je razmerje med človekom in okoljem, ki je bilo v ravnovesju od desetega stoletja dalje, neuravnoteženo. V primerjavi z drugimi deli Benečijskih predalp Monte Grappa ni tako zelo degradirana, vendar je treba njene geosisteme zavarovati, preden bodo njeni viri nepopravljivo poškodovani.

L'IMPACT ANTHROPIQUE DANS LE VERCORS

ČLOVEKOV VPLIV NA SEVERNEM VERCORSU (FRANCIJA)

MICHEL CHARDON

Izvleček UDK 504.05(44)

Michel Chardon: Človekov vpliv na severnem Vercorsu (Francija)

Vercors je kraško sredogorje v francoskih Severnih Alpah. Do zadnje vojne je bil človekov vpliv na naravno okolje omejen, kmetijsko-pašniška dejavnost pa je nazadovala. V zadnjih 50 letih pa turizem, še posebej v alpskih smučarskih središčih, spreminja pokrajino, gozdove, predvsem pa površinske in podzemeljske vodne tokove. Avtorjeva pozornost je usmerjena v največji meri na polje Corrençon in porečje reke Bourne.

Ključne besede: krasoslovje, človekov vpliv na kras, sredogorski kras, turizem, Francija, francoske Severne Alpe, Vercors

Abstract UDK 504.05(44)

Chardon Michel: Man's impact in the Northern Vercors (Alps, France)

Vercors is a mid altitude karstic mountain in the French northern Alps. Till to the last war, the human impact on the natural environment was limited, while the agro-pastoral activities were declining. For 50 years, touristic management specially with alpine ski resorts is now tranforming the lansdscapes, the areas of forests and mainly the superficial and subterranean water flows. A special attention is paid to Corrençon polje and Bourne water basin.

Key words: karstology, man's impact on karst, middle mountainous karst, tourism, France, French Northern Alps, Vercors

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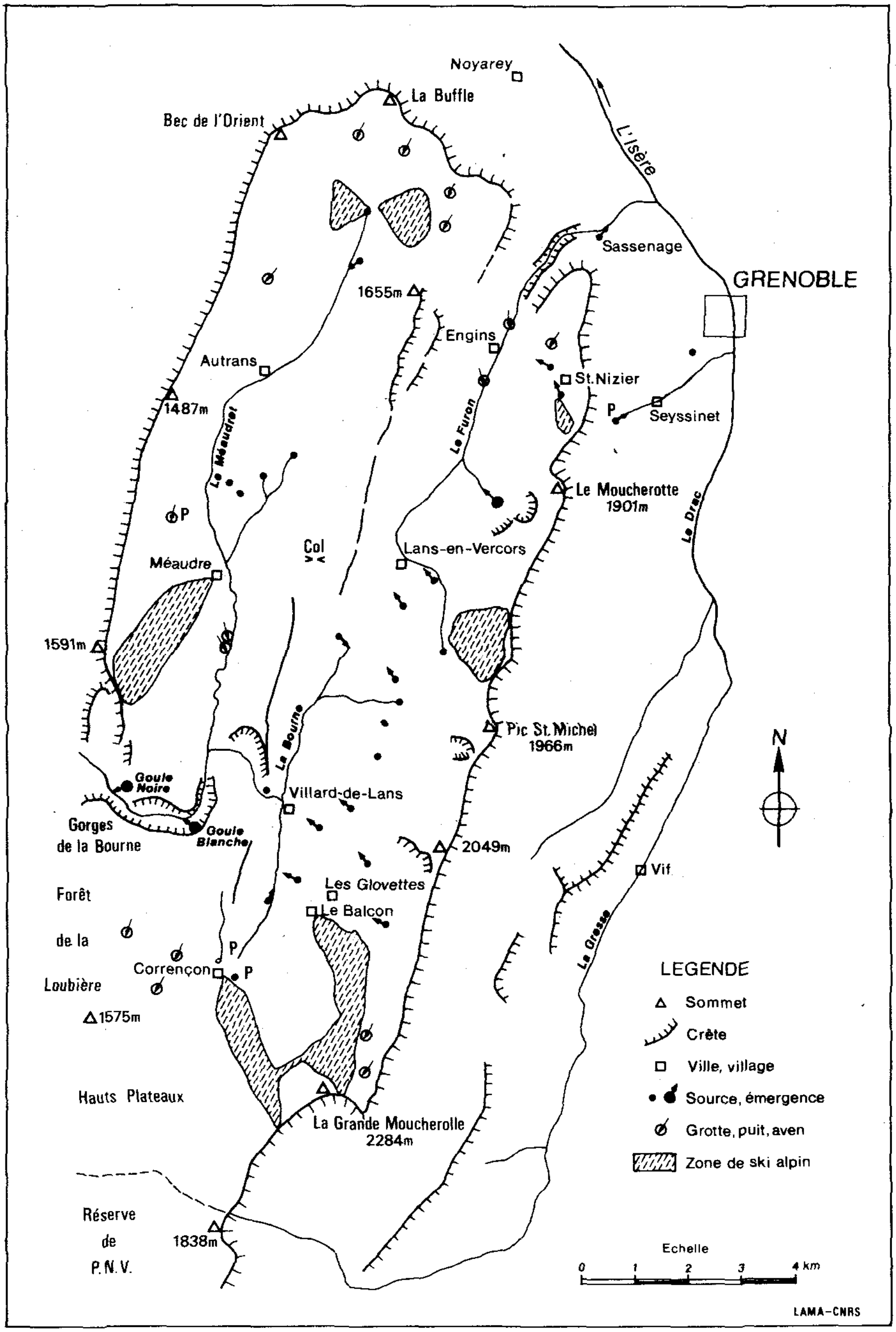
Dans les Alpes françaises du Nord, le Vercors est un massif préalpin situé au sud de Grenoble. Les paysages de ce karst de moyenne montagne ont été bouleversés par les transformations économiques et humaines depuis un siecle.

I - DONNÉES GÉNÉRALES SUR LE SYSTÈME KARSTIQUE DU VERCORS SEPTENTRIONAL.

C'est une région de moyenne montagne culminant à la Grande Moucherolle (2285 m). Les arêtes sommitales (1800 à 2200 m) dominent une suite de bassins synclinaux dont l'altitude se place vers 1000 m: Lans, Villard-de-Lans, Corrençon, Méaudre et Autrans. Le drainage superficiel des fonds synclinaux n'évacue qu'une partie des eaux. L'écoulement souterrain se fait vers des émergences localisées dans les Gorges du Furon (Sassenage) et de la Bourne (Goule Blanche, Goule Noire...).

La structure géologique explique cette dualité. L'ossature du massif est constituée par des calcaires massifs urgoniens, d'âge Crétacé inférieur, plissés et fracturés. Du fait de leur puissance et de leur continuité (3/400 m), ils permettent un long drainage souterrain vers les points bas des canyons karstiques. Les calcaires gréseux et marneux du Crétacé inférieur, les dépôts glaciaires et fluvioglaciaires du Quaternaire, la molasse sablo-conglomératique miocène, alimentent des sources de faible débit localisées dans la partie centrale des synclinaux.

Le climat est frais et humide. Les précipitations sont de l'ordre de 1200 à 1500 mm par an, avec un enneigement de 3 mois vers 1000 m, 6 à 7 mois sur les crêtes. A l'état naturel, le massif paraît avoir été un karst presque entièrement forestier. Aujourd'hui, l'étage collinéen atteint 800 à 1000 m tandis que le montagnard occupe la tranche altitudinale 800-1500 et le subalpin (principalement des épicéas) celle de 1500-1800 m. La limite supérieure de la forêt - d'origine anthropique -est floue entre 1800 et 2000 m. Le caractère forestier et humide explique l'importance de la dénudation karstique évaluée entre 150 et 200 mm/1000 ans au niveau des émergences de Choranches (J. J. DELANNOY, 1981). Celle-ci se produit pour l'essentiel dans la partie superficielle au contact du sol et de la roche (MUXART T., 1977). La végétation intervient également dans l'importance de la tranche d'eau écoulée dans le karst (P') puisque c'est un des facteurs fondamentaux régulant l'évapotranspiration. D'après P. ROUSSET (1983) le déficit d'écoulement


Noyarey
La Buffle
Bec de l'Orient
L'Isère
Sassenage
GRENOBLE
1655m
Engins
Autrans
St.Nizier
1487m
Le Méaudret
Le Furon
Seyssinet
P
Le Moucherotte
1901m
Le Drac
ØP
Col
Lans-en-Vercors
Méaudre
1591m
Le Bourne
Pic St.Michel
1966m
N
Goule Noire
Villard-de-Lans
Gorges
de la Bourne
Goule Blanche
2049m
Vif
Les Glovettes
Forêt
Le Balcon
de la
P
Correnҫon
P
Le Gresse
Loubière
LEGENDE
Sommet
Crête
Ville, village
Source, émergence
Grotte, puit, aven
Zone de ski alpin
△1575m
Hauts Plateaux
La Grande Moucherolle
2284m
Réserve
de
P.N.V.
1838m
Echelle
0 1 2 3 4 km
LAMA-CNRS

à Villard-de-Lans (1030 m) serait de 42 % pour un total annuel des précipitations de 1260 mm. La corrosion karstique de subsurface, en domaine forestier, représente de 60 a 90 % de la corrosion mesurée aux émergences. Elle est plus faible sous les prairies d'altitude et dans les zones cultivées. D'après T. MUXART (1977), sous hêtraie-sapinière, la quantité de carbonates dissous est de 90-100 mg/l, soit de 10 a 25 % supérieure à celle des prairies supraforestières. Toute modification anthropique aura des conséquences sur le fonctionnement du géosystème.

II - L'IMPACT ANTHROPIQUE DANS L'ÉCONOMIE ANCIENNE DU VERCORS.

L'occupation humaine commence des la Paléolithique, bien qu'elle devienne importante seulement à l'époque moderne. Dans l'ensemble du canton de Villard-de-Lans, elle n'a jamais été forte. Au début de ce siècle la densité de population était de 18 habitants/km^2, très inférieure à ce chiffre à Corrençon (5 hab/km^2). La civilisation agropastorale avait défriché les terres arables des fonds de vallées et des premiers versants, laissant boisés les ubacs et les plateaux karstifiés. Elle avait étendu les prairies d'altitude devenues alpages au détriment de la forêt. Celle-ci était utilisée pour le bois d'oeuvre, pour les scieries, les chantiers et la marine, pour la consommation locale de combustible et la fabrication de charbon de bois. Elle conserve au début du siècle un place primordiale couvrant 62 % du territoire communal à Corrençon, 45 % à Villard-de-Lans de Land, 79 % à Méaudre. Compte tenu de l'existence des alpages, rochers, la surface en cultures était faible: 20 a 25 % à Villard, 7 % à Corrençon.

Quel a été l'impact de l'homme pendant cette longue période ?

- une déforestation limitée et une modification du couvert végétal au profit des feuillus, diminuant l'érosion karstique.
- l'utilisation naturelle des ressources en eau et notamment des sources jalonnant la bordure des fonds synclinaux, le long desquelles se fixaient fermes et hameaux (cartes anciennes).
- une pollution des écoulements par les hommes et les animaux.
- une faible utilisation des rivières et de leur force hydraulique (moulins, forges).
- l'utilisation des cavités comme abri et réserve, voire refuge (glacières...).

Au total, l'impact anthropique est limité. L'hydrographie et l'écoulement tant souterrain que de surface, ne sont pas dérangés. Jusqu'à une époque récente, des étendues marécageuses, des tourbières, des fonds de vallées hydromorphes se transformant en étangs à certaines périodes, ont persisté à Corrençon, dans le val de Lans, près de Méaudre et d'Autrans... Le fonctionnement du géosystème ne paraît pas avoir été sérieusement perturbé comme semble le prouver l'accumulation des concrétions à Choranches (tufs de Gournier, dépôts souterrains...).

III - TRANSFORMATIONS ÉCONOMIQUES ET DÉVELOPPEMENT TOURISTIQUE DANS LE VERCORS DEPUIS UN SIÈCLE

A la fin du XIXème siècle, le Vercors est une montagne inégalement anthropisée où l'installation humaine a composé un nouveau paysage. Avec le XXème commence une révolution économique qui change les données du milieu. Quels en sont les éléments?

- La dépopulation rurale commence vers 1850 et s'accentue de 1900 à 1950, amenant une déprise rurale: réduction des terres labourées et des alpages, accroissement des surfaces en prairies et forêts. Ce changement se fait progressivement. De 1900 à 1990 la part de la forêt est passée de 62 % à 75 % de la surface communale à Corrençon, de 45 % à 53,4 % à Villard,
- La construction d'une série de prises d'eau, de dérivations et d'usines hydroélectriques le long du cours de la Bourne a artificialisé les débits et le régime du cette rivière. Celle-ci n'a plus qu'un écoulement réduit, hormis pendant les fortes crues. Son rôle morphologique dans le creusement du canyon (transport, érosion...) est pratiquement nul en temps normal. Le "pavage" de blocs du lit torrentiel en est le signe apparent, manifestation de l'état de biostasie du milieu amplifié par l'aménagement anthropique,
- La révolution économique récente est celle du développement touristique. Elle s'annonce entre 1920 et 1940 pour connaître un essor prodigieux de 1960 à 1985. Dans cette partie du Vercors elle repose sur plusieurs éléments : un tourisme de villégiature principalement en été, un tourisme climatique pour enfants, des résidences secondaires de plus en plus nombreuses, et surtout une fréquentation hivernale pour le ski alpin et nordique. En période de "haute saison" hivernale (février), la population présente sur le canton de Villard est estimée à 40 000 personnes. Par rapport à la population résidente (6617 h.) elle est 6 à 7 fois supérieure. Le tourisme est devenu la première source de revenus. Un fort équipement en remontées mécaniques traduit cette évolution: celles-ci forment un réseau dense à Villard et Corrençon entre 1000 et 2000 m, secondaire à Autrans, Méaudre ou Lans.

Quelles sont les implications d'un tel bouleversement pour le milieu déja anthropisé du Vercors?

- L'extension d'une urbanisation mal contrôlée autour et à l'écart des villages et hameaux: maisons individuelles, lotissements, immeubles... infrastructures routières et autres. Cela se traduit par une artificialisation du milieu: emprise du bâti, imperméabilisation, création d'écoulements artificiels...,
- Une accélération de la déprise rurale: le nombre des agriculteurs se réduit, la surface cultivée en terres labourables décline, au profit des prairies. Corrençon ne compte plus que 8 exploitations et 272 ha de surface

agricole utile dont 71 en labours soit 26,1 %. Evolution identique pour l'ensemble du canton où les terres cultivées représentent 26,5 %,

- Les exigences du ski alpin (altitude, enneigement pentes...) conduisent à l'ouverture de pistes en milieu forestier et supraforestier où l'arbre est éliminé et le relief naturel modifié. Avec l'essor du tourisme de ski alpin, le phénomène s'est considérablement développé, pistes nombreuses, plus hautes, pistes de liaisons... Les besoins en neige, c'est à dire un enneigement suffisant et prolongé pour assurer la pratique du ski, ont conduit, depuis plus de 10 ans, à l'installation d'un réseau de production de neige artificielle, dite neige de culture. D'où des besoins considérables en eau sur les versants calcaires ou elle est rare, voire absente,
- La fréquentation - et la surfréquentation - touristique ont accru les besoins en eau de façon drastique à certaines périodes. Lorsque Villard-de-Lans compte seulement 15000 personnes, sur la base modérée de 300 litres/jour/ habitant, cela fait 4500 m^3 par jour soit un débit moyen et constant de 52 litres/seconde. En période d'étiage hivernal ou estival, les ressources traditionnelles sont insuffisantes,
- Les exigences de ces transformations économiques et sociales dans un milieu de moyenne montagne où la plus grande partie de l'eau s'écoule souterrainement, pose des problèmes et entraîne des perturbations dans le fonctionnement du géosysteme karstique.

IV - TRANSFORMATIONS ET PERTURBATIONS DEPUIS UN SIÈCLE

Ces mutations ont des conséquences multiples sur les paysages karstiques, l'écoulement des eaux, la qualité de celles-ci.

1) Transformations paysagères et leur impact.

a) - Progression de la forêt de conifères

Le déclin de la population agricole et des activités agropastorales, se traduit par une extension de la forêt soit sous forme d'une progression spontanée et lente soit par un reboisement organisé et rapide. Dans les deux cas celle-ci profite aux conifères: pins, épicéas, sapins et mélèzes. Ils constituent des peuplements denses à la périphérie de la zone cultivées, au détriment de la forêt mixte feuillus - conifères de l'étage montagnard. A la limite supérieure de la forêt, la progression naturelle de celle-ci se fait au profit des pins, tandis que dans la zone des étages montagnards et subalpins, les conifères gagnent de la place naturellement et par reboisements (Villard). Cette évolution déterminée par l'homme, va dans le même sens: le karst forestier s'accroit aux dépends du karst nu et sous prairie. Dans tous ces cas, le résultat est une acidification des sols, un accroissement de l'agressivité des eaux karstiques par apport de CO_2 biologique, de la dissolution de subsurface et de profondeur. Faute de mesures anciennes, le phénomène ne peut être, pour l'instant apprécié quantitativement.

b) - Dégradations superficielles liées aux équipements de sports d'hiver

Depuis plus de 30 ans, les exigences du ski alpin et du tourisme ont bouleversé les paysages forestiers.

Les déboisements divers (routes, pistes, constructions) détériorent le paysage (saignées, clairières...). Les arbres ont été éliminés, parfois désouchés à l'explosif. A Corrençon et à Villard-de-Lans (Côte 2000) des couloirs de déboisement défigurent le paysage forestier de certains versants. Une planimétrie rapide a permis d'évaluer les superficies déboisées à plus de 110 ha à Villard, 90 à Corrençon, 45 à Lans (stade de neige). Avec les communes d'Autrans, Méaudre... ce sont plus de 3 km^2 qui ont disparu. Hormis le bouleversement paysager, les effets pour le karst ont été:

- la destruction de sols de type rendzines. Le ré-engazonnement artificiel, en dépit d'un concassage des matériaux, n'a donné que des résultats médiocres, hormis dans les zones basses.

- les formes superficielles du karst ont été arrasées et nivelées qu'il s'agisse des tables de lapiez ou des dépressions comme les dolines et puits. Le résultat en est une suractivation de la dissolution superficielle sur du matériau nouveau et concassé, au détriment de celles de subsurface et de profondeur. Quant ce matériau est fin et compact, sur les fortes pentes il en résulte un ruissellement et des ravines.

- la concentration de l'eau et son écoulement ont pu être modifiés par l'arrasement du relief, le colmatage complet ou partiel des dolines (combe de l'Ours, scialets du plateau de Charvet).

- la destruction du couvert végétal et pédologique tend à diminuer l'agressivité des eaux karstiques, au niveau local.

c) - Un bilan général

Malgré l'imprécision de certaines données statistiques concernant la forêt (les surfaces boisées tiennent-elles véritablement compte des défrichements du domaine skiable?). L'avantage est au reboisement si on considère la durée du siècle: la surface forestière a progressé de 482 ha sur Villard-de-Lans, de 570 à Corrençon..., avec toutes les conséquences énoncées précédemment.

Sur la période des trois dernières décennies, cette évolution est contrariée, peut-être annulée. Le paysage, le fonctionnement local du géosystème karstique, les formes de surface sont perturbés par l'impact anthropique.

2) Conséquences sur les écoulements de surface des eaux

Celles-ci sont multiples et leur impact difficile á évaluer, le bassin de Corrençon constituant un cas original.

- La quantité d'eau écoulée dans le karst est accrue de façon sensible mais difficilement appréciable par l'enneigement artificiel (30 %?) mais cela ne concerne qu'un espace restreint et délimité.

- Les captages d'eau effectuées á partir des sources du karst d'altitude (Vallon de la Fauge) et des bas versants ont privé les écoulements de surface d'une partie de leur alimentation naturelle. Il en est résulté un abaissement du niveau de la nappe dans les fonds de vallée, ce qui a contribué, avec le drainage, à faire disparaître les zones basses marécageuses (Lans, Méaudre).

- Le cas du bassin de Corrençon est exemplaire. Le fond du synclinal est constitué de calcaires gréseux (Aptien) de sables et grés glauconieux (Albien) recouverts en grande partie par des dépôts glaciaires et des colluvions. L'ensemble est fermé au nord par l'escarpement de ligne de faille de Combeauvieux.

Ce bassin fonctionne comme un poljé "imparfait". Si les eaux des plateaux de calcaires urgoniens sont évacuées souterrainement vers la Goule Blanche, en surface et en subsurface celles-ci convergent vers les zones basses des Mengots et des Martins, situées de part et d'autre du village et de l'ancien chateau. Avant le développement touristique, la première était occupée par un lac temporaire dont les eaux étaient évacuées de deux façons. Au moment des hautes eaux, un émissaire franchissait temporairement le seuil pour s'ecouler vers le nord. Un écoulement souterrain soit profond, soit de subsurface drainait le fond vers les sources du ruisseau de Corrençon, situé plus au nord. Ce lac était formé par les eaux pluviales des divers talwegs - dont le plus important était celui du col de Liorin - mais surtout par l'affleurement de la nappe phréatique collectant les eaux des formations superficielles et des terrains du Crétacé supérieur. Cette nappe proche de la surface, donnait une ligne de sources aux Martins et toutes les fermes s'approvisionnaient en eau par des puits peu profonds. Même lors d'étés secs, le village n'a pas manqueé d'eau: le vallon des Martins est resté une zone humide.

Avec l'essor du tourisme, Corrençon compte aujourd'hui 264 habitants permanents, 105 résidences principales et 782 secondaires sans mentionner les hébergements collectifs. La population présente peut atteindre 3000 personnes. Des réseaux d'adduction d'eau potable, d'évacuation des eaux usées et de collecte des eaux pluviales ont été construits. Deux stations pour le pompage de l'eau ont été édifiées l'une au dessus des Martins et la seconde plus récente sur le seuil. En évacuant les apports d'eaux pluviales et en prélevant sur la nappe phréatique, le niveau de celle-ci s'est abaissé: nombre de puits et de sources ont tari, les fonds humides ont disparu. La construction de la route du Liorin barrait la dépression des Mengots et accroissait son endoréisme. La réalisation d'une conduite, le creusement du chenal assurent un meilleur drainage, d'autant que eaux usées et pluviales (pour une part) sont collectées. Au total, le talweg se creuse à la sortie du bassin, les eaux étant mieux évacuées. Le lac temporaire ne se forme qu'exceptionnellement après des pluies diluviennes ou à la fonte des neiges. L'hydrographie comme l'hydrologie de cette dépression sont devenues artificielles.

a) - Insuffisance des approvisionnement en eau: pompage et recyclage de l'eau à partir des émergences

Si Corrençon, Lans et Autrans disposent de ressources suffisantes et proches, il n'en est pas de même pour Villard, St Nizier et Méaudre. Le problème est résolu pour l'instant en captant l'eau des émergences du réseau profond. Saint-Nizier (1168 m) s'approvisionne aux sources des Arcelles (942 m) sur la commune voisine de Seyssinet. Les eaux sont remontées et stockées. Méaudre s'alimente dans le réseau souterrain du Trou qui souffle par pompage à - 324 m (débit horaire maximum de 100 m^3/h). Villard-de-Lans est le cas le plus démonstratif. Toutes les ressources proches étant utilisées et les besoins restant énormes, une prise d'eau a été installée à l'émergence de la Goule Blanche (813 m) dans les gorges de la Bourne. L'eau est pompée (débit possible 74 l/s) pour être stockée dans une suite de réservoirs jusqu'à une altitude de 1700 m. De cette façon sont alimentiés les canons à neige de la Côte 2000, les complexes touristiques du balcon de Villard et des Glovettes, le centre ancien, les villages et hameaux qui gravitent autour de celui-ci.

Quels sont les impacts d'un tel aménagement ?

- La réduction et l'artificialisation des débits des cours d'eau issus des émergences captées, ce qui est le cas de la plupart d'entre elles. Actuellement une seule émergence reste à l'état "naturel", celle du Bruyant. A Goule Blanche (débit moyen annuel 2,5 m^3/sec, jusqu'a 20 m^3/sec en crue), il peut être prélevé jusqu'a 0,2 m^3 pour l'alimentation en eau et 3,5 m^3/sec pour la centrale hydroélectrique, ce qui constitue, de tres loin, l'essentiel de l'utilisation.

- Une partie minime de l'eau écoulée sur cette partie du plateau du Vercors est "recyclée" pour des besoins anthropiques divers: alimentation humaine, neige, agriculture... Elle doit être traitée et surveillée: les pollutions sont fréquentes, comme l'ont montré des analyses, en particulier au Trou qui souffle. Ces risques sont accrus lors des fortes averses quand l'eau s'engouffre dans le réseau souterrain. Celui-ci et ses émergences étant à l'aval des zones polluantes, toutes les conditions de pollution bactériologique sont réunies.

b) - Les pollutions et leur traitement

Dans l'économie ancienne, les pollutions étaient fréquentes sur les réseaux karstiques du fait de l'absence de toute installation cohérente et organisée d'évacuation des eaux usées des habitations, étables, bergeries. Le pastoralisme en altitude, le pacage libre des animaux sur les prairies et dans les forêts des plateaux karstiques (avens, puits, glacières...), le rejet sans contrôle des eaux des habitations et des étables, favorisent les pollutions. Longtemps le village et les hameaux de Saint Nizier ont déversé leurs eaux vers le Pas du Curé dont le ruisseau avait été transformé en égout, de meme que dolines, avens... ont été le réceptacle des détritus.

Avec le développement du tourisme, la multiplication des résidences secondaires et principales (rurbanisation), les pressions des mouvements écologiques, la quasi-totalité du canton traite les eaux usées.

- Les exploitations agricoles sont équipés de bacs et cuves à fumier.

- Un réseau d'égouts collecte les eaux usées. Villard, Corrençon et Lans ont construit la station d'épuration des Jarrands, Saint-Nizier évacue les siennes vers la vallée de l'Isère. Seules quelques localités et fermes isolées ne sont pas encore reliées au réseau général et disposent de leurs propres installations (par ex. Les Nobles près de Villard). Le plus souvent, la gestion de l'eau a été confiée à une entreprise privée spécialisée.

Cependant tout risque de pollution grave d'origine accidentelle, humaine ou technologique n'est pas écarté du fait de l'importance de la fréquentation et des installations touristiques, de la fréquence des travaux de génie civil, du maintien d'une agriculture intensive sur un faible espace. Les analyses d'eau dans les réseaux souterrains de Goule Blanche et du Trou qui souffle prouvent une pollution bactériologique et chimique (nitrates), importante après de fortes précipitations les eaux sont traitées. A Autrans et Méaudre, elles sont utilisées comme appoint aux périodes de pointe, vu le coût élevé de production.

L'anthropisation des massifs et la construction de routes, chemins... en avaient fait un lieu de choix pour des parcours et des compétitions destinées aux véhicules 4 x 4. Leur interdiction est une mesure de sauvegarde.

CONCLUSION

L'impact de l'homme est ancien. Cependant il a changé de forme et prend une intensité jamais connue. La création du Parc du Vercors avait pour but d'inventorier et de protéger cet espace naturel, ce qui est en cours.

Milieu anthropisé, ce karst de moyenne montagne reste vulnérable face aux entreprises touristiques. Celles-ci bouleversent paysages, équilibres du géosystemes, écoulements. Milieu plus sensible que d'autres aux pollutions hydriques, plus fragile du fait d'une reconstitution plus lente de certains écosystemes. Les aménagements futurs de ces communes devraient être pensés en tenant compte de ces données et de la limite d'utilisation des ressources en eau, dans la perspective d'un développement plus équilibré et à long terme.

BIBLIOGRAPHIE

Blache J., 1931: Les massifs de la Grande Chartreuse et du Vercors, Grenoble.Thèse d'Etat.- Impression Allier, 2 volumes.

Courrier du Parc Naturel du Vercors n°22: La préhistoire en Vercors, Lans-en-Vercors.- 1979 Ed P. N. R. V, 51 p.

Delannoy J. J., 1981: Le Vercors septentrionnal, le karst de surface et le karst souterrain.- Grenoble, Institut de Géographie Alpine, thèse de 3e cycle, 517 p.

Delannoy J.J., 1984: Le Vercors, un massif de moyenne montagne alpine.- Karstologia, n°3 p. 34-35.

Mourral D., 1927: La forêt du canton de Villard-de-Lans.- Revue de Géographie Alpine, T. XV, p. 133-143.

Muxart T., 1977: Note sur l'agressivité potentielle des eaux de percolation des différents sols dans le Vercors.- Revue de Géographie Alpine, t. 65, p. 177-183.

Rousset Ph., 1983: Carte hydrogéologique du massif du Vercors.- Grenoble, thèse Institut de Géologie Dolomieu, 72 p., 1 carte h. t.

Roy L, 1986: Etudes préalables au schéma directeur d'assainissement du Vercors.- Grenoble Institut de Géographie Alpine. Mémoire M. S. T., 72 p.

Sarrot Reynauld J., 1962: Hydrologie karstique du massif du Vercors.- Paris, Mémoires Association Internationale des Hydrogéologues. Réunion d'Athènes.

ČLOVEKOV VPLIV NA SEVERNEM VERCORSU (FRANCIJA)

Povzetek

Severni Vercors je kraško sredogorje v Zahodnih Alpah, med 800-2200 m n.m. Zanj so značilne kraške in kraško-ledeniške oblike ter predvsem podzemeljsko odtekanje voda.

Do 1930 je bila človekova dejavnost skladna s kmečko naselitvijo: gozdarstvo, poljedelstvo in pašništvo. Kljub poljem, pašnikom in alpskim travnikom, kraški geosistem ni bil moten. Od 1930, še posebej pa v zadnjih štiridesetih letih, sta se ob upadanju kmetijske dejavnosti močno povečala zimski in letni turizem. Po 1950 so bile zgrajene številne velike žičnice, smučišča so se raztegnila do vrhov in orografskih razvodnic, postavljenih je bilo mnogo novih zgradb. Med zimskimi počitnicami se število prebivalcev povzpne na 40 000, medtem ko je stalnih prebivalcev le 5 000. Da bi zadovoljili potrebe turistov po smučiščih, prebivališčih in predsem po vodi, prihaja do motenj v kraškem geosistemu zaradi:

- velikih posek na pobočjih za pripravo smučišč,
- uničevanja površinskih kraških oblik in spreminjanja kraške visokogorske pokrajine,
- vrtanja in črpanja vode iz globokega krasa in velikih izvirov v dolinah, da bi zadovoljili potrebe po vodi turističnih središč,
- onesnaževanja vode in umetnega odvajanja odpadnih voda, kar je privedlo do vzpostavitve novega, umetnega hidrološkega sistema.

Proti tem številnim spremembam v kraškem okolju se že 20 let borijo lokalne skupnosti in zveze: z ustanovitvijo "Regionalnega parka Vercors", z ustanavljanjem posebnih varovalnih območij, z omejevanjem nekaterih dejavnosti, kot so gradnje, lov, vožnje in tekmovanja s terenskimi vozili in kontrolo uporabe voda.

THE TIMAVO HYDROGEOLOGIC SYSTEM: AN IMPORTANT RESERVOIR OF SUPPLEMENTARY WATER RESOURCES TO BE RECLAIMED AND PROTECTED

HIDROGEOLOŠKI SISTEM TIMAVE: POMEMBEN DODATNI VODNI VIR, KI MORA BITI UPORABLJEN IN ZAŠČITEN

M. CIVITA & F. CUCCHI & A. EUSEBIO & S. GARAVOGLIA & F. MARANZANA & B. VIGNA

Izvleček UDK 556.38(450)
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M. Civita[1] & F. Cucchi[2] & A. Eusebio[3] & S. Garavoglia[4] & F. Maranzana[5] & B. Vigna[6]: Hidrogeološki sistem Timave: pomemben dodatni vodni vir, ki mora biti uporabljen in zaščiten

Hidrogeološki sistem Reka-Timava sestavljata površinski in podzemeljski del. Tako velik sistem je pomemben vodni vir. Zato je izredno pomembno vzpostaviti okoljevarstveni program za njegovo varovanje. Prispevek končuje z vrsto sklepov in napotkov za polno izkoriščanje znanih virov ter za njihovo varovanje pred onesnaževanjem.

Ključne besede: hidrogeologija krasa, vodni viri, varstvo voda, Italija, Slovenija, Kras, Reka - Timava.

Abstract UDC 556.38(450)
504.4(450)

M. Civita[1] & F. Cucchi[2] & A. Eusebio[3] & S. Garavoglia[4] & F. Maranzana[5] & B. Vigna[6]: The Timavo hydrogeologic system: an important reservoir of supplementary water resources to be reclaimed and protected

The Reka - Timavo hydrogeologic system consists of surface und subsurface parts. Such a system presents a noteworthy water supply source. It is therefore of paramount importance to establish a sound environmental programme for its protection. The paper ends with a serie of conclusions and suggestions for the full exploitation of identified resources and their protection from contamination.

Key words: karst hydrogeology, water resources, water protection, Italy, Slovenia, Carso, Reka - Timavo.

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INTRODUCTION

The Reka-Timavo hydrogeologic system, consists of two parts, the first one surficial and the second subsurficial (Fig. 1). The first corresponds to the drainage basin (407 km^2) of the Reka river (54 km) completely flowing toward WNW in Slovenian territory over flyschoid formations. Stream losses begin near Vreme, where the river flows well over highly karstified limestone and down to S. Canziano aven where losses are total. Starting from this point, the subsurficial part of the system, named Timavo river, begin to flow underground for 41 km till S. Giovanni di Duino where the watercourse re-appears at the ground surface discharging by a number of important springs. This is

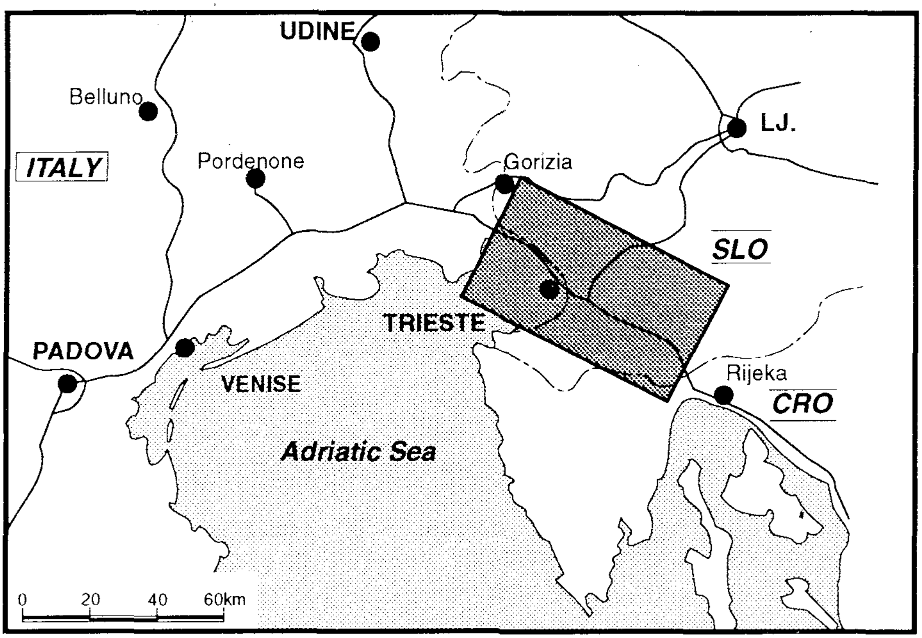


Fig. 1 Location of Reka-Timavo System

one of the main karstic phenomena of Mediterranean region which roused the interest of ancient and modern scientists (Pliny the Old, Strabo, T. Livius etc.), from the second century AD up the last century and the present.

In spite of this great interest, the phenomenon is, however, not well understood from both the scientific and the water resource planning point of view. On the other hand, it is clear that such a system represents a noteworthy water supply source, fed not only by the surficial stream going underground but also by an important diffuse (direct) recharge. It is also evident that the whole hydrogeologic system is vulnerable to contamination, quite ubiquitous in both courses.

It is therefore of paramount importance and of extreme urgency to carry out an in depth investigation aimed at establishing a sound environmental programme for the recovery and protection of such a valuable water resource.

This work represents a preliminary synthesis of known data with special reference to the geometry of the system, to its dynamic processes and qualitative charges which make nowadays the resource itself scarcely exploited.

OUTLINE OF HYDROGEOLOGIC BOUNDARIES

Various sources converge in feeding the ground water flow of the hydrogeologic system (Fig. 2). Among some subsystems called here *external tributaries* (Reka, Vipava, high Raša and others), the Reka basin is the major contributor. At the hydrometric station of Cerkvenikov mlin it shows an average yearly discharge of about 8 m^3/s, reaching a maximum at about 305 m^3/s.

According to IDROGEA (1993), the average value needs to be increased by 18% for a better estimate of the average discharge contributing to the subsurficial course. It must be stressed however that the global spring discharge, even in the case of extreme and prolonged hydrologic low, is of the order of 9 m^3/s (Gemiti, 1984) against the 4.2 m^3/s recorded under the same conditions at Cerkvenikov mlin (IDROGEA, 1993). The system must obviously add a considerable amount of recharge on top of the one supplied by the losses of Reka river.

In the north and south-east sectors, the boundary of the system corresponds to the stratigraphic contact between limestone of the "Comeno Platform" and Eocene flysch. From Kačiče (limit of outcropping flysch) the positioning of the boundary towards the east going to Trieste is not clear. It is however located within Palaeocene limestone, where a somehow mobile ground water divide exists between the Timavo's structure and that feeding the springs of Bagnoli, Pisano, etc., SE of Trieste. Towards SW, the hydrogeologic units boundary continue in a straight line from Trieste to Aurisina and corresponds to the front of the "Comeno Platform" limestone overthrusting the complex structure of the Ćićarija (Placer, 1981), which comprises the impermeable terrigenous horizons extensively outcropping along the coast of the Trieste Gulf. Such a schematic outline is based on a lot of survey, gauging and tracer tests confirming the connection between the main surficial streams and springs.

The identified system (Fig. 2) appears to possess an area of 736 km^2 and the hydrogeologic structure is defined by several interacting rock complexes. The *alluvial complex*, formed by recent and present alluvial terrains (north-west sector, including the middle Isonzo flats), does not influence the dynamics of ground water. The *terrigenous complex* comprises Eocene low permeable marls and sandstones. It behaves as a relative aquiclude in relation to the carbonate complex and gives a permeability sill (Civita, 1973), super-imposed northward and underlain in the SE and SW side of the structure.

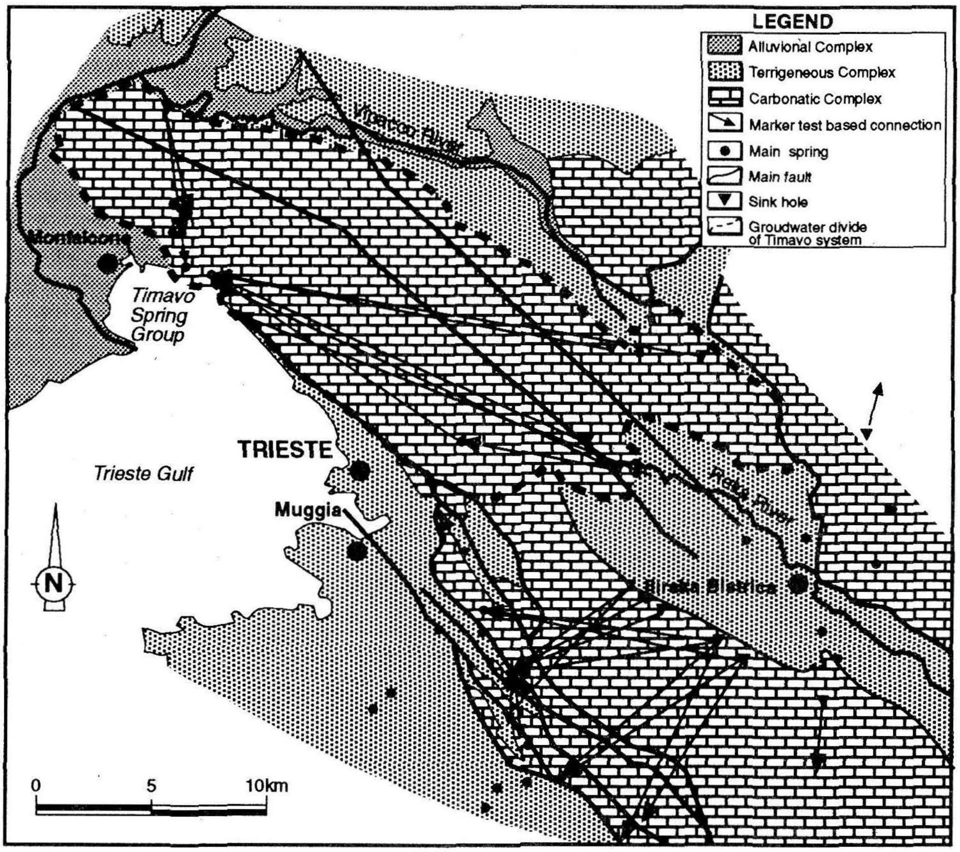


Fig. 2 Hydrogeological scheme of karst area

The *carbonate complex* is composed of several sub-complexes which exhibit a similar behaviour and a different degree but the same type of relative permeability. From the top, the sequence comprises stratified limestone (sometimes marly), thinly bedded limestones, fractured and partly karstified, of lower Palaeocene-Eocene age (40 to 450 m thickness). A thick sequence (300-1000 m) of Upper Cretaceous massively stratified limestone follows representing the most important sub complex of the hydrogeologic system. They are compact but fractured in great blocks and pervasively karstified both in depth and on the surface. They are underlain by a dolomite sub-complex of Middle Cretaceous age with a 300 to 600 m thickness.

The dolostone are poorly stratified, little karstified and have a relative permeability degree lower than that of the overlying limestones. They crop out in two main sub parallel bands along the Italo-Slovenian border, cut northward by the "Raša fault" (Cucchi & Forti, 1981). As the dolomite complex constitutes, particularly in the eastern section, an indefinite permeability limit for the overlying karstic limestone, where the saturated zones of the deepest active caves are located, it creates variable of conditions for the ground water flow. Furthermore, the dolomites, being wedged between the two main calcareous terms, behave as if they were the boundary between two semi-independent reservoirs, and influence flow directions and velocities in the highly permeable media.

The series, then, ends, with Middle-Lower Cretaceous limestone (about 300 m thickness) thinly bedded with a medium-high karstification level and high degree of permeability. Although differentiated, the entire carbonate complex contain an intense ground water circulation, which is based on a high ingestion index as well as on a high seepage index.

OUTPUT POINTS OF THE SYSTEM

The hydrogeologic system has a certain number of output points (Fig. 3), some quite evident other much less or even hidden or not directly observable. Among those are:

The Timavo spring group, at 2.40 m a.m.s.l., near S. Giovanni di Duino comprise several resurgences distributed in a wide area but interconnected underground, taking the period 1972-83, the overall average discharge 30.2 m^3/s (Q_{min} 9.1 m^3/s; Q_{max} 127 m^3/s).

Daily discharge variations can be very sudden (Fig. 4), with rapid growths reaching 60 m^3/s in two days or 15 m^3/s in less than five days. There are three main springs (Timavo I-II-III) closed by regulations bulkheads. Near springs (Randaccio and Moschenizze) as well as some further ones (Aurisina spring group) are affected by regulating the Timavo discharge.

At about 500 m northward from the Timavo resurgences is located the Sardos-Randaccio spring group, at 2.30 m a.m.s.l. with average discharge 1.9

m^3/s ($Q_{min.}$ 1.5m^3/s - Gemiti, 1984).

Further northward again are located the Moschenizze spring group, along the narrow valley of the same name, at 1.3 m a.m.s.l., with an average flow of 0.5 m^3/s. There is a cluster of 12 springs the main of which is the Molino spring (average discharge 0.23 m^3/s - Mosetti, 1966).

The Doberdò springs are NW of the same lake, at 6 to 12 m a.m.s.l. The average discharge of the main spring is 0.3 m^3/s, to which the value of the other numerous springs should be added, all having high variability index. Southward of the Daberdò lake a series of sinkholes drains the water toward Pietrarossa lake (about 1 km southward, 5 m a.m.s.l.). In case of exceptional flood, the level rises to 5.7 m a.m.s.l. not lining with the Sablici lake, located about 1 km to SE. Presently, a reclamation canal drains the waters of Pietrarossa lake and of Sablici springs, with a total discharge of 1.2 m^3/s. Along a front of 490 m, 8 springs constitute the Lisert spring group, located southward of the lake, at 0.4 m a.m.s.l. with an average yearly discharge 1.0 m^3/s (Gemiti, 1984). The dye tracing performed by Boegan in 1938 showed that the tracers, introduced at Sablici lake sinkholes took five hours to reach the Lisert springs still in high concentration.

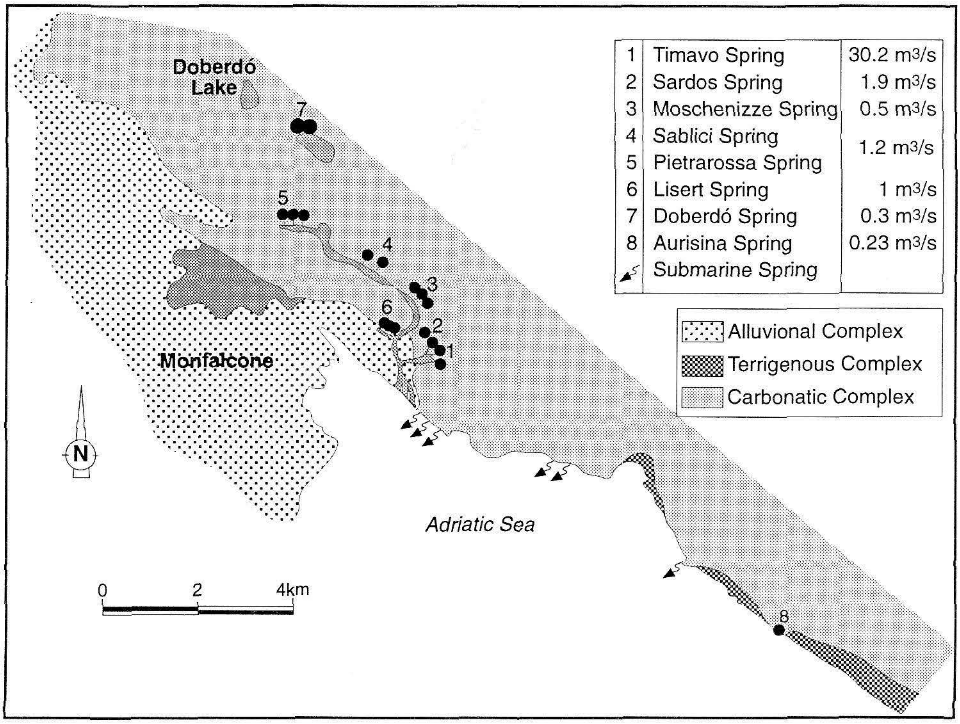


Fig. 3 Emergence zone of Timavo System

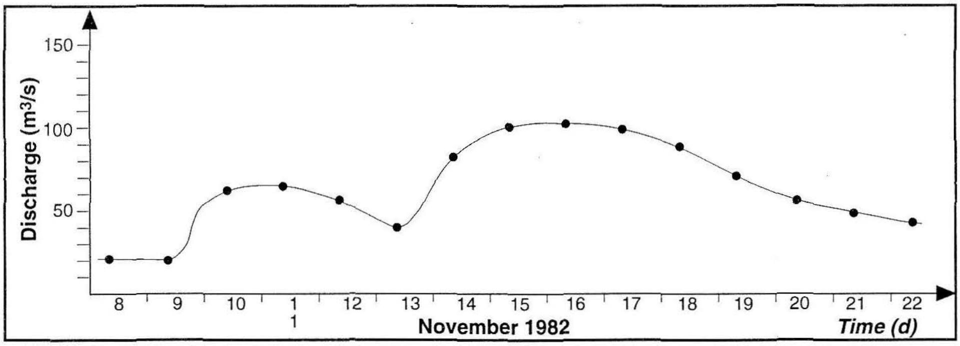


Fig. 4 Discharge of Timavo Springs in November 1982 (After: Gemiti, 1984, modif.)

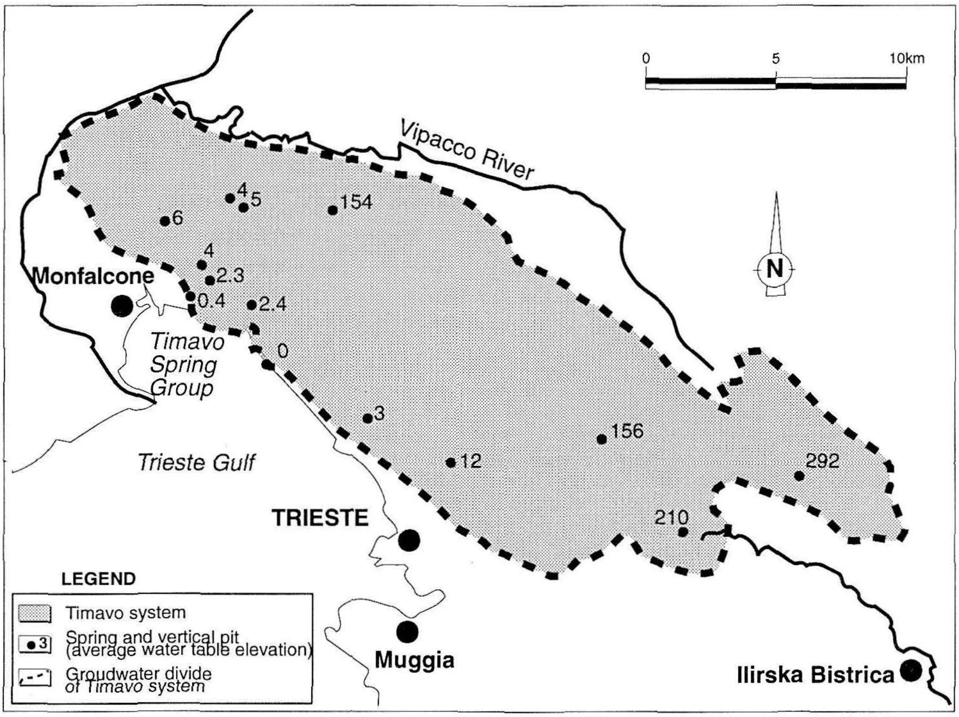


Fig. 5 Groundwater elevation of Timavo System

The Aurisina spring group is located at sea level, 13 km NW of Trieste, along a front of 350 m, where a cluster of 9 springs gives a discharge of 0.23 m^3/s. Impermeable flyschoid deposits at 3 m below sea level, constitute the underlying sill. In 1910, a tapping tunnel 263 m long was dug reaching a level of 0.61 m a.m.s.l. connecting only minor springs but not the main ones. Other submarine springs within the Gulf of Trieste (Villaggio dei Pescatori, Cerniza, Duino) were surveyed and LANDSAT thermographic imagery shown submarine discharges along the coast between Sistiana and Aurisina. Several authors have advanced the hypothesis of subsurficial linkages between the karstic structure and the Isonzo plain, taking into consideration both the piezometric level of the limestone and alluvial aquifers and the presence of *Proteus* in some wells located in the Isonzo flats (Mosetti, 1966).

PIEZOMETRIC DATA

Piezometric data of the karstic aquifer are scarce (Fig. 5). In the eastern part of the system an effective saturated zone seems to be lacking, while siphoning conduits are mainly present as submerged sectors of the draining network. In this sector the Gabranca cave behaves as inversac with low-water level at 292 m elevation.

Some km further west, low piezometric levels in the S. Canziano cave are at 210 m lifting at maximum flood level to 346 m a.m.s.l. (Boegan, 1938). Only 1500 m NW, in the Serpenti cave (Kačna jama), runoff water from the surficial Reka river flows along galleries fed by a siphon at 182 m and disappears again at 156 m elevation. During floods, the piezometric levels rise of about 90 m. In the Trebiciano cave, the ground water appears at 12 m reaching during floods the elevation of 115 m. Near Prosecco at the Massimo aven, the low-water level is 3 - 4 m a.m.s.l. Further downstream, at 12 and 7 km respectively from the resurgences, two caves (Cristalli cave and Lindner cave) which descend to 20 and 5 m elevation a.m.s.l. are generally dry,

Maker test	Year	Place		Velocity (m/h)	References
		Intput	Output		
Lithium chlorlde	1907	S. Canziano	Timavo springs	164	Timeus, 1928
Uranine	1908	Trebiciano	Timavo springs	102	Timeus, 1928
Pechblenda	1909	S. Canziano	Timavo springs	177	Timeus, 1928
Lithium chloride	1910	Vipacco River	Doberdò springs	104	Timeus 1928
Uranine	1911	Sablici lake	Lisert springs	108	Boegan, 1938
Tritium	1962	S. Canziano	Timavo springs	88	Mosetti, 1965
Tritium	1962	S. Canziano	Aurisina springs	52	Mosetti, 1965
Carbon tetrachlonde	1982	Trebiciano	Timavo springs	306	Gemiti, 1984
Carbon tetrachloride	1982	Trebiciano	Timavo springs	83	Gemiti, 1984
Carbon tetrachlonde	1982	Trebiciano	Sardos springs	306	Gemiti, 1984
Uranine	1987	Sajeviski potok	Sardos springs	83	Habic, 1989
Uranine	1987	Sajeviski potok	Timavo springs	25	Habic, 1989
Rodamine	1987	Rasa Lakovnik	Timavo springs	86	Habic, 1989
Rodamine	1987	Rasa Lakovnik	Sablici springs	64	Habic, 1989
Rodamine	1987	Rasa Lakovnik	Sardos springs	136	Habic, 1989

Table 1

whereas floods reach piezometric levels of 10 and 30 m a.m.s.l. respectively (Cucchi & Forti, 1981).

In the Slovenian karst, the Preserska cave, located 13 m from Timavo springs, present a siphoning zone at 154 m (low-water) reaching 210 m (high-water). Further west (5 km from the springs) the caves Dolenjca and Drča reach the piezometric level at 4 and 5 m elevation respectively. High level fluctuations are gauged in these caves due to consistent recharge rates. In the Timavo spring area, several caves reach the saturated zone at the same elevation of the springs, while in the Doberdò sector, the only reliable piezometric data are the same elevation as the springs (6 - 1.5 m a.m.s.l.).

GROUND WATER FLOW VELOCITY

The ground water apparent velocities, which are calculated by tracing techniques (Table 1), are generally high (over 100 m/h). Tracing tests from S. Canziano and Trebiciano have determined during floods flow velocity exceed-

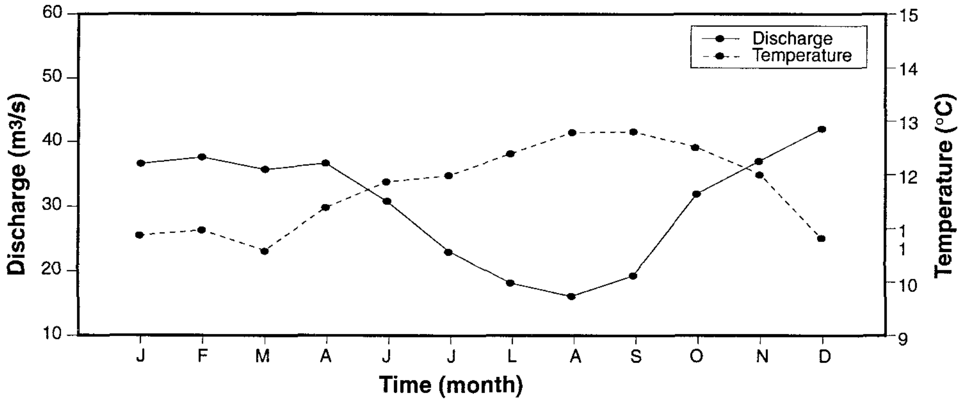


Fig. 6 Discharge-Temperature plotting of Timavo Springs

ing 300 m/h in relation to discharge rate about 90 m^3/s (Gemiti, 1984). At mean-water (32 - 37 m^3/s) the velocity is reduced to 109 m/h (Mosetti, 1965) and 164 m/h (Timeus, 1910). During low waters velocities about 90 m/h have been assessed, while tests performed by Habič (1989) from the north-eastern limit of the system gave about 80 m/h.

The velocities between the losses of Vipava at Vrtoče and the Doberdò, Pietrarossa and Sablici springs are, according to Timeus (1910), within 88 and 91 m/h. The few reliable tracer restitution curves (Gemiti, 1984) show a high peak over a short time with a single restitution pulse characteristic of a ground water flow mainly based on a main dominant conduit model (Civita et al. 1991).

CHEMICAL AND PHYSICAL CHARACTERISTICS OF GROUND WATER

Water temperatures of the Timavo springs (Fig. 6) show sharp variations (Tommasini, 1968; 1969; Flora et al., 1990) with cyclical fluctuation around 10°C in winter and a maximum of 13°C in summer. Lower values coincide with winter floods, while higher temperatures are related to secondary infiltration, when primary and secondary recharge are at their lowest.

The springs of north Moschenizze (11.8 - 13.8°C, Tommasini, 1969) and of

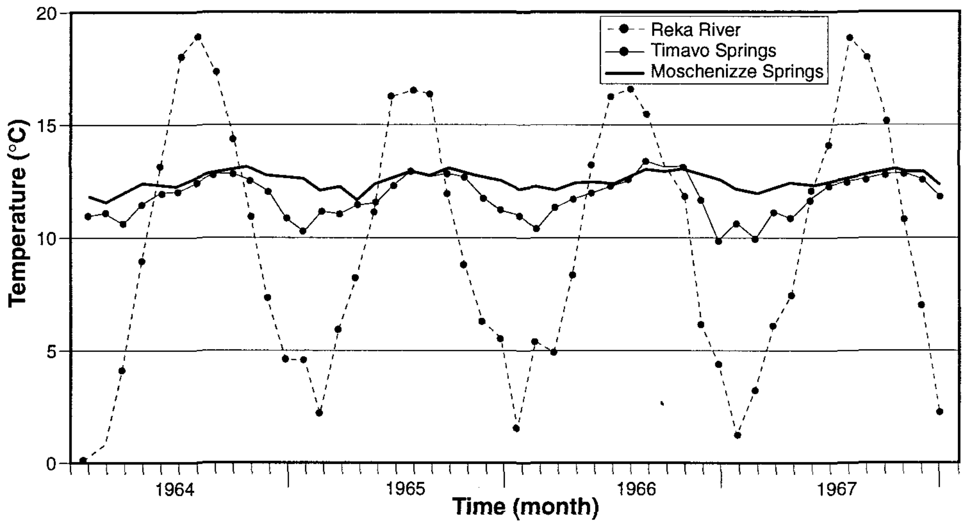


Fig. 7 Average monthly temperature (1964-1967)

Sardos (11.2 - 13.1°C, Gemiti & Licciardello, 1977), present a behaviour similar to the isochronous one of Timavo (Fig. 7). There are, however, no rapid variations thus confirming a fractures network flow type rather than a wide conduits flow. Similar data are shown in the Doberdò, Pietrarossa and Lisert (low of 9.5° in March and 15° in summertime) while for the Timavo springs the lowest temperature is recorded in February and a summer high of 13°.

The hydrochemical data so far available show marked differences in water composition at different springs. While the Timavo springs exhibit a rather particular chemical imprint, different from the others, the water of the Doberdò, Pietrarossa, Sablici and Lisert springs are similar to but at the same time different from those of Moschenizze, Sardos, Aurisina, where the chemistry indicate the presence of local circuits fed by a complex fracture and small conduits network, more or less independent from the main system.

It is impossible to verify and quantify the recharge from the Vipava and

Isonzo rivers to the subsystem of the Doberdò springs. This opinion is also shared by Flora et al. (1990) taking into consideration isotopic analyses (limited to the determination of 180 in period Nov. 84 - July 88), enhancing the importance of mixing of different waters.

GROUND WATER RECHARGE AND REGULATING RESERVES OF THE SYSTEM

The system's hydrodynamic is highly, but not widely, based on circulation through large conduits, while ground water reserves are being formed in various ways and not only by surficial watercourse losses. There exists in fact a strong *secondary infiltration*, which is well identified by waters of the Reka river, penetrating in the S. Canziano cave, as well as in other surficial points further up stream (assessed average discharge = 9.6 m^3/s), by losses from other rivers (Vipava being the most important with an estimated loss of 1 m^3/s) and from runoff inflow from no-karstic terrains outside the basin. A *primary infiltration* derives from rains (1633 mm/year) over a mature karstic morphology with a high index of surficial karstification.

The average recharge through primary infiltration was calculated through a numerical model HYDRAC (Civita et al., 1984) assembled in raster mode by a GIS.

Average rainfall were taken by historical records of 14 rain gauges well distributed in Italy and Slovenia, with elevation's corrections. The weight of the average yearly temperature to each cell of the model was also calculated on the base of two recording gauges, with corrections for elevation and average monthly rainfall.

The average hydrogeologic balance was competed (Table 2) knowing

INPUT			OUTPUT		
	m^3/s	Mm^3/y	Mm^3/y	m^3/s	
Surface contribution of Reka River	9.6	302.7	952.4	30.2	Timavo Springs
Surface contribution of Vipacco River	1.0?	31.5?	37.8	1.2	Sablici Springs
			31.5	1.0	Lisert Springs
Recharge of Karst Area (Infiltration)	20.7	652.2	15.8	0.5	Moschenizze S.
Surface contribution of Rasa River	?	?	60.0	1.9	Sardos Springs
			6.3	0.2	Aurisina Springs
			?	?	Submarine S.
INPUT	31.3	986.4	1103.8	35.8	OUTPUT

Table 2 Hydrogeologic Balance of Timavo System

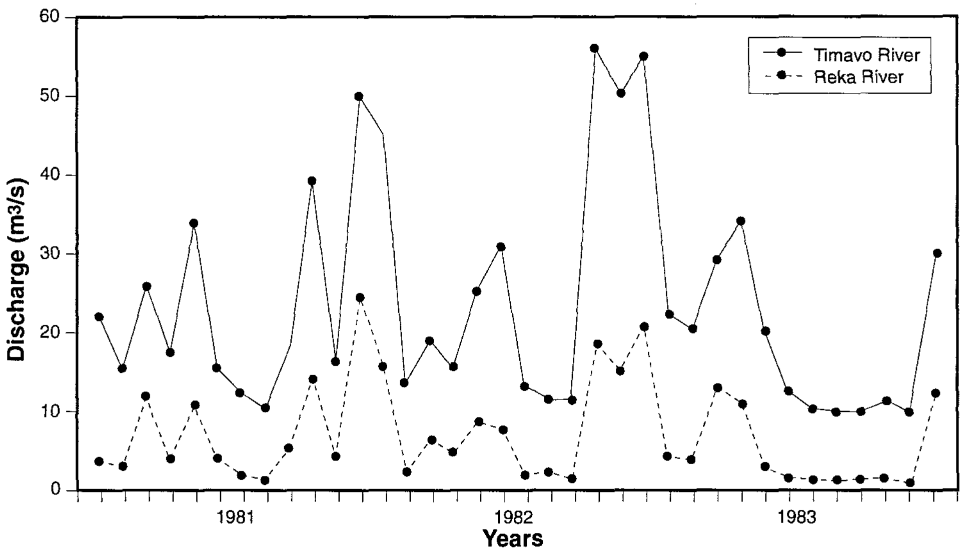
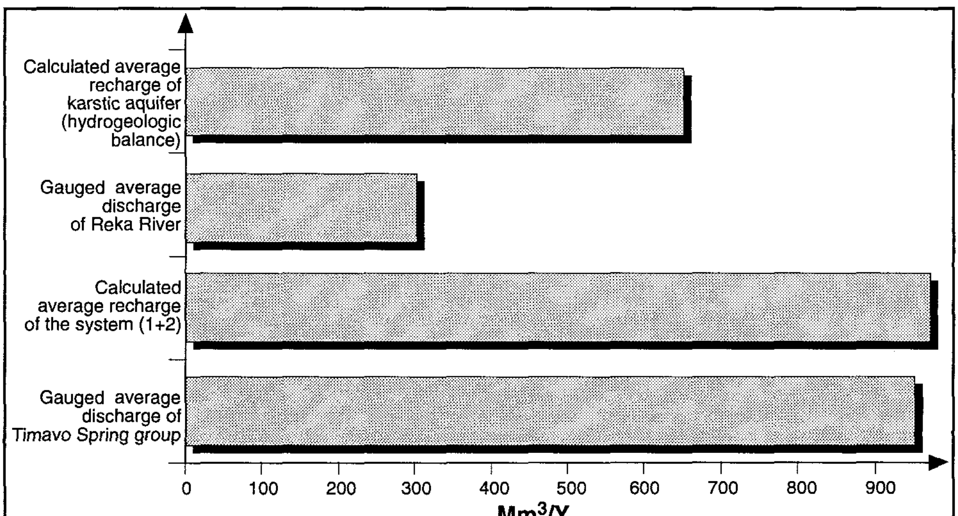


Fig. 8 Average monthly discharge (1981-1983)



Calculated average recharge of karstic aquifer (hydrog. balance)	652.2
Gauged average discharge of Reka River	302.7
Calculated average recharge of the system (1+2)	954.9
Gauged average discharge of Timavo Spring group	952.4

Fig. 9 Hydrogeological balance results comperend with average discharge gauged data.

however that such a balance represents more than anything a technical mean to evaluate the identification of boundaries and of the geometry of the system. In this case, the difference between recharge and discharge amount to 10%, a well acceptable value in view of the quality of data and of the often inconsistent historical records. Such differences in balance can also be explained by the underestimated losses from Vipava; by the interflow to the Goritian aquifer in the north-western sector of the structure; by the lack of gaugings of other losses from small impermeable basins, branching the structures; by and overestimation of the runoff probably all seeping into high karstified limestone. The dimensions and geometry of the hydrogeologic system so identified, can therefore be assured as sufficiently verified.

THE REKA - TIMAVO SYSTEM WORKING

As was said earlier, the Reka-Timavo hydrogeologic system l.s., which embraces a territory of over 1000 km^2 is made up of a surficial part corresponding to the Reka and minor drainage basins (Vipava basin p.p., Upper Raša basin p.p., minor drainage basins); and of an extensive hydrogeologic basin, covering 736 km^2, for the most part within Slovene territory (534 km^2), whereas the remaining 202 km^2 lie within the Italian karst.

By integrating the hydrodynamic data obtained from tracer tests with hydrochemical and thermal data, it is possible to hypothesise the presence of more or less interconnected subsystems within the general hydrogeologic system.

The main subsystem is the Reka - Timavo springs one. This is undoubtedly a complex system in which ground water flows along the main *dominant drain* (conduit) during floods and preferrentially along a number of *interdependent drains* (conduits) (Civita et al. 1991) during normal and low-water. The dominant drain is made up of a series of cavities and conduits which link the losses from the Reka to Timavo emergences. It runs predominantly through the undifferentiated carbonate complex and is probably conditioned by the presence, on the bed, in the eastern sectors, of the predominantly dolomite sub complex characterised by a lower relative permeability. The existence of a main dominant conduit is demonstrated by speleological explorations, flood velocity (over 300 m/h) and the tracer restitution curve type characterised by a single very sharp peak. A further control is provided by the abrupt variations in the physical and chemical parameters of waters and the striking changes of flow well correlated to the condition of the Reka and the propagation times of its flood waves. By subtracting the average isochronous monthly discharge rates of the Reka from the perfectly correlated rates of the Timavo springs (Fig. 8), it can also be seen that there is a massive component of ground water flow which cannot be provided by anything other than the massive and virtually immediate primary infiltration of congruent rainfall in the highly permeable rocks of the karst (Fig. 9). A second dominant drain, of lesser importance, could be located in correspondence with the Vallone di Doberdò. It may link the losses from the Vipava with the spring groups of the Doberdò, Pietrarossa and Sablici lakes, as well as with the Lisert springs themselves. This hypòthesis is confirmed by tracer tests which have provided relatively high flow velocity, and by chemical and thermal changes in the waters. Even the limited piezometric measurements confirm the existence of a gradient (1.3 %) from NNW, with a flow whose direction and velocity are completely different from that of Timavo, but with distinctly lower discharge.

Within the system, therefore, part of the deep circulation runs through the dominant drains, in particular at times of high recharge rates, whereas at low water an incomparably slower circulation becomes preponderant running through the complex network of interdependent drains. The former interfere in the said circulation both by powerfully draining the network during periods of medium water, and by inducing, during flooding, piston-like and retroflexion actions of the ground water flow which are restricted in time but are important in quantitative terms when levels within the dominant drains increase by as much as several dozen metres. It is worth underlining that, at times of heavy rainfall, the subterranean system becomes enormously overloaded, raising the piezometric level from approximately 30 m in western sectors (Cristalli cave, Lindner cave) to over 100 m in the Trebiciano cave and in cavities near the sinks of the Reka river. A similar phenomenon exerts a powerful effect on the overall hydrodynamics of the system, since it slows down the ordinary flow in the fracture and small-sized conduit network when it does not even succeed in annulling the ground water velocity and inverting, even if partially and briefly, the flow directions.

Even if apparently discontinuous, the dolomite sub complex seems to represent an important element of hydrogeologic separation between the southern (site of the Timavo subterranean river) and northern zone of the karst system. This sector should contain better quality ground water originating from the substantial contributions of primary infiltration, which are well distributed across the wide karst area. Before reaching the risings, these were mixed with the poorer quality waters circulating in the dominant drain, thus improving the characteristics above all during low-water periods.

The south Moschenizze and Sardos springs are fed by the slower circulation originating from the body of the main aquifer itself (interdependent drains circulation) as is shown by the relative constancy of chemical and thermal parameters which are distinctly higher than those of nearby springs. They are only very marginally influenced by the contribution of main drains, generally only during periods of considerable discharge when partial mixing between the various waters take place.

The Aurisina springs, partially linked to the main system as is shown by numerous tracer tests, are strongly fed by the local flow in fractures and small conduits, as shown by the chemical and thermal load which is the highest of all the system's outputs (Gemiti & Licciardello, 1977).

The proposed model justifies the existence of mixed conditions, with the main springs being characterised by accentuated flood peaks (main drains contribution) but with a high and relatively constant basal flow in the absence of direct recharge. It also justifies the many reports regarding periodical turbidity and the hydrochemical differences between the various spring waters. These differences are small but important to attain an adequate understanding of the numerous processes that take place in the system.

CONCLUSIONS

To summarise, it is possible to draw a series of conclusions and make a series of useful suggestions for the full exploitation of the identified resources and their protection from contamination. For this purpose, it therefore appears vital:

- to ascertain the existence of good quality ground water resources which differ from those flowing in the main dominant drain;
- to quantify the contamination induced in the system and identify its type and origin;
- to locate the precise and widespread sources of direct and indirect contamination (brought by surficial contributors);
- to make an analytical assessment and zoning of the vulnerability of the aquifer system.

On the basis of these necessary studies, it will be possible:

- to plan the adequate actions to restore and reclaim the water bodies;
- to plan the rational fractionated exploitation of the resource in relation to its varying levels of quality;
- to design the contamination elimination systems and ways to protect the different parts of the aquifer;
- to study the necessary limitation severity to be set on the dominant territorial system and their graduation over space and time.

In this way it will be possible to achieve the complete recovery of a major water resource which, if well tapped, exploited and protected, may represent an outstanding strategic reserve in the immediate future for replacing or integrating traditional resources in all adjacent areas, in particular those exposed to a strong depletion or contamination hazard and making possible to develop new socio-economic opportunity in the border areas.

REFERENCES

Boegan E. (1938) - *Il Timavo - Studio sull'idrografia carsica subaerea e sotterranea.* Mem. Ist. It. Spel., s. geol. e geof., Mem II.

Civita M. (1973) - *Schematizzazione delle sorgenti normali e delle relative opere di captazione.* Mem. e Note Ist. Geol Appl., Napoli, 12.

Civita M., Vigna B., Peano G. (1984) - *La stazione sperimentale della Grotta di Bossea nel quadro delle ricerche idrogeologiche sui sistemi carsici del Monregalese, Alpi Marittime.* Mem. Soc. Geol. It., 29.

Civita M., Manzone L., Olivero G., Vigna B. (1991) - *Approcci sinergici nelle ricerche sui sitemi idrogeologici carbonatici del Piemonte meridionale.* Atti Conv. Naz. "Ricerca e protezione delle risorse idriche sotterranee delle aree montuose", Brescia.

Cucchi F., Forti F. (1981) - *La "cattura" del Timavo superiore a Vreme.* Atti e Mem. Comm. Grotte E. Boegan, 21.

Flora O., Galli G., Negrini L., Longinelli A. (1990) - *Studio geochimico-isotopico di alcune sorgenti carsiche: un nuovo modello idrogeologico.* Atti Mem. Comm. Grotte E. Boegan, 29.

Gemiti F. (1984) - *La portata del Timavo alle risorgive di S. Giovanni di Duino.* Annali Gruppo Grotte Ass. XXX Ottobre, Trieste, 11.

Gemiti F., Licciardello M. (1977) - *Indagine sui rapporti di alimentazione delle acque del Carso Triestino e goriziano mediante l'utilizzo di alcuni traccianti naturali.* Annali Gruppo Grotte Ass., XXX Ottobre, Trieste, 6.

Habič P. (1989) - *Kraška bifurkacija Pivke na jadransko-črnomorskem razvodju.* Acta carsologica, 18, Ljubljana.

IDROGEA, (1993) - Azioni preliminari di studio del piano di risanamento delle acque superficiali e sotterranee del bacino idrografico del Fiume Timavo (Rapporto preliminare). Ljubljana, 1993 (unedited).

Mosetti F. (1965) - *Nuova interpretazione di un esperimento di marcatura radioattiva del Timavo.* Boll. Geol. e Geof., Mem. II, Trieste.

Mosetti F. (1966) - *L'idrogeologia della Carsia Giulia e dei territori limitrofi.* Adriatico, XII, n. 5-6.

Placer L. (1981) - *Geološka zgradba jugozahodne Slovenije.* Geologija, 24, Ljubljana.

Timeus G. (1910) - *Studi in relazione al provvedimento d'acqua per la città di Trieste.* Trieste.

Tommasini T. (1968) - *Indagine termometrica alle risorgive del Timavo a S. Giovanni di Duino ed alle sorgenti del vallone di Moschenizze (Carso triestino).* Atti e Mem. Comm. Grotte E. Boegan, 7.

Tommasini T. (1969) - *Indagine termometrica alle risorgive del Timavo a S. Giovanni di Duino ed alle sorgenti del vallone di Moschenizze (Carso triestino).* Atti e Mem. Comm. Grotte E. Boegan, 8.

HIDROGEOLOŠKI SISTEM TIMAVE: POMEMBEN DODATNI VODNI VIR, KI MORA BITI UPORABLJEN IN ZAŠČITEN

Povzetek

Hidrogeološki sistem Reka-Timava sestavljata površinski (porečje Reke - 407 km^2) in podzemeljski del (Timava, 41 km razdalje med ponorom v Škocjanske jame in izviri pri Devinu). Tako velik sistem je pomemben vodni vir, ki ga ne predstavljajo le vode ponikalnic ampak tudi padavine, ki padajo na Kras. Zato so izredno pomembne poglobljene raziskave, ki bodo omogočile vzpostaviti okoljevarstveni program za varovanje teh vodnih virov. Prispevek končuje z vrsto sklepov in napotkov za polno izkoriščanje znanih virov ter za njihovo varovanje pred onesnaževanjem. Prispevek je predhodna sinteza znanih podatkov s posebnim poudarkom na geometriji sistema, dinamiki procesov in kvalitativni obremenitvi, zaradi katerih je danes sistem tako malo izkoriščan.

APPLICATION OF THE DIRECTIONAL PREDICTION METHOD TO THE DRAINAGE OF THE REKA - TIMAVO UNDERGROUND RIVER

UPORABA METODE PREDVIDEVANJA NAJPOGOSTEJŠIH SMERI ODTOKA V KAMNINI NA PRIMERU PODZEMELJSKE REKE REKE - TIMAVA

ADOLFO ERASO & FRANCO CUCCHI & JOAQUIN FERNANDEZ & JOSE ANTONIO DE LA ORDEN & LOUIS TORELLI

Izvleček UDK 556.38(450)

Adolfo Eraso & Franco Cucchi & Joaquin Fernandez & Jose Antonio de la Orden & Louis Torelli: Uporaba metode predvidevanja najpogostejših smeri odtoka v kamnini na primeru podzemeljske reke Reke - Timava

Metoda predvidevanja najpogostejših smeri odtoka v kamnini se je izkazala kot pravo orodje za *študij karbonatnih ali drugih anizotropnih kamnin*. Metodo, podprto z računalniškim programom, so uporabili na več kot 50 različnih primerih, od Arktike do Antarktike. Tudi rezultati 265 terenskih meritev tektoglifov na področju podzemeljskega toka Reke, so se izkazali kot zelo dobri. Raziskovalne metode, prikazane v tem prispevku, so prvi koraki k uporabi omenjene metode na Krasu.

Ključne besede: strukturna geologija, tektonika, metoda predvidevanja, podzemeljski pretok, Italija, Slovenija, Kras, sistem Reka-Timavo

Abstract UDC 556.38(450)

Adolfo Eraso & Franco Cucchi & Joaquin Fernandez & Jose Antonio de la Orden & Louis Torelli: Application of the Directional Prediction Method to the drainage of the Reka - Timavo underground river

The Prediction Method of the water drainage in karst regions has proved to be a genuine tool for study of karst massif anisotropy. The Method, supported by three computing programmes, has been applied in more than 50 examples all over the world from Artic to Antartic. The results of realized 265 field work measurements of tectoglyphs or tectoglyphs conjunctions in the Reka-Timavo Region were again very successful. Investigations mentioned in this text are the first steps for the application of the "Prediction Method of the underground drainage main directions" to the Reka -Timavo Karst Region.

Key words: structural geology, tectonics, prediction method, underground drainage, Italia, Slovenia, Kras, Reka-Timavo system

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INTRODUCTION

During the last decade, the Prediction Method of the drainage main directions in karst has proved to be a genuine tool for the study of karst and/ or the quantification of a rocky massif anisotropy.

Applied yet in more than 50 different examples all over Europe, Asia, America, Oceania, the Arctic and Antarctica, from which the balance has been made in 1990 of the 33 first cases with excellent results, we think it is time now to apply it in the Kras-Carso-Karst region, where the history of this part of science started last century.

The Reka-Timavo underground river traject seemed to be, for us, the appropriate place to initiate the application of the Prediction Method in this interesting region, due to its historical importance.

GEOLOGICAL AND STRUCTURAL CHARACTERISTICS

The underground karst system of the REKA-TIMAVO river develops in a 50 km long, 12 km wide and several thousands meters thick carbonatic massif, with a SE-NW direction.

The massif consists, from a morphological point of view, in a rather ondulated platform extending in a NW direction, with levels going from 450 m (in Škocjan) to 100 m (in Isonzo), (Habič, 1984).

From a geological point of view, the massif belongs to the denominated Komen platform (Comeno), strong Cretacious-Tertiary series, mainly of limestone, on which overthrusts the Trnovo, Hrušica and Snežnik tectonic shield in its NE part. In the SW part, the referred platform also overfolds through the Ćićerija overlapped structure, over the Capodistria area, one of the southern Dinaric linements which features the south-west Slovenia and the north-east Adriatic area (Placer, 1981).

During the alpine orogenesis, this structure was dislocated as a consequence of the N-S oriented stresses (Alpine thrusts) and NE-SE ones (Dinaric thrusts).

The mentioned Komen platform is characterized, from a structural point of view, by a wide anticlinal with a NW-SE axis, complicated by a series of subparallel folds and some faults. The main ones of them are parallel to the main structure, dislocating it partially into small subparallel graben and horst. Other minor faults perpendicularly intersect the structure generating movements with strike slip components within parts of the anticlinal flank (Fig. 2.-1).

The anticlinal axis is ondulated and imerses both at the SW (under the Friulian plain) and at the SE (within the Illirska Bistrica underground).

The lithotypes which form the Komen platform are from the Lower Cretaceous to the Eocene ages, with a global thickness of almost 4000 m of carbonatic sequences and nearly 2000 m of **flysch** sandy-marly levels (Pleničar, 1960).

The Reka-Timavo karstical system develops within limestones, dolomitical limestones and Cretaceous-Tertiary dolomites which are very pure, intensively karstified (probably during the Pliocene age), limited on the sides by the non-karstified lithotypes of the flysch formation.

More in detail, we would say that the karst of the region is characterized by a monoclinal vergence - with a NW-SE direction and a 5° to 50° imersion southwards - complicated on the SE by a series of inverted ondulations and faults which are subparallel to the main structure axis and on the NW by a series of differently oriented faults which give origin to some small graben (Cucchi et al. 1987).

Only a few parts of the Reka-Timavo underground course are known: the Škocjan ponor, the spring near San Giovanni al Timavo, with medium range flows of 30 m^3/s, which comes from the three existing gaps and the shorts parts of the course which can be reached both at the Abisso serpenti (Kačna jama) and the Abisso di Trebiciano, the last one has been the world record of deepness, with 327 m, from its exploration in the XIX century until fairly late in the XX century.

The Reka-Timavo underground course develops in a NE direction during at least 40 km according to a hipsographic curve which has a more than 50‰ slope during the first 4 km (from the 323 m a.s.l. in Škocjanska jama-caverna Michelangelo, to the 88 m a.s.l. in Abisso dei serpenti - Kačna jama). The following 11 km part of the course has a 7‰ slope (from Kačna jama to Trebiciano) and the rest of the course, until the San Giovanni al Timavo spring, only has a 0,5 ‰ slope (Cucchi, Forti, 1981).

THE PREDICTION METHOD OF THE MAIN UNDERGROUND DRAINAGE DIRECTIONS IN KARST (ERASO, A., 1985/86)

The underground aquifer circulation within rock massif is established due to the interconnection of weakness plans systems or privileged fissures, within a discrete tridimensional net of conducts.

We have got to take into account that in these preferential channels genesis, stresses operate on the lithologic material, as a consequence of the

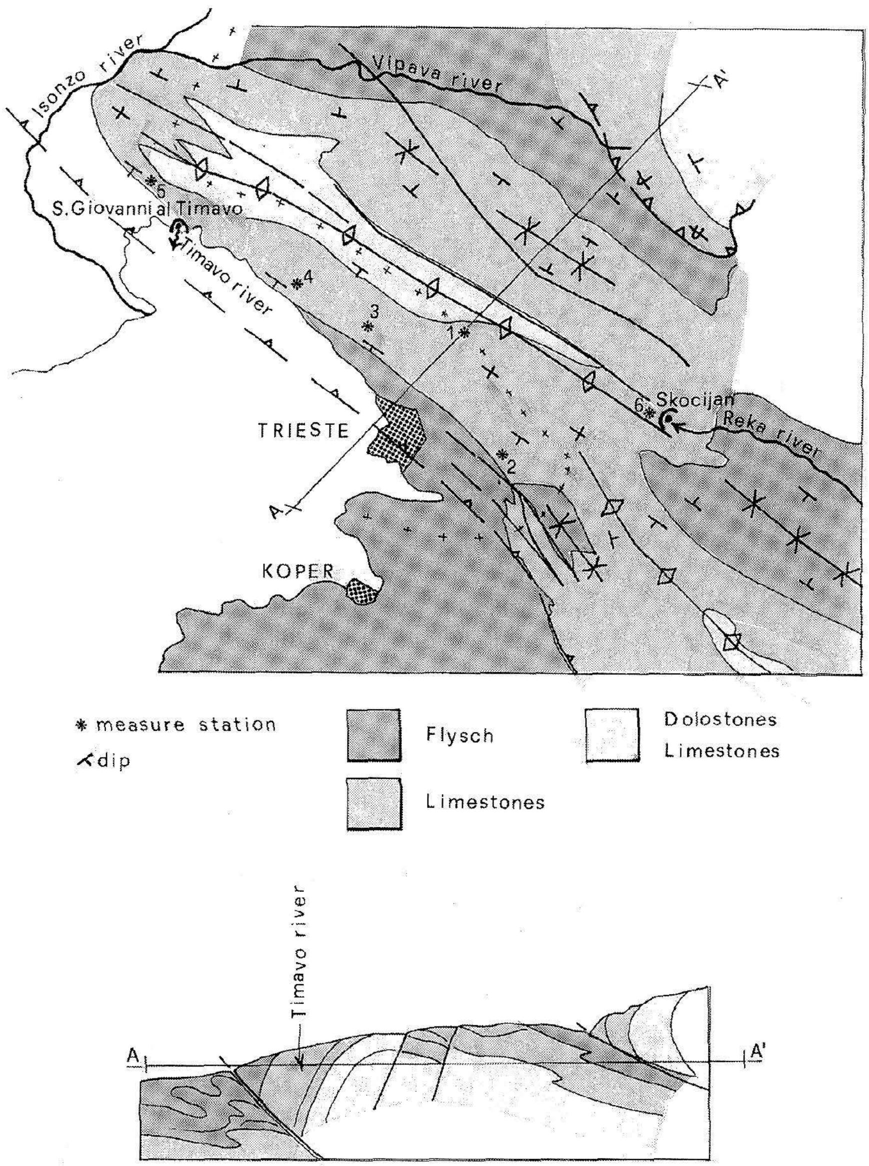

Isonzo river
Vipava river
A'
S.Giovanni al Timavo
Timavo river
5
4
3
1
2
6
Skocijan
Reka river
TRIESTE
A
KOPER
measure station
dip
Flysch
Limestones
Dolostones
Limestones
Timavo river
A
A'

Fig 2.1

orogenic processes, responsible of the variation of the tensional state.

The stresses are of two types:

- normal or direct (σ), which, in its turn, can be a textensional or a compressive one, and
- scissors type (τ), which, in its turn, can be a dextral or a senistral one.

If we consider the efforts which act on the unitary cubic element, orientated according to the three cartesian axis, we can distinguish nine components. Three of them constitute the normal stress and are respectively parallel to the cartesian axis; the other six correspond to the scissors stress and each two of them are orthogonal to a main stress.

The action of these stresses permits different reactions which produce elastic, plastic or fragile deformations of the rock.

Anyway, an efforts tensor can be established, as a result of the joint three components: hydrostatic effort, deflecting effort and unbalance component, as well as a deformation tensor, composed by three diferent effects: dilatation, distorsion and rigid rotation.

Through the study of folds and faults, structural geology permits to establish the orientation and disposition, in the space, of the three principal components of the deformation ellipsoid: $\sigma 1$ (major), $\sigma 2$ (medium) and $\sigma 3$ (minor).

Now, on a detailed scale, the possibilities of these components definition increase in a significant way, analysing the micro-structures and specially the tectoglyphs which are some traces of the permanent deformation, printed in the rock, as a consequence of the tectonic efforts.

Among these tectoglyphs point up, due to its interest, the following types:

- stylolites joints,
- veins or mineral dykes, and
- frictional striation in the fault planes.

Each of them has got a genetic significance which makes it usefull to define the ellipsoid.

The stylolites constitute junctions of the rock discontinuity, where the material situated on both sides has come closer and has got interpenetrated, part of it disappearing due to the under pression dissolution mechanism.

Its form, in peaks of parallel orientation, which can be seen when the junction is open, indicates the direction of shortening. This direction is statistically orientated, in a coincident way, with the component of the major axis of the deformation ellipsoid (σ_1) or, what is the same, the stylolitic junction is statistically orientated in an orthogonal way to this component.

The limestone veins, quartz dykes or other mineral, constitute discontinuity junctions/unions in the rock, in which the material situated on both sides got separated at the same time that the gap got filled, generally, with the predominant recrystallized material of the rock.

The veins have got a planar morphology, resulting of a traction effort, and are statistically orientated, in a coincident way, with the minor component of the deformation ellipsoid (σ_3) or, what is the same, the plan of the vein is statistically ortogonal to the mentioned component.

So we can say that the mineral gets dissolved on the sides when the main compression effort takes place, and is depositated again in the sides where the main traction effort takes place. Thus, stylolitic plans and recrystallization veins are perceptibly orthogonal (when they correspond to the same tectonic phase).

The friction striations, in the plans of fault, indicate the displacement suffered by both sides of the referred plan, as a consequence of some particular scissors type components.

The plan of the fault forms a certain θ angle with the major component of the deformation elipsoid (σ_1). The value of θ, which is generally 30°, really depends on the angle of the rock internal friction, on the massif scale, according to the relation:

$$\varphi = 90^{\circ} \equiv - 2.\theta$$

Practically, although the plans of the fault present a major continuity in the space than the stylolites and veins, they don't constitute true geometric plans, due to the rock anisotropy and heterogeneity, what produces fluctuations in the average orientation of the referred fault. This is why we need a major number of observations in order to get reliable statistical values.

Fig. 3.-1, by Arthaud & Mattauer (1969), represents the mentioned tectoglyphs and their meaning.

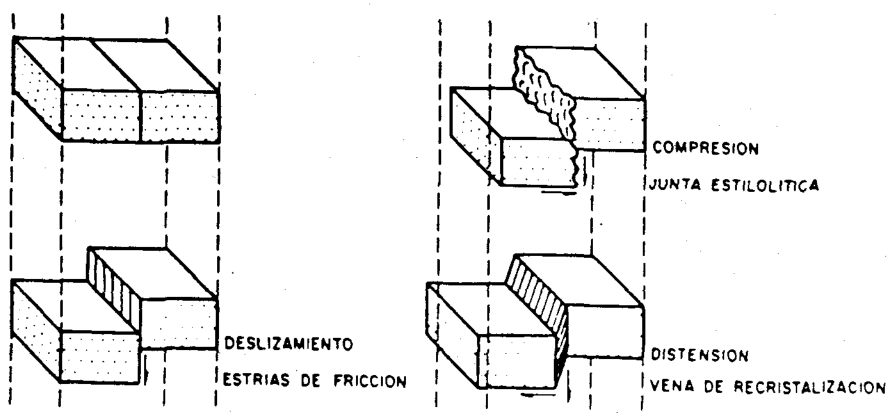


Figure 3.-1 Tectoglyphs genesis.

These tectoglyphs appear interconnected in the nature, and each of them can follow any direction with regard to the stratification plan.

We'll have the more favourable situation to define the deformation ellipsoid when two or more different tectoglyphs are combined, as we define with them the main efforts components. The more suitable combinations (Fig. 3.-2) are the following ones:

a) combined faults,
b) fault- vein,
c) stylolite - vein, and
d) fault - stylolite.

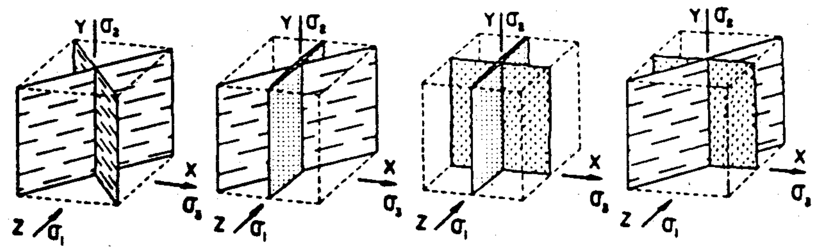


Figure 3.-2 Main tensions in combined tectoglyphs.

Thus, since as a massif gets older, the possibility of its having undergone a large number and variety of stresses increases, the probability to find different families of tectoglyphs, which present different orientations and makes it possible to identify their corresponding stresses ellipsoids.

The method needs to know the succession of the tectonic phases and assign them to different tectoglyphs families which will be used to identify each and every ellipsoid.

This way, in order to know the relative ages of the tectonic phases, we havet to find pairs of homogeneous conjunctions, preferably of vein-vein or stylolite-stylolite types, with the criteria that, in them, the displaced plans are older than the displacing ones.

As, in a tectoglyphs singenetic family, the ellipsoid components are orthogonal ones, we'll be able to identify each tectonic phase, if we've got the sufficient number of conjunctions.

As for the distensive, elapsing or compressing characteristic of the referred tectonic phase, we can determine it according to which is the main ellipsoid component, with the more vertical orientation.

The field work consists in locating the major number of the formerly mentioned tectoglyphs conjunctions and to measure in them the plan orientation and the dip with its vergence.

Thus, as there is a fifth possibility to define the ellipsoid, the localization of a fault where we can determine the "pitch" and the displacement orientation, in this case the following parameters have to be registered:

- orientation of the fault plan,
- dip with vergence sense,
- pitch with vergence orientation, and
- displacement orientation of the fault.

In order to identify the tectonic phases, through the normal efforts directions in the ellipsoids, we will have to make also an inventory of the homogeneous conjunctions connecting:

- its type (preferably the vein-vein and stylolite-stylolite conjunctions),
- the discontinuity orientation,
- the dip with vergence sense, and
- its relative age (the more modern one is the displacing one).

The more appropriate sites to locate tectoglyphs are the recent anthropic excavations and, of course, the natural cavities.

The data obtained in the field are computed, in the laboratory, with the tool which gives the stereographic projections, taking into account that, for each conjunction, the normal efforts are oriented in a different way.

The stereographic projection is used, for this analysis, using the representation in the Wulff's equiangular net and the Schmidt's equiareal net.

The measured plans are reflected in these nets by a maximum circle or by a pole. When we operate with statistically representative data, we can define, in the space, the existing modes, according to the poles density, quantified through the Kalsbeek's net.

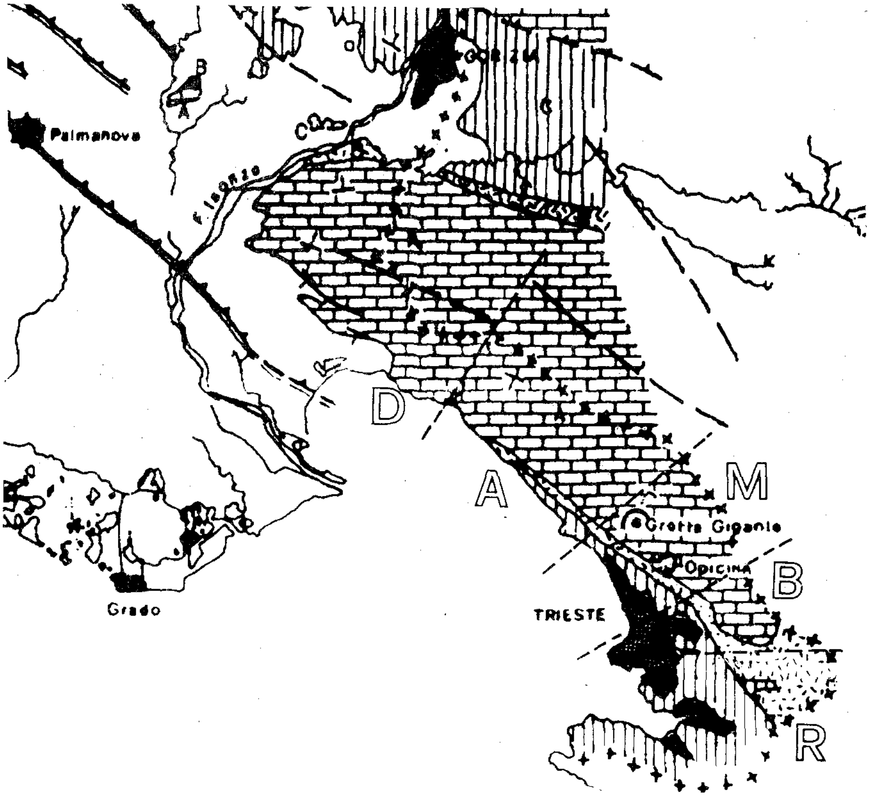
To make easier the work, the method has got three computing programmes (Eraso A., Fernandez Rubio, R., 1990):

- **GEORED**, which draws the equiareal (Schmidt) and equiangular (Wulff) stereographic nets, for any inclination angle of the reference sphere axis, between 0° and 90°.
- **GEODRE**, which computes and draws the position of the elipsoid components (σ_1, σ_2 and σ_3), for the tectoglyphs conjunctions and for the unique fault. This programme gives us the drainage plans, and
- **GEOPOL**, which calculates and draws, for a determined population of plans and/or the areas with the same poles concentration, according to the established percentage chart.

From all the gathered and computed information, the Method (we expose) determines the threedimensional components of the net of underground aquifer three circulation channels, applying two hypothesis:

The first, qualitative one:

- the tectonic efforts have shaped both the net of drainage preferential channels, and the anisotropy of the drainage directions, and



TOTAL CAVES LENGTH			21.689	KM
D	AREA	DUINO	2.8	»
A	»	AURISINA	7.4	»
M	»	MONRUPINO	1.6	»
B	»	BASOVIZZA	6.5	»
R	»	VAL ROSANDRA	3.2	»

Fig 5.-2

The second, quantitative one:

- the more probable directions of this drainage are located within the defined plans, by the
directions of the normal efforts σ_1 and σ_2 of each ellipsoid.

With regard to them, the drainage preferential directions are statistically defined.

APPLICATION OF THE METHOD TO THE REKA-TIMAVO REGION

The result of the realized field works was 265 measurements of tectoglyphs or tectoglyphs conjunctions made in 6 different stations:

- Station n° 1: Monrupino with 41 measurements,
- Station n° 2: Basovizza with 48 measurements,
- Station n° 3: Aurisina with 28 measurements,
- Station n° 4: S. Pelagio with 55 measurements,
- Station n° 5: Sorgenti di Duino with 41 measurements,
- Station n° 6: Škocjan with 42 measurements,

The results obtained as a consequence of the application of the programmes of the method has got are expressed in the following steps:

1. the prediction given by the method, in three dimensions (6 spheric gaussians) for each of the 6 stations.
2. the prediction given by the method, in three dimensions, (spheric gaussian) for the measurements global, with specification of the poles of drainage plans in each station.
3. 6 histogrammes of the prediction given by the method (in two dimensions) for each station.
4. Global histogramme (in two dimensions) of the prediction.
5. 3 spheric gaussians (in three dimensions) with indication of the poles density modes of each principal components (σ_1, σ_2, σ_3) of the ellipsoids.

The analysis of the whole results leads us to do the following interpretation:

1. The existence of four directional modes of the drainage plans with the following characteristics:

- a main mode according to N135° to N150° with a 15,5 % associated probability;
- two secondary modes: one according to N60° to N75° with a 12,8 % probability, another one according to N0° to N15° with a 11,3 % probability;
- a (minor) mode according to N90° to N105° with a 5,3 % probability.

2. The existence of thrusts according to:

- NE-SW, fluctuating from both sides with a 45° inclination, generating overthrusts,
- N150° (of minor importance) with low angle,

- vertical one, (vertical σ_1) gravitational, generating normal faults,
- vertical σ_2 generating strike slip faults.

DIRECTIONS OF THE CAVES ACCORDING TO TOPOGRAPHIES

The results of the conducts and caves directions, topographied in the Carso Triestino, and kept in the archives of "Commissione Grotte E. BOEGAN" were realized in two dimensions, in 15° to 15° statistical classes. They were represented in 360° radial histogrammes, having computed a total of 21.689 km underground course, with the following distribution of stations:

- Station R: Valrosandra area with 3.2 km,
- Station B: Basovizza area with 6.5 km,
- Station M: Monrupino area with 1.6 km,
- Station A: Aurisina area with 7.4 km,
- Station D: Duino area with 2.8 km,
- Global station : with the before mentioned total: 21.689 km,

whose localization appears in Fig.- 5.-2.

COMPARISON OF THE RESULTS

The objective consists, due to the whole available data and results, in comparing, in a quantified way, the prediction given by the applied method and the known reality of the topographied karst conducts.

As the correspondence between the tectoglyphs measurement stations (from 1 to 6) and the topographies ones (from A to Global) do not correspond exactly:

. Station 2 partially covers R and B stations,
. Station A partially covers 3 and 4 stations,
. Station 6 has no correspondence, at the moment, we only made the comparison between both global histogrammes:

- one corresponding to the global tectoglyphs with 265 measurements, and
- the last box of Fig. 5.-1, with the whole 21.689 km underground conducts.

The process we followed is:

- homogenize the radial histogramme of all the caves (box n° 6) from 0° to 360° at 0° to 180°,
- compare it (from 0° to 180°, yet) with the global tectoglyphs histogramme,
- draw, in two dimensions, from both polimodals, the corresponding cumulative curve, according to the 12 used statistic classes (from 0° to 180°), every 15°,
- superpose the figures of both cumulative curves in order to find the maximum difference between both of them:

. this one belongs to the class 9 (120° to 135° interval) with a 10.1% absolute value;

- apply the Kolmogorov statistical test, in order to calculate the maximum error in the comparison:

$$\sum \max. \leq \frac{10.1\%}{\sqrt{12}} \leq 2.92\%$$

- and finally, quantify the statistical accuracy between the prediction given by the applied method and the known reality:

$$ACCURACY\,GRADE \geq 100 - \sum \max \geq 100 - 2.92 \geq 97.08\%$$

These results are quantified in Table 6.-1.

COMPLEMENTARY COMMENTS

The investigations made in order to write the present work contains the first steps for the application to the Carso Triestino of the "Prediction method of the underground drainage main directions", and were completed by authors who belong mainly to the Trieste University and the Polytechnical University of Madrid.

We wish to extend its application on the investigations on the whole Kras-Carso-Karst region, so we need the participation of scientists from Slovenia specialized in the study of karst, as the main area belongs to this country.

The first steps were already taken with the monographic workshop held in Postojna May 31th and June 1st, 1993, organized by the Institut za raziskovanje krasa ZRC SAZU.

REFERENCES

ARTHAUD, F., (1969): *Méthode de determination graphique des directions de racourcissement, d'allongement et intermédiaire d'une population de failles.* Bull. Soc. Geol. de France (7) XI, pp. 709-939. Paris.

CUCCHI, F., FORTI, F., (1981): *La «catturaČ del Timavo superiore a Vreme.* Atti e Memorie Grotte E. Boegan 21, pp. 55-64.

CUCCHI, F., PIRINI RADRIZZANI, C., PUGLIESE, N., (1987): *The carbonate stratigraphic sequence of the Karst of Trieste (Italy).* Mem. Soc. Geol. It. 40(1987), pp. 35-44.

ERASO, A., (1985/86): *Método de Predicción de las Direcciones Principales de Drenaje en el Karst.* KOBIE (Serie Ciencias Naturales) nº XV, pp. 15-165. Bilbao.

ERASO, A., FERNANDEZ RUBIO, R., (1990): *Predicción de las direcciones de drenaje subterráneo en macizos rocosos. Estado actual de la cuestión.*

CLASS	INTERVAL	CONDUCTS $L = 21.7$ km %	Σ_C	TECTOGLYPHS $N = 265$ %	Σ_T	DIFFERENCE $\lvert\Sigma_C - \Sigma_T\rvert$
1	0° - 15°	8,5	8,5	11,3	11,3	2,8
2	15° - 30°	9,8	18,3	8,7	20,0	1,7
3	30° - 45°	7,8	26,1	7,5	27,5	1,4
4	45° - 60°	10,5	36,6	7,5	35,0	1,6
5	60° - 75°	7,5	44,1	12,8	47,8	3,7
6	75° - 90°	7,8	51,9	3,4	51,2	0,7
7	90° - 105°	8,4	60,3	5,3	56,5	3,8
8	105° - 120°	6,7	67,0	3,0	59,5	7,5
9	120° - 135°	10,5	77,5	7,9	67,4	10,1
10	135° - 150°	8,4	85,9	15,5	82,9	3,0
11	150° - 165°	8,6	94,5	9,1	92,0	2,5
12	165° - 180°	5,3	99,8	7,9	99,9	0,1

MAXIMUM ERROR:

$$\Sigma_{max} \leq \frac{\lvert\Sigma_C - \Sigma_T\rvert}{\sqrt{\phi}}$$

ACCURACY GRADE:

$$100 - \Sigma_{MAX} \geq 100 - 2.92 = 97.08\%$$

Table 6.-1

Livro de Homenagem a Carlos Romariz, pp. 1-20, Secçâo de Geologia Economica & Aplicada. Lisboa.
HABIČ, P., (1984): *Relief units and structural lines on classical karst.* Acta carsologica XII (1983), pp. 3-26.
PLACER, L., (1981): *Geologic structure of southwestern Slovenia.* Geologija 24/1, pp. 27-60.
PLENIČAR, M., (1960): *The stratigraphic development of Cretaceous beds in Southern Primorska and Notranjska.* Geologija 6, pp. 22-145.

UPORABA METODE PREDVIDEVANJA NAJPOGOSTEJŠIH SMERI ODTOKA V KAMNINI NA PRIMERU PODZEMELJSKE REKE REKE - TIMAVA

Povzetek

V zadnjem desetletju se je "Metoda predvidevanja najpogostejših smeri odtoka v kamnini" izkazala kot pravo orodje za študij karbonatnih ali drugih anizotropnih kamnin. Metodo so uporabili na več kot 50 različnih primerih po vsej Evropi, v Aziji, Ameriki, Oceaniji, Arktiki in Antarktiki. Z "Metodo predvidevanja" so raziskovalci v večini primerov dosegli uspeh, v zadnjem času pa tudi potrditev pričakovanih razmer v naravnem okolju. Za preizkus metode so si avtorji izbrali tudi področje podzemeljskega toka reke Reke med Škocjanom in Devinom v Italiji.

Raziskovano ozemlje je pretežno karbonatni masiv, ki pripada Tržaško-Komenski planoti, ki jo karakterizira široka antiklinala z osjo v smeri NW-SE. Apnenci so tam večinoma kredne in terciarne starosti. Med alpidsko orogenezo so bile osnovne strukture premaknjene glede na pritiske, ki so delovali v smeri N-S (alpski narivi) in NE-SW (dinarski narivi).

Tridimenzionalni splet kanalov se v podzemnem vodonosniku oblikuje s povezovanjem za vodo lažje prehodnih ravnin oziroma pomembnejših razpok. Tvorba kanalov ob ugodnih razmerah je posledica litološkega stanja, orogenetskih procesov in tenzijskega stanja kamnine.

Avtorji obravnavajo dva tipa pritiskov:
-normalne ali direktne in
-strižne.

Vhodni podatki za "Metodo predvidevanja" so elementi vpada mikrostruktur (tektoglifov), med katere uvrščajo
-stilolitne šive,
-kalcitne žile ali mineralne dajke,
-strije na prelomnih ravninah.

Vsak od navedenih tektoglifov vsebuje namreč značilnosti, s katerimi si pomagamo izdelati elipsoid.

Na terenu pridobljene podatke obdelajo naslednji računalniški programi:

-GEORED, ki rezultate izriše na Schmidt-ovi ali Wulff-ovi mreži.

-GEODRE, ki izračuna in izriše komponentne elipsoida. Rezultat so ravnine drenaže.

-GEOPOL izračuna in izriše pole vnešenih ravnin drenaže.

Analiza vseh podatkov, pridobljenih z raziskavo, je pokazala naslednjo sliko:

1. Prisotnost štirih smeri ravnin drenaže:
   - -glavna smer s karakteristikami N 135^0 do N 150^0 ;
   - -dve sekundarni smeri s karakteristikami od N 60^0 do N 75^{0}in od N 0^0 do N 15^0;
   - -manj pomembna smer s karakteristikami od N 90^{0}do N 105^0.
2. Prisotnost narivov z značilnostmi:
   - -NE-SW, nagnjen z obeh strani za 45^0;
   - -N 105^0 (manjše pomembnosti);
   - -navpičen, ki je povzročil normalne prelome;
   - -navpičen, ki je povzročil drsne prelome.

Pričujoča raziskava, ki je nastala v sodelovanju med Univerzo iz Trsta in Politehnično univerzo iz Madrida, je prvi poizkus "Metode predvidevanja najpogostejših smeri drenaže v kamnini" na Tržaškem krasu.

CAVES GRAVITY DEPOSITS

JAMSKI GRAVITACIJSKI SEDIMENTI

ANDREY G. FILIPPOV

Izvleček UDK 552.55:551.44

Andrey G. Filippov: Jamski gravitacijski sedimenti

V jamah so najobsežnejši gravitacijski sedimenti. Mogoče jih je klasificirati po genezi na dva načina: glede na prevladujoči proces in glede na dinamično obliko transporta teh sedimentov. Avtor predlaga klasifikacijo po prvem načinu, in sicer jih deli na 11 razredov, nekatere razrede pa še na podrazrede.

Ključne besede: speleologija, jamski sedimenti, jamski gravitacijski sedimenti

Abstract UDC 52.55:551.44

Andrey G. Filippov: Caves gravity deposits

Gravity deposits are the most common sediments in the caves. There are two approaches to their genetic classification: according to leading process and according to the dynamic form of their transport. The author propose the classification based on the first approach. Caves gravity deposits are classified into 11 classes, some of them are subdivided into subclasses too.

Key words: speleology, cave sediments, cave gravity sediments

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Exploitation of karst caves as excursion objects deals inevitably with the estimation of steadiness of walls, ceilings and investigation of collapse process. Gravity deposits are more distributed in karst caves , but their state-of-art is still under investigation. Considering the influence of gravitation on sedimentation on the whole and on the cave deposition in particular, it is necessary to recognize that practically all the deposits are "gravity" ones to some extent - i.e. they have the traces of formation under the conditions of Earth gravity.

However, more vividly and obviously the influence of gravitation in the caves are shown with the formation of breakdown accumulations and as well as of deposits forming on inclined sites of floors, walls and at their foots in result of desplacement of destruction host-rock products under the influence of their own weight. Gravitation is the only force determining their formation directly without participation or with insignificant participation of other forces.

Hence, gravity cave deposits are clastic accumulations forming in caves under the influence of attraction as a result of breakdown, crumbling, slipping, shifting on inclined sites. In Russian speleological literature there are two methodological approaches to genetic classifications of cave deposits:

1) division of genetic types and subtypes according to leading process which prepares and/or stipulates substance release for further gravitation transfer (for example, thermo- and seismogravity deposits of V.N. Dubljansky, 1977, desquamation accumulations of V.P. Dushevsky, 1989),

2) division according to dynamic form of transport and accumulation of desintegrated stuff - in other words, the genetic types in conception of E.V. Shantser (1966) (for example, cave colluvium of R.A. Tsykin, 1985 classification, breakdown deposits of G.A. Maximovich, 1963 and D.S. Sokolov, 1962). Both approaches are correct, and, moreover, they supplement each other.

The following genetic classification of cave gravity deposits based on the first approach is proposed:

1 - thermogravity;
2 - frozen gravity;
3 - ice gravity, connected with breakdown of:
  a) thawing tongues of ice,
  b) alien inclusions thawing from ice;
4 - desquamation gravity;
5 - desquamation corrosion gravity;
6 - hydration gravity;

7 - crystallization gravity;
8 - corrosion gravity:
a) seepage corrosion gravity,
b) condensation corrosion gravity,
c) aquecorrosion gravity;
9 - deposits initiated by rock pressure which forms at domes (arch) and walls falling in result of:
a) removal of buoyant force of water,
b) excess of glaciostatic pressure;
10 - seismogravity;
11 - technogenic gravity.

Thermogravity deposits described by V.N. Dubljansky (1977) are formed in the entrance part of the caves due to daily changes of air temperature. They are widely distributed. They are built of debris of 1-100 mm size with admixture of biogenic materials (mammal bones, shells of terrestrial molluscs, dry leaves, etc.). The thermogravity accumulations which were formed in kataclastic and kakiritic carbonate rocks, in thin and middle flaggy limestones are the thickest and are more distributed around the area. The examples of such caves are Irkutskaya and Aikta in Eastern Siberia.

Frozen gravity deposits are formed in the entrance part of caves owing to the transition of host-rocks temperature across zero. Debris are mobilized by the splitting action of ice formed in the result of water freezing. Debris chipped off host-rock fall down on the floor after ice melting, forming clastic accumulations . The sizes of clasts depend on the splinterness degree of host-rocks. Block accumulations are formed in the entrances developing in massive and thick bedding rocks more than 0,5 m thickness. The example is Stary Zamok cave on Birusa river, East Siberia. Clastic accumulations with debris of 1-100 cm size appear in the caves developed in the middle and thin flaggy rocks (Oyusutskaya-9 cave, Yakutia, A.G.Filippov, 1988).

Ice gravity deposits are of debris accumulation character which are formed in result of breakdown, gliding of some parts of underground and surface glaciers, "naleds" and the alien inclusions thawing from ice. The last ones are residual ice gravity deposits. Usually, they are built from debris of host-rocks, of flowstones and popcorns, of animal bones and trees, and redeposition soil. Moraines of cave glaciers also belong to ice gravity deposits. As a rule, pressure and spreaded moraines consist of nonsorted accumulations forming the base of dirty layers in glacier body (Dmitriev, 1980). A great amount of plant detritus is found in them. The examples of such deposits are moraines of Bidginskaya and Vinogradovskaya caves, Kuznetsky Alatau, Siberia (Dmitriev, 1980). Ice gravity deposits consisting of accumulations of ice debris are non-longlived ephemeral formations. They are formed due to ice collapse in the result of cave glaciers and naleds melting as well as due to increasing of their weight by freezing. The example is Scarasson abyss, Italy. M. Siffre (1982) described numerous ice falls of this abyss.

Desquamation gravity deposits are formed due to thermal and moisture interchange between air flows and fissured bed rocks. Alternation of damping and wasting of rocks brings to flags exfoliation and their falling down to the floor. V.P. Dushevsky (1989) was the first who discribed such deposits in the short caves of the Crimea. Desquamation gravity accumulations consist of flaggy debris with size from 1 mm to the first tens of centimetres. Debris with the size from 1 to 10 cm prevail in the Crimean caves which are formed in sandy and marl limestones. Debris with the size from 1 to 10 mm prevail in the caves which are formed in bedding lime sandstones. Debris with the size more than 1 cm are accumulated in blind alley parts, where the maximum velocity of weathering is observed. In the middle parts of the short caves (between the entrance and blind alley), thin and frail lamellas and crusts exfoliate. They fall down to the floor reduced to dust and sand.

In many cases, it is practically impossible to distinguish the influence of periodical damping and wasting, temperature weathering and the splitting action of the frozing water on separation of debris from the walls and ceiling without special investigations.

Desquamation corrosion gravity deposits are typical to dry-gallery stage of cave development. They are accumulations of debris of flowstones, crusts of "aqual" crystals and corallites. Usually, crusts splitting off from walls and ceilings of caves occur in weakening zones from 5 to 50 mm deeper than the contact with karst rock. According to data of V.M. Philippov (1987), in marbles this zone is presented by strongly dissolved cavernous materials with cavities filled with clay. In the bedded limestone-dolomite rocks these zones are formed from friable small-dispersed carbonate-terrigenous substance. Rocks of dissolution zone posses sharply reduced solidity, which stipulates the formation of fissures and crust splitting off. The reason of karst rock lixiviation on the contact with flowstones and other crusts lies in the existence of more favourable conditions for filtration of waters which are exudated from karst massive by fissures and pores (Philippov & Ovodov, 1989). The size of split flowstone crusts varies from 1 to 50 cm depending on initial thickness of crust, on height falling, on degree of flowstone crushing before splitting, and on character of the deposits on the floor.

Hydration gravity deposits are formed in the caves which were developed in gypsum-anhydrite, gypsum-anhydrite-dolomite, anhydrite-aleurolitic and similar rocks due to hydration of anhydrite. Gypsotization is often accompanied by increasing of rock volume from 30 t0 67 % (Pisarchik, 1958; Strakhov, 1962). It makes additional pressure and may cause collapse of cave ceilings and walls. Increasing of rock hydration causes decreasing of rock solidity and also favours collapses.

Crystallization gravity deposits are stipulated by crystallization of gypsum within the limestones from underground waters which are rich in sulphates.

Such flaggy and splintered accumulations are known in the Mammoth cave, USA (Ford & Williams, 1989).

Corrosion gravity deposits are formed due to collapse of ceilings and walls as result of solution of karst rocks. The influence of underground water of different genesis causes accumulation of nonidentical material. Aggressive infiltration of descending waters dissolving the rocks along fissures weaken ceilings. It stipulates collapse of ceilings and appearence of seepage corrosion gravity deposits on the floor (Argarakanskaya cave, East Siberia).

The dissolution of walls by condensation waters may produce numerous flaggy and splintered breakdowns in good aerated caves as noted D. Ford & P. Williams (1989). Such condensation corrosion gravity deposits are widely distributed on the floor of Aya cave in Siberia. These deposits are of marble crumb, which was formed due to release of calcite grains on ceiling and walls of the cave as the result of broadening of intergranular cracks by aggressive condensate waters.

Another kind of condensate corrosion gravity deposits is gypsum "snow" distributed on the floor of gypsum caves. According to observations of V.A. Maltsev & I.I. Turchinov (1989), the growth of small gypsum crystals (up to 3 mm) take place on ceilings in summer due to crystallization from capillary pellicle of unsaturated gypsum solution. In winter, under conditions of more air humidity, the crystalls partially dissolve and completely crumble to the floor forming the accumulations with thickness up to 5 cm. They are better studied in Jurinskaya cave in Podolia, Ukraine (Maltsev, 1990).

Aqueocorrosion gravity deposits are formed as the result of corrosion or corrosion-erosion separation of debris from bed rock, e.g., the separation of pendants, of overhead covers between cave levels, and of channel walls at their curves, under conditions of phreatic movement of water flows in siphon circulation zone. The deposits are rounded or smoothed out blocks with diameter of 0,3-1,5 m. Usually, it is impossible to find the separating place on cave roof or the walls. Such blocks were described in Spasskaya, Ledyanaya, Kolodets, and Kolonok caves on Russian Far East (Bersenev, 1989).

In some cases, gravity deposits in caves are formed when rock pressure amount exceeds the limits of cave roof steadiness. These phenomena can take place at the transition of cave from phreatic zone to vadoze zone owing to removal of buoyant force of water. Drainage of caves is a regular process at uplifting of karst massives, cutting in of rivers, lowering of ocean and sea level in glaciation periods, changing of river course, and lowering of underground water-level as the result of pumpings during exploitation of quarry, mines. Gravity deposits formed in the result of removal of buoyant force of water may be determined only hypothetically and in rare cases by detailed studies.

J. Schroeder & D. Ford (1983) suggested that in caves developing under glaciers the extensive breakdown may occur owing to repeated loading and unloading of glacier weight plus uneven application of shearing stresses, as flowing glaciers have waxed and waned overhead on the example of Castleguard cave. Probably, release of pressure by spalling is typical of caves in many formerly glaciated terrains (Ford & Williams, 1989).

Seismogravity deposits were described by V.N. Dubljansky (1971) as breakdown deposits subtype in karst caves and shafts of the Crimea. Criteria relating to seismogravity deposits are large sizes of blocks (weight to 100-200 thousand ton) and shifted and fallen stalagmites and columns with diameter 4-6 m and length 8-10 m. Undoubtedly, identification of seismogravity deposits is debatable and rather subjective.

Technogenic gravity deposits are stipulated by economic activity of man both in caves and on the surface. Technogenic gravity deposits are formed as the result of breakdown of roofs of halls and of cave passages, as well as breakdown, pouring out of material from geological organs because of technogenic earthquakes (explosions in the quarries, etc.), of weight of heavy machinery. The example of man's activity in caves is the layer of limestone debris on the bottom of underground river Punkva in Punkevni cave, Czech Republic. This layer was formed while spalling the rocks from ceiling by blasting operations.

Genetic types of gravity deposits which are similar to surface ones (Manual on methods.., 1987) may be distinguished according to type of exogenous process of transfer and accumulation in caves. They are: colluvium (subtypes: deruptium, desperium); and solifluction formation (subtypes: tardofluxium, congelifluxium, defluxium).

Deruptium (from Latin "deruptus" - "steep") is a breakdown nonsorted agglomerate, built of blocks. They are formed in the result of collapses of roof, walls, interlevel spaces. Deruptium is especially characteristic for sites of crossing or close situation of few fissures. It is the most distributed genetic type among gravity deposits.

Desperium (from Latin "despero" - "to pour") is talus formed from debris 0,1-1,0 m in diameter. Bad sorting of accumulations is often observed: debris are smaller in upper part of talus and larger in the lower part. In some cases, talus is "live," i.e. it creeps down. In other cases, they are anchored by calcite flowstones or clays, or seasonally by ice. Formation of desperium is stipulated by rolling of debris on steep planes (20-40°). It is widely distributed both in interior parts of the caves, and exterior ones.

There are deposits of warm (defluxium) and cold (tardofluxium, congelifluction) solifluction formation.

Defluxium (from Latin "defluxe" - "to flow down") is formed in the result of clay transfer on vertical or steep inclined walls, more rarely on inclined floors of caves by action of attraction under conditions of intensive moisture. Clay deposits with slip ripples on the walls of Kurtuiskaya shaft, Prisajan territory, Eastern Siberia, are typical examples of this genetic subtype. These clays are washed away by infiltration water from subsoil layers and are transported along joints into the cave where they "flow down" by walls gradually.

Congelifluction (from French "congelation" - "to freeze") formations are deposits formed as a result of desplacement on contact of frozen and melting rocks under the influence of gravitation. Rocks have tough fluid consistency on the contact and tough plastic consistency above it. They are formed under permafrost condition in exterior part of caves on steep parts of passages (10 -30°) in zone of temperature Earth surface influence. Congelifluction formation often forms rock rivers, the bases of which are frozen into ice or soil. Presence of bent clay layers and lenses is characteristic for small-debris types of congelifluction cross-sections.

Tardofluxium (from Latin "tardos" - "slow", "fluxus" - "to flow") is solifluction formation formed at slow displacement of tough fluid soils down cave floors with steepness of 2-10 during variable freezing and melting. Tardofluxium is found in cave entrance parts in surface temperature influence zone.

Gravity deposits are regular and integral components of cave environment and cave landscapes. In some cases they are of great scientific value, especially in the exterior cave parts, as a source of information for paleogeographic reconstruction and as receptacles of palaeontological remains.

REFERENCES

Bersenev, Y.I.1989. Karst of Far East. Moscow. Science, 172 p.- in Russian.

Dmitriev, V.E. 1980. Glaciation of caves as part of glaciosphere of the Earth. In: Karst of Far East and of Siberia. Vladivostok, p. 130-145. - in Russian.

Dubljansky, V.N. 1971. Genesis and hydrogeological value of large karst caves of Ukraine. Doctor's thesis, Perm State University. - in Russian.

Dubljansky, V.N. 1977. Karst caves and shafts of Mountain Crimea. Leningrad. Science. 182 p. - in Russian.

Dushevsky, V.P. 1989. Recent deposits of karst caves of foothills Crimea. In: Minerals and deposits of caves and their practic value. Perm, p. 56-57. - in Russian.

Filippov, A.G. 1988. Gypsum karst caves on Vilyui river. In: Reports of USSR Academy of Sciences, vol. 299, no. 3, p. 696-701. - in Russian.

Ford, D.C. & Williams, P.W. 1989. Karst geomorphology and Hydrogeology. London, Unwin Hyman, 601 p.

Maltsev, V.A. & Turchinov, I.I. 1989. Gypsum ephemeral formations of Jurinskaya cave. In: Geology and prognosis of mineral deposits in Eastern Siberia. Irkutsk, p. 82-83. - in Russian.

Manual on methods to be used in the studies and geological survey of the Quarternary deposits /A.K.Agadzhanyan, O.A.Braitseva, E.A.Vangengeim, e.a. - Leningrad. Nedra, 1987. - 308. - in Russian.

Philippov, V.M. 1987. Splitting of flowstones in caves. In: Problems on study, ecology and conservation of caves. Kiev, p. 62-63. - in Russian.
Philippov, V.M. & Ovodov, N.D. 1989. Role of gravity processes in cave formation of Prisayan and Altai. In: Karst of Altai-Sayan mountain territory and surrounding mountain countries. Barnaul, p. 45-46. - in Russian.
Pisarchik, N.K. 1958. Gypsum and anhydrites. Moscow, vol. 2. - in Russian.
Schroeder, J. & Ford, D.C. 1983. Clastic sediments in Castleguard cave, Columbia icefields, Alberta, Canada. In: Arctic and Alpine Research, vol. 15, no. 4, p. 451-481.
Shantser, E.V. 1966. Essays of theory on genetic types of continental sediment formations. Moscow. Science. 239 p. - in Russian.
Siffre, M. 1982. In the Earth abyss. Moscow. Progress, 236 p. - in Russian.
Sokolov, D.S. 1962. Main conditions of karst development. Moscow. 322 p. - in Russian.
Strakhov, N.M. 1962. Principles on lithogenesis theory. Moscow. Academy of Sciences, vol. 3. - in Russian.
Tsykin, R.A. 1985. Deposits and mineral resources of karst. Novosibirsk. Science, 163 p. - in Russian.

JAMSKI GRAVITACIJSKI SEDIMENTI

Povzetek

V jamah, ki so cilj ekskurzij, je treba nujno preučiti tudi stene, strope, stabilnost in podorne procese. Največ je gravitacijskih sedimentov, vendar ni dovolj, da zgolj zabeležimo njihovo stanje. Genetsko jih je mogoče klasificirati na dva načina: glede na prevladujoči proces, zaradi katerega nastajajo ti sedimenti in ki vzpodbuja njihov transport s pomočjo gravitacije, in glede na dinamično obliko transporta in akumulacije razpadlega gradiva. Avtor predlaga klasifikacijo po prvem pristopu, glede na prevladujoči proces:

1. termogravitacija;
2. zmrzovalna gravitacija;
3. ledna gravitacija, povezana s podiranjem:
    a) taljenje ledenih jezikov
    b) tujki v ledu, ki pridejo na dan zaradi taljenja ledu;
4. deskvamacijska gravitacija;
5. deskvamacijsko-korozijska gravitacija;
6. hidratizacijska gravitacija;
7. kristalizacijska gravitacija;
8. korozijska gravitacija:
    a) korozijska gravitacija zaradi pronicujoče vode

b) korozijska gravitacija zaradi kondenzne vode
c) akvakorozijska gravitacija;
9. gravitacija, nastala zaradi pritiskov v kamnini, vzpodbujena s:
a) prenehanjem sile deroče vode
b) glaciostatičnim pritiskom;
10. seismo gravitacija;
11. tehnogena gravitacija.

APPLICATION OF BAIKAL CAVES IN HUMAN LIFE

ČLOVEK IN JAME V PRIBAJKALJU

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Izvleček UDK 903.3:551.44(571)

A.G. Filippov & O.I. Goryunova & V.M. Vetrov & N.E. Berdnikova: Človek in jame v Pribajkalju

Človek je v razne namene (zatočišča, skrivališča, pokopališča) uporabljal pribajkaljske jame od paleolitika (mousterien) do moderne etnografske dobe (16. - 19. stol.). Avtorji poimensko naštevajo 13 jam, v katerih so odkrili sledi človekovega bivanja ali njegove dejavnosti.

Ključne besede: speleologija, antropospeleologija, arheologija, etnografija, človek in jama

Abstract UDC 903.3:551.44(571)

A.G. Filippov & O.I. Goryunova & V.M. Vetrov & N.E. Berdnikova: Application of Baikal caves in human life

Man used for different purposes (as temporal sites-refuges, caches, burial sites) Baikal caves from the Palaeolithic (Mousterien) to Contemporary Etnography Period (16 - 19 Cent. A.C.). The authors ennumerate 13 caves where the remains of human dwelling or their activities were found

Key words: speleology, anthropospeleology, archaeology, etnography, man and cave.

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This report is based mostly on materials which were obtained during 1987-1990 by Complex Research Speleological Expedition. This expedition was organized by Dr. A.G. Filippov for research of Pribaikal National Park caves. During 1987-1989 the archaeological groups of the Archaeology and Ethnology Laboratory from Irkutsk University under the leadership of Dr. O.I. Goryunova took part in the expedition. Complementary materials were received as a result of short field investigation in 1991-1993. Among 56 caves which were investigated, only 22 contain archaeological artifacts (fig. 1). Beside our own collections, we analysed collections kept in Irkutsk State Regional Museum and its branch in Khuzhir settlement on Olkhon Island.

The first archaeological findings in Baikal caves were made by Prince P.A. Kropotkin in 1865 and by Polish exile I.D. Tchersky in 1879 and 1880 . In 1913 and 1916 B.E. Petry who was a founder of "Irkutsk archaeological school" discovered two cave archaeological sites of V-X centuries A.C. In the 1920s, archaeologists P.P. Khoroshikh, I.I. Veselov, and G.F. Debets collected floor artifacts and conducted insignificant excavations in caves already known.

In the 1940s and 1950s this century, P.P. Khoroshikh carried out excavations in a number of caves and published the first generalized papers. He also made an attempt to define functional appllication of caves. In his opinion, in the Neolithic period these caves were used as temporal seasonal dwellings. In later time (in the Iron Age) "some caves which were situated high in the mountains served as sentry posts and were used by ancient peoples for giving of fire and smoke signal" (Khoroshikh, 1955).

Interpretation of most of Baikal cave archaeological materials is mainly based on analogies known from publication on some burial-grounds, multilayered stratified settlements-site of ancient people. The interpretation becomes complicated due to the absence of distinctive criteria of division of medieval complexes, especially Turkish and Early Mongolian periods (Konovalov, Danilov, 1981; Mandelshtam, 1974). The same sites or similar ones were used for proof of their Early Mongolian (Okladnikov, 1958; Sedyakina, 1965), Early Buryat (Sarkisov, Svinin, 1978) or Turkish (Konstantinov, 1970) origin.

The majority of Baikal caves containing cultural remains are accessible and sufficiently applicable for people staying during for long or short times. Some caves served as caches (e.g., Boro-Khukhan, Kurtun-7, Oktyabrskaya caves) and as burial-grounds (Vsadnik, Shida caves). Archaeological artifacts as a rule are situated in light and dry entrance parts of caves. Korallitovy Hall of

Bolshaya Baydinskaya cave is the only exception as it is sufficiently far from the surface. People repeatedly attended that Hall from Bronze to the transitional period from Late Bronze to Early Iron Ages (VII-V centuries B.C.).

All the "cave-snares" are sterile from the archaeological point of view. Some of them contain human bones (e.g. Vologodskogo and Sluchaynaya caves which entrances are vertical wells). However, the presence of human bones in these caves should be considered perhaps as consequences of accidents.

The traces of the first human use of Baikal caves are related to Musterian Epoch. They were exposed in Kurtun-1 cave situated in rocks of Primorsky ridge. Here there was found remains of a bonfire in the layer of brown clays with carbonate rocks debris at depth of 0.9-1.0 m. Radiocarbon dating on wood coal is 44715+5740 (CO AH 2902). The location of bonfire remains in the low mouth part of the hole, which was used in different times by cave hyena, brown bears, foxes and wolves as a den, allows us to suppose that the fire was used with the aim of hunting predators. Later, the cave was used as

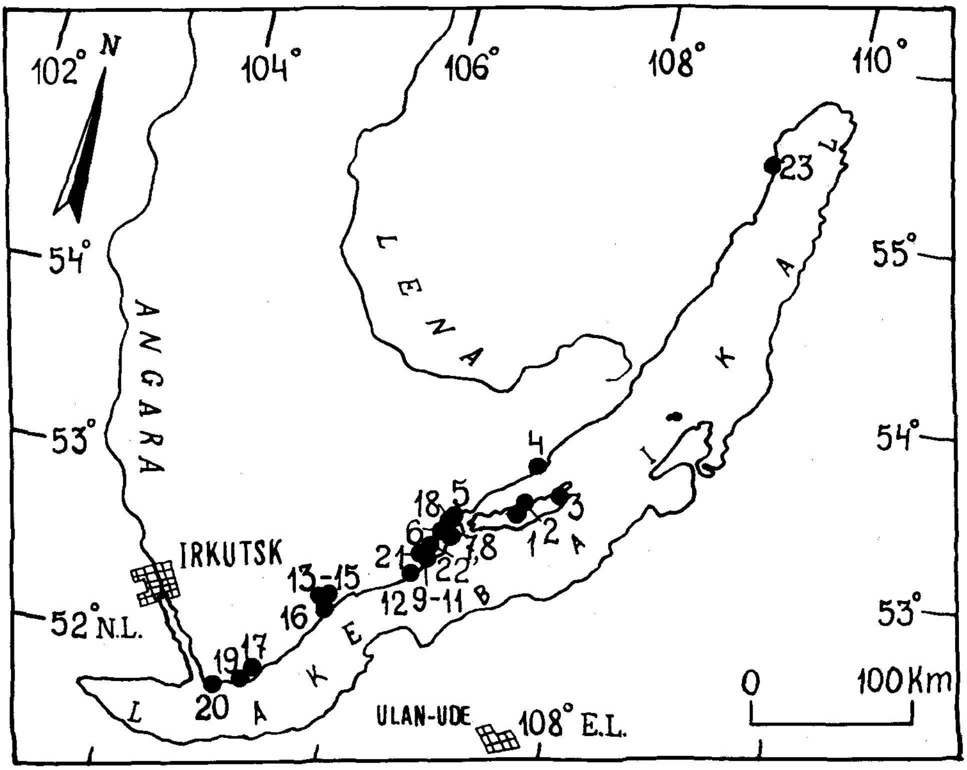

Fig. 1. Cave archaeological sites on the west coast of Baikal. Names of the caves are given on fig. 2.

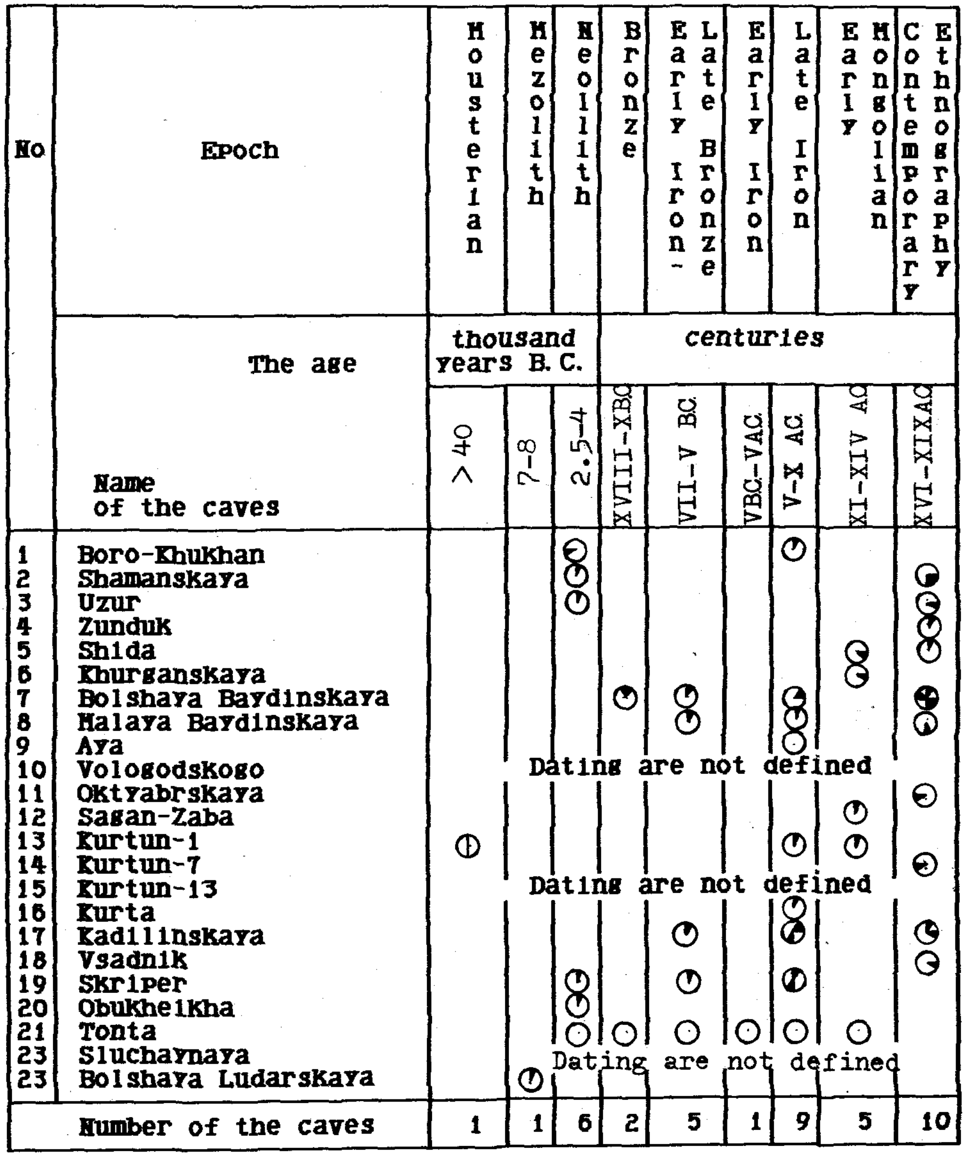

Fig. 2. Application of Baikal caves.
functional application of cave is not defined; temporal site-refuge; seasonal dwelling; burial-ground; ritual; signal and sentry post; cache; site for treatment; site for clay output; attendence with hunting aim.

a temporary refuge. Separate articles of bone (harpoon, fish-hook, needle-case, spike, arrow-head) found in this caves preliminary dated to Iron Age, testify to that.

The next traces of human cave use are related to Mezolithic Epoch. Bolshaya Ludarskaya cave to the North of Baikal was used as a temporary refuge 7-8 thousand years ago B.C.

A more widely human exploitation of Baikal caves was related to the Neolithic Age (the middle of III - the end IV-th thousand years B.C.). Shamanskaya, Tonta, Skriper, Obukheikha, Uzur caves looked like temporary refuge-sites, Boro-Khukhan cave was either cache or temporary refuge. Occupations of the caves were sporadic or single. The scanty number of artifacts witnesses to that. Chronological dating material is represented by grinding nefrite axes, fragments of ceramic vessels, bone artifacts. Caves with Neolithic artifacts are distributed in cliffs of Lake Baikal and in two cases on relatively far distance from the shore (Tonta, Boro-Khukhan caves).

Tonta and Bolshaya Baydinskaya caves were periodically used as temporary refuges in the Bronze Age (XVIII-XI centuries B.C.). In Tonta cave there were found a fragment of ceramic vessel and a part of bone spoon. In Korallitovy Hall of Bolshaya Baydinskaya cave there are remains of fire with ^{14}C dating of 3420+25 B.C.(CO AH 2714). Perhaps, clay for ceramic goods was obtained in this cave because there was found there a bone pick at depth of 20 cm. Cave clays lie immediately below cultural-bearing layer.

Episodic use of caves by ancient people was observed during the transitional period from Bronze to Early Iron Age (VII-V centuries B.C.). Archaeological materials from Kadilinskaya, Malaya Baydinskaya and Skriper caves are represented by single fragments of ceramic vessels. In Korallitovy Hall of Bolshaya Baydinskaya cave there were found pointed larch stakes frozen into the base of ancient "naled" with thickness more than 6 m. Radiocarbon dating obtained on wood is 2710+30 B.C.(CO AH 3047). Later, the entrance to the Hall was filled with thick "naled". The Hall was again opened in 1984 by Irkutsk City Grotto cavers who drove a 14-m tunnel in the ice-body. In Tonta cave numerous fragments of 6 ceramic vessels were found. Perhaps, caves were used as temporary refuge during this period. Tonta cave was used repeatedly.

In Earlier Iron Age, only Tonta cave was used by a man as a temporary refuge. For the first time, on Pribaikal territory Hunna ceramics and a bone clasp have been found in this cave. This fact is evidence that Hunnu people stayed in Pribaikal area. This conclusion changes considerably the old view about northern boundery of Hunnu culture spreading.

More actively, caves were assimilated by Kurikane local people (Turk) in Late Iron Age (V-X centuries A.C.). Kurikane cultural complexes were identified in 9 caves of 23 containing archaeological materials (fig. 2). Large quantities of kitchen waste, numerous remains of bonfire and domestic objects are evidence of more continuous use of caves in the Late Iron Age. Most likely, caves were used as seasonal dwellings in cold seasons. Some of them (Kadilinskaya and Skriper caves) were used as signal and sentry posts for giving of fire and smoke signals when enemies were approaching. Stone walls - "defensive building" on the surface - are dated the same time too. In Bolshaya Baydinskaya cave there are found four unbroken stratigraphically pure cultural levels. They contain artifacts (fragments of ceramic vessels, iron arrow-heads and knives) and bonfire remains of Late Iron Age.

The most numerous artifact collection, consisting of many hundreds of specimens, was received from Kadilinskaya cave. This fact alongside with rather a large thickness of cultural levels (about 1-1.5 m) rich in bonfire remains testifies to the use of Kadilinskaya cave as a permanent dwelling or to regular seasonal staying in it.

Beginning from Early Mongolian period (XI-XIV centuries-A.C.) to Contemporary Ethnography period (XVI-XIX centuries A.C.), the use of caves changed. Caves were connected with ideas about the other world and were used for burial of people (Shida, Bolshaya Baydinskaya, Tonta, Uzur, Shamanskaya, Kadilinskaya, Khurganskaya, Vsadnik caves). During that period Kurtun-7 cave was used as a cache. Remains of a wooden sledge were found in it.

The legends connected with caves and also numerous coins of XVIII-XX centuries A.C. found in Shamanskaya and Bolshaya Baydinskaya caves testify to ritual (cult) use of these caves. Shamanskaya cave on Olkhon Island was the most revered cave on Baikal. In the XIX century it was used as Buddist (lamaist) temple. Later, a wooden cross was put above Shamanskaya cave. The icon of St. Nicola-Miracle Man was placed in this cave. An orthodox chapel was built near it on isthmus of Shamansky peninsula. After the October Revolution of 1917, Shamanskaya cave was pillaged, the chapel and the cross were destroyed as were majority of other religious holy things. P.P. Khoroshikh found (1955) a slate plate with carved image of "women-shaman" witnessing about more earlier worship at the cave by Buryats-shamanists.

According to oral Buryat legends noted by P.P.Khoroshikh, the lake water of Bolshaya Baydinskaya cave was salubrious for eye treatment, and many Buryats from far distances came to that cave with the hope of miraculous recovery. Malaya and Bolshaya Baydinskaya caves were considered to be sacred caves for local Buryat-shamanists. Beginning from the second half of the last century, Buddism began to penetrate into the Priolkhon area. Lamas trying to support this sense of holiness, wrote Buddist sacred characters above the entrances of those marble caves.

At present, caves are attended by numerous non-organized tourists causing considerable damage to the caves. Only Mechta cave has been used for organized tourism in 20 years.

REFERENCES

Goryunova, O.I. 1984: Complexes of Early Bronze Age of Tyshkine-3 multy-layered site. In: Archaeology of south of Siberia and Far East. Novosibirsk. Science, p. 57-69.

Kchoroshikh, P.P. 1955: Cave sites of Siberia as historical source. Doctor's thesis, Irkutsk State University, 433 p.

Konovalov, P.B. & Danilov, S.V. 1981: Middle Age burial-ground in Kibalino (West Zabaikalie). In: News in Zabaikalie archaeology. Novosibirsk, p. 64-73.

Konstantinov, I.V. 1970: Burial-ground with horse in Yakutia (new data on ethnogenesis of Yakuts. In: By traces of anchient cultures of Yakutia. Yakutsk, p. 183-197.

Mandelshtam, A.M. 1974: Marquee burial-ground near Nure Lake (Olkhon Island). In: Bronze and Iron Age of Siberia. Novosibirsk, p. 150-155.

Okladnikov, A.P. 1958: Arhaeological data on appearence of first Mongols in Pribaikal territory. In: Phylology and history of Mongolian peoples. Moscow, p. 202-213.

Sarkisov, V.R. & Swinin, V.V. 1978: New ancient Buryat burial-ground on Baikal (Olkhon Island). In: Archaeology and - ethnography of East Siberia. Irkutsk, p. 43-44.

Sedyakina, E.F. 1965: Ust-Talkin burial-ground. In: Proceedings of Buryat Research Institute, issue 16, p. 196-202.

ČLOVEK IN JAME V PRIBAJKALJU

Povzetek

Najstarejše sledi človekove dejavnosti v pribajkaljskih jamah so iz paleolitika (mousterien - pred več kot 40 000 let B.P., jama Kurtun 1). Jame so bile uporabljane tudi v neolitskem času (konec 3.-4. tisočletja pr. Kr.., jame Boro-Khukhan, Shamanskaya, Tonta, Skriper, Obukheikha, Uzurskaya, Ludarskaya, Bolshaya Bajdinskaya). Te jame so bile najbrž občasna zatočišča ali skrivališča (Boro-Khukhan). Občani obiski jam so znani tudi iz bronaste (18. - 11. stol. pr. Kr., jame Tonta in Bolshaya Bajdinskaya) in starejše železne dobe (jama Tonta) ter iz zgodnjega mongolskega obdobja (11. - 14. stol. po Kr., jame Shida, Sagan-Zaba, Tonta). Intenzivneje je človek uporabljal jame v prehodnem času iz mlajše bronaste v starejšo železno dobo (7. - 5. stol. pr. Kr., jame Tonta, Malaya Bajdinskaya, Kadilinskaya, Skriper) in v mlajši železni dobi (5. - 10. stol. po Kr., 9 jam). Velike količine kuhinjskih odpadkov, ognjišča in gospodinjski objekti pričajo o kontinuirani uporabi jam v mlajši železni dobi. Začenši z zgodnjim mongolskim obdobjem pa do moderne etnografske dobe (16. - 19. stol. po Kr.) so jame povezane s pojmom onostranstva in so jih uporabljali za človeške pokope (jame Shida, Tonta, Bolshaya Bajdinskaya, Shamanskaya, Uzurskaya, Kadilinskaya).

LAND USE IN DOLOMITE REGIONS IN SLOVENIA

RABA TAL NA DOLOMITNIH OBMOČJIH SLOVENIJE

MATEJ GABROVEC

Izvleček UDK 552.54(497.12)

Matej Gabrovec: Raba tal na dolomitnih območjih Slovenije

Dolomit pokriva 12% slovenskega površja (glej karto 1), kar je skoraj 2500 km^2. Večina pripada triasu, nekaj dolomita pa je tudi jurskega in krednega izvora (glej tabelo 1).

Ključne besede: dolomit, izraba tal, Slovenija

Abstract UDC 552.54(497.12)

Matej Gabrovec: Land Use in Dolomite Regions in Slovenia

In Slovenia, dolomite covers 12 % of all land (see map 1), almost 2500 km^2. The majority is of Triassic origin, with some of Jurassic and Cretaceous origin (see Table 1).

Key words: dolomite, land use, Slovenia

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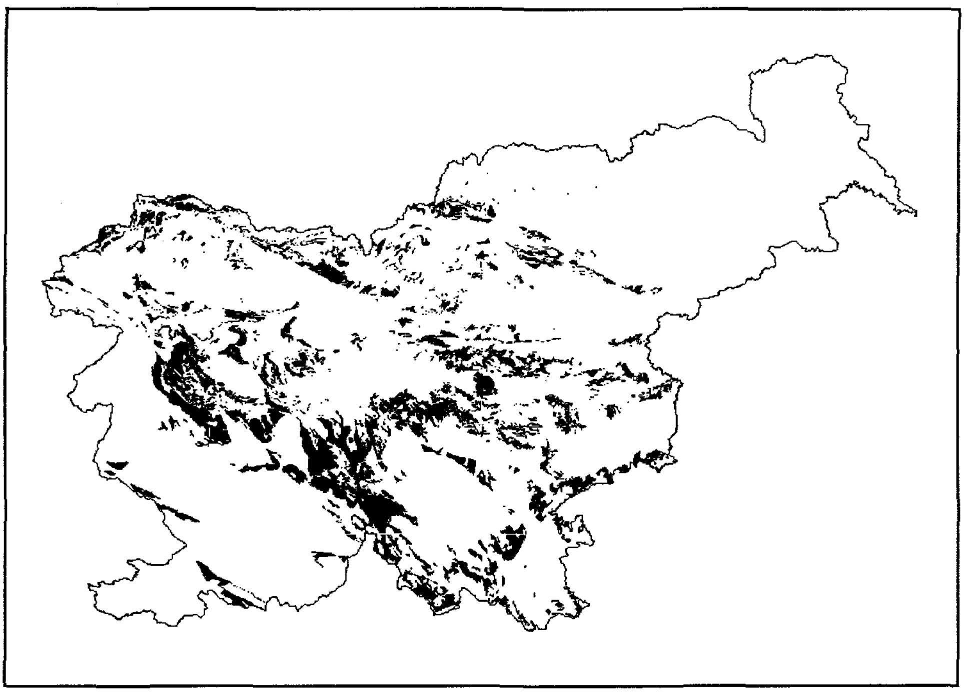
The dolomite surfaces in Slovenia cover approximately 2500 km², which is 12 % of the territory of the Republic of Slovenia. Most of the dolomites are of Triassic age and a tenth of Jurassic or Cretaceaus age. Most of the dolomite areas are in the pre-alpine areas and on Dinaric plateaus. The land use of the dolomite regions differs greatly from the one of the karst limestone and the non-karst areas. A high percentage of meadow areas, which can be often found on very steep slopes, is rather typical. A growing number of steep meadows and pastures has lately been abandoned. Thus, it is the dolomite regions that take the biggest share of surfaces which are in the process of being overgrown.

In Slovenia, dolomite covers 12 % of all land (see map 1), almost 2500 km². The majority is of Triassic origin, with some of Jurassic and Cretaceous origin (see Table 1).



Map 1: Dolomite regions in Slovenia / Karta 1: Dolomitna območja v Sloveniji

Table 1: Dolomite in Slovenia by age

Geological Period	Area in km^2	% of Area
Permian	14	1
Triassic	2153	86
Scythian	35	1
Anisian	307	12
Carnian (mainly Cordevolian)	535	21
Rhaetian-Norian	1146	46
Bača dolomite	130	5
Jurassic	252	10
Cretaceous	83	3
Total	2502	100

The sources for Table 1 are the basic 1 : 100000 scale geological maps. In some questionable cases when the data on the basic geological maps did not match, I utilized the newest 1 : 500000 scale geological survey map. In the scythian layer, the dolomite alternates with limestone and sandstone. The table considers only dolomite which is particularly distinct on the geological maps. On the majority of geological maps, lithological links from this period are not distinguished, and therefore the actual areas of dolomite from this period are considerably larger.

According to the natural geographical macroregions of Slovenia (Gams, 1992), the proportion of dolomite is quite varied. The smallest is found on the bottom of the Ljubljana Basin, only 2 %, and the greatest in the Dinaric karst of continental Slovenia, 20 %. The high Alps and the alpine foothills account for 15 % each (see table 2).

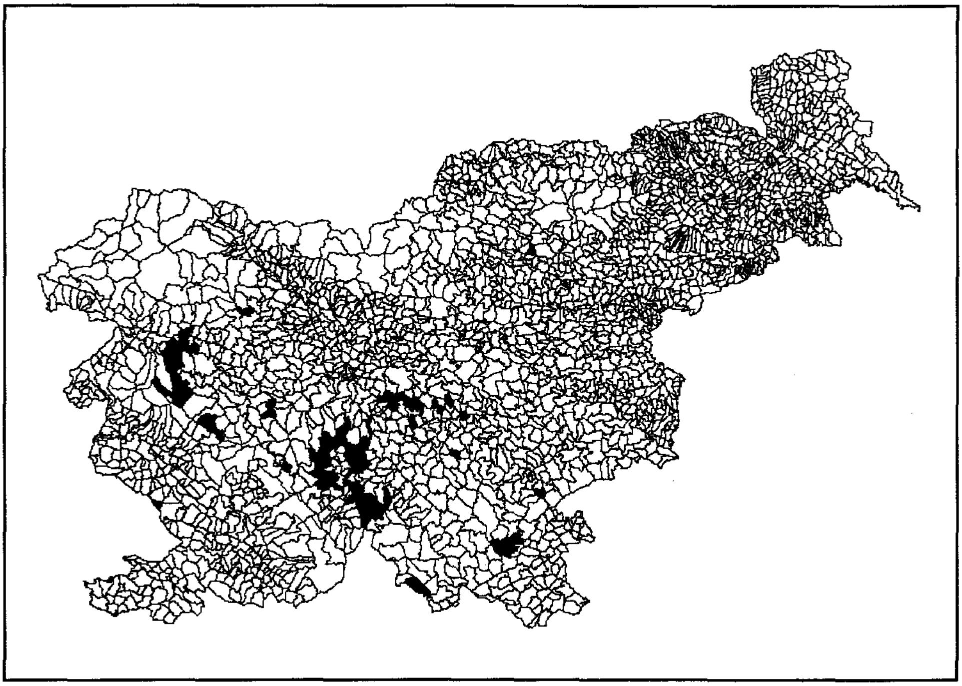
Table 2: Proportion of Dolomite according to the Natural Geographical Macroregions of Slovenia in %

High Alps	15
Alpine Foothills	15
Ljubljana Basin	2
Sub-Pannonian Slovenia	5
Dinaric Karst of Continental Slovenia	20
Primorska (Littoral)	5

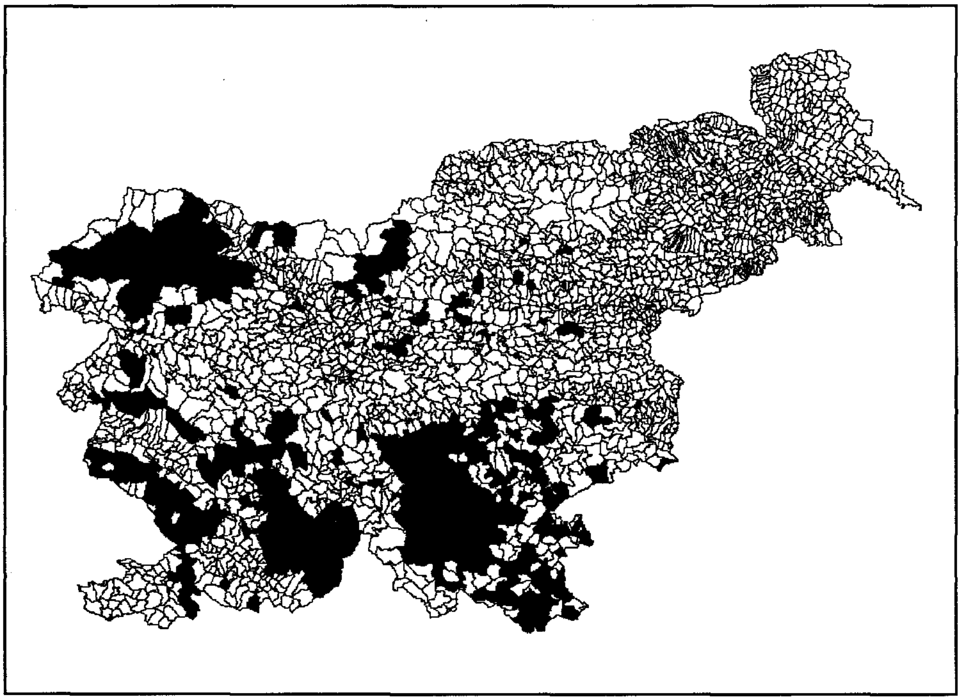
In the high mountain world, the dolomite regions are distinguished from limestone areas by major mechanical weathering and therefore much scree is found here (Šifrer, 1963, Kunaver, 1983). We determined the relationship between dolomite and land use primarily in the subalpine and dinaric regions. Here characteristic dry valleys are most typical among relief forms, and shallow dolines and uvalas also occur. The bottoms of the dry valleys are naturally filled with periglacial rubble; here the soil is thicker and in the past there were cultivated fields here. The slopes of these dry valleys were cleared for meadows which today are often overgrown. The dry valleys develop downhill into gullies. In general, dolomite areas are more suitable for agricultural use because they are less rocky and therefore they have been cleared to a greater extent than land over limestone. Of course, they are less intensively exploited for agriculture than areas of various noncarbonate rocks.

According to their relief characteristics, which are also reflected in land use, dolomite areas differ considerably from karst areas and areas of fluvial relief. On the survey speleological maps of Slovenia, they are characterized as partial fluviokarst (Habič, 1982). In further work, I attempted to determine whether differences in land use are significant enough to be reflected in official cadastral data as well.

With the help of the Register of Territorial Units (ROTE) (Lipej, 1990) and digitalized geological maps, we divided all Slovene cadastral districts into three groups according to their dominant type of stone. In the first dolomite prevailed, in the second limestone, and in the third noncarbonate rocks. In our analysis we ranked only those cadastral districts where one of the mentioned types of rock occupied at least two-thirds of the surface area of the cadastral district. We excluded from our analysis cadastral districts where unconsolidated sedimentary rocks prevailed (see Maps 2-3).



Map 2: Cadastral districts where dolomite dominates
Karta 2: Katastrske občine, kjer prevladuje dolomit



Map 3: Cadastral districts where limestone dominates
Karta 3: Katastrske občine, kjer prevladuje apnenec

For each cadastral district we calculated the proportion of cultivated fields, meadows, pastures, and forest in 1953 and 1987 (Kladnik, 1985). When combined all the data, we were able to calculate average land use for dolomite, limestone, and noncarbonate rock areas for all of Slovenia.

Table 3: Land use in Slovenia according to type of rock

	% field		% meadow		% pasture		% forest	
	1953	1987	1953	1987	1953	1987	1953	1987
Dolomite	10	8	26	25	15	11	45	53
Limestone	9	7	16	15	22	16	44	49
Noncarbonate	15	11	16	18	13	9	47	52

The first fact we can observe from Table 3 is that there is somewhat more field on dolomite than on limestone, but there are more significant differences in the proportions of meadow and pasture. On dolomite we have substantially less pasture areas than on limestone and rather a larger proportion of meadow. This fact clearly reflects intensive agricultural exploitation in dolomite areas compared to limestone karst areas.

Because the official cadastral data followed the changes in land use with quite considerably delay and we could therefore not get an accurate picture, we verified the data on a test area with data from the Agrokarta (Germek, 1987). In the framework of the Agrokarta project which goal was the assessment of current and future use of agricultural land, land use for the whole country was charted on a 1 : 5000 scale. For several districts there were data available in digital form on agricultural use according to survey units and cadastral districts. The computer records also contained data about so-called pedosequence and categories of agricultural land. For analysis we selected the Idrija District because it has a large proportion of dolomite area. The advantage of the data from the Agrokarta is that it also includes overgrown areas.

Table 4: Land use relative to various rock in the Idrija District in 1987 (Source Agrokarta, analysis deals only with agricultural land)

	% field	% meadow	% overgrown
Dolomite	4	89	7
Limestone	2	94	3
Noncarbonate	6	92	1

An interesting finding is that there is a greater proportion of overgrown land on dolomite than on limestone. This can be explained by the fact that in contrast to limestone areas, some very steep slopes in dolomite areas were used for meadows which today are not suitable for mechanized farming. We achieved similar results in an analysis of land use in the Polhov Gradec hills (Gabrovec, 1990).

REFERENCES:

GABROVEC, M., 1990: Pomen reliefa za geografsko podobo Polhograjskega hribovja. Geografski zbornik 30, 5-68. Ljubljana.

GAMS, I., 1992: Geografske značilnosti Slovenije. Ljubljana.

GERMEK, V. et al., 1987: Navodila za izdelavo agrokarte. Republiški komite za kmetijstvo, gozdarstvo in prehrano. Ljubljana.

HABIČ, P., 1982: Pregledna speleološka karta Slovenije. Acta carsologica 10-1/1981, 8-22.

KLADNIK, D., 1985: Problematika zemljiške strukture v luči dolgoročnega razvoja SRS. Inštitut za geografijo Univerze v Ljubljani.

KUNAVER, J., 1983: Geomorfološki razvoj Kaninskega pogorja s posebnim ozirom na glaciokraške pojave. Geografski zbornik 22/1982, 197-346.

LIPEJ, B. 1990. ROTE in EHIŠ. Ljubljana.

ŠIFRER, M., 1963: Nova geomorfološka dognanja na Triglavu. Geografski zbornik 8, 157-210.

RABA TAL NA DOLOMITNIH OBMOČJIH SLOVENIJE

Povzetek

V Sloveniji zavzemajo dolomitne površine približno 2500 km^2, kar predstavlja 12 % ozemlja Republike Slovenije. Večina dolomitov je triasne starosti, desetina pa jih je jurske ali kredne starosti. V Sloveniji je največ dolomitnih pokrajin v predalpskem svetu in na dinarskih planotah. Dolomitna območja se glede rabe tal precej razlikujejo tako od kraških apnenčastih območij kot tudi od nekraških predelov. Značilen je velik delež travniških površin, ki so pogosto tudi na zelo strmih pobočjih. Strmi travniki in pašniki na dolomitnih pobočjih se v zadnjem času vse bolj opuščajo. Tako v Sloveniji opažamo, da je največji delež zaraščajočih se površin prav na dolomitnih predelih.

SPELEOLOMORPHOLOGICAL AND SPELEOHYDROGEOLOGICAL CLASSIFICATION OF SPELEOLOGICAL FEATURES (CAVES AND PITS) IN THE CROATIAN CLASSICAL KARST AREA

SPELEOMORFOLOŠKA IN SPELEOHIDROGEOLOŠKA KLASIFIKACIJA SPELEOLOŠKIH OBLIK (JAM IN BREZEN) NA HRVAŠKEM KLASIČNEM KRASU

MLADEN GARAŠIĆ

Izvleček UDK 551.44:551.49(497.13)

Mladen Garašić: Speleomorfološka in speleohidrogeološka klasifikacija speleoloških oblik (jam in brezen) na hrvaškem klasičnem krasu

Speleološka in hidrogeološka klasifikacija je napravljena na podlagi velikega števila raziskanih objektov. Avtor deli hrvaški kras na notranji, srednji in zunanji pas. V zunanjem prevladujejo vertikalni objekti, v srednjem pa razvejani oziroma objekti v nivojih, često s funkcijo estavele.
Smer glavnih rovov je v tesni zvezi s tektonskimi linijami: 66 % speleoloških objektov je v dinarski smeri, 16 % je nanjo pravokotnih, 18 % pa ima drugačno usmeritev. Po hidrogeološki klasifikaciji deli avtor objekte (od vseh jih ima 35 % hidrološko funkcijo) na 7 skupin.

Ključne besede: speleologija, kraška hidrogeologija, kraška morfologija, jame, brezna, Hrvaška, hrvaški kras.

Abstract UDC 551.44:551.49(497.13)

Mladen Garašić: Speleomorphological and speleohydrogeological classification of speleological features (caves and pits) in the Croatian Classical Karst area

Speleological and hydrogeological classification based upon the great number of investigated speleological objects. The author divides Croatian Karst into Inner, Middle, and Outer Karst belts. In Inner belt vertcal objects predominate while in the Middle one branching and level speleological objects did, often with "estavele" function. Directions of main channels are connected to the tectonics: 66 % of objects are "Dinaric" oriented, 16 % is perpendicular to them, 18 % have other orientation. 35 % of objects have hydrological function and they are divided in 7 groups.

Key words: Speleology, Karst Hydrogeology, Karst Morphology, Caves, Shafts, Pits, Croatian Karst

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INTRODUCTION

Several different classifications of speleological objects have been made up to now. Unfortunately, inconsistencies in some classifications have resulted in the appearance of several criteria within a single division which in turn gave rise to different interpretations and provoked confusion among speleologists and hydrogeologists (Garašić,1993). For example, the division into caves, pits, "ice holes" and potholes in itself contains classification according to the main channel inclination (caves, pits), according to hydrogeological function (potholes), according to the physical condition of materials in a particular object (ice, snow) and, finally according to local names.

The intention was to create a universal classification of speleological objects using speleomorphologic and speleohydrogeologic criteria. Furthermore, numerous examples of objects investigated in the Croatian karst could not be avoided. These classifications can be applied in all karst zones of the world (despite different speleogenesis, tectonics, lithostratigraphy etc.). Classifications of speleological objects made in 1976 and 1982 (Garašić M. & Čepelak, R. 1976, 1982) served as the starting point for this investigation.

SPELEOMORPHOLOGICAL CRITERIA

The shape of a speleological object (cave) depends on lithologic and stratigraphic characteristics of the rocks from which it originates (Moore, G.W. & Sullivan, G. 1978) on the intensity and type of tectonic activity, the underground water activity, the karstification rate and, finally on speleogenesis (Alboy, L. 1975, Garašić, M. 1989a, 1989b, Jasinski, M. 1966).

2.1. Types of speleological objects

While studying the features of caves in the Croatian (Dinaric) karst (Garašić, M. 1986, 1987, Garašić, M. & Cvijanović, D. 1985, 1986) I noticed that their most correct division is based on the main channel inclination (Čepelak, R. & Garašić, M., 1982) since, in this way, the speleological objects, i.e. all cavities in the Earth's crust in which a man can be physically present (Curl, R. 1964, Gvozdeckij, N. 1981), can be divided into caves and pits. It is essential (according to UIS - Union International de Speleologie) that caves must be over 10 meters long, while the depth of pits should exceed 5 meters. Smaller objects are classified only exceptionally if they are characterized by some specific features (e.g., if they are found in rocks where their occurrence is not normally expected or if they are the collapsed parts of some greater objects, etc.).

Other classification, e.g. into caves, pits, potholes, "ice holes", sinkholes etc. could not be regarded as the most appropriate solution since several criteria are adopted in a single division. The same applies for the classification according to local names such as zvekaras, bezdankas, semicaves, potholes,pits,.. etc. as these names are in fact synonyms for the same type of speleo-features.

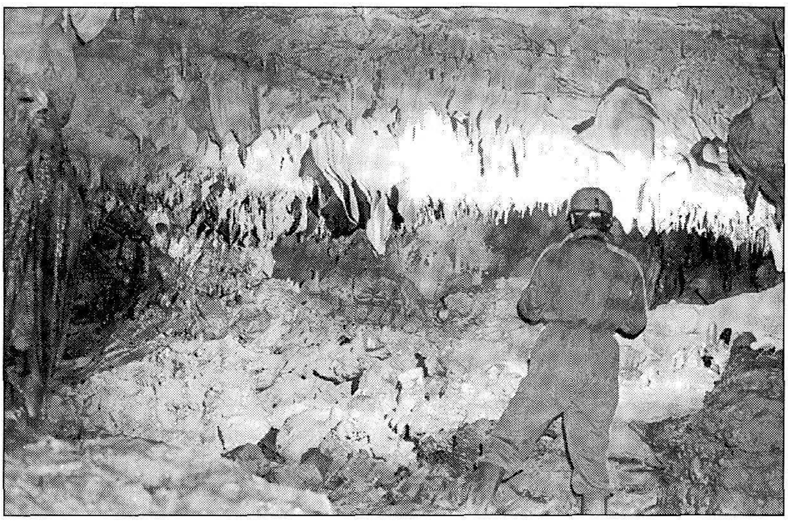
Horizontal speleo-features in Croatia are most commonly formed in zones of slightly inclined bedded rocks, along horizontal longitudinal faults or, less frequently, next to nappes.

Vertical speleo-features encountered in Croatia are usually found near deep reverse faults, anticlines and overturned beds and folds.

Over 7300 speleological objects (caves and pits) are registered in the Croatian karst region (Fig. 1.) and the data for 5263 of such objects are considered in this paper (i.e. dimensions, strikes, forms, types, geological and hydrogeological characteristics, etc.).

2.1.1. Caves

Caves are one type of such speleo-features (Kyrle, G. 1923, Ford, T. & Cullingford, D. 1976) where the main channel is slightly inclined or horizontal. Theoretically, caves include all objects whose main channel is inclined from 0 to 45° (rise or dip) (Renault, P. 1970, Martinoff, A. 1976). About 29% (1526) of all speleo-features encountered in the Croatian karst region are horizontal speleo features. Some examples are: Drljića Cave (Pazarište, Lika), Dančinova



In Croatian karst there are more than 7300 registered caves and pits. Cave Čavle in Dalmatia.

Cave (Raduč, Lika), Pčelina Cave (Mogorić, Lika), Veternica (Medvednica, Zagreb), Cave Lipa (Lokve, Gorski kotar), Kuštrovka (G.Dubrave, Kordun)...total : 1526 caves.

The arrangement of caves in relation to hydrogeologic regionalization is different for individual karst regions (Herak, M. 1976, 1984, 1986). In other words, most of the caves in Croatia are situated in the Inner Karst region (over 65 %), while they are less frequently found in the Outer Karst region (about 24%). Caves are distinguished according to the arrangement of the main channel and side channels: simple caves, dendritic caves, multi-level (etage) caves and cave systems.

2.1.2. Pits

Pits are vertical or inclined speleo-features (inclination from 45° to 90° - rise or dip) (Burke, A. & Bird, F. 1966). In the karst region of Croatia the number of registered pits predominates over the number of caves (3631 pits = cca 69%). Some examples are: Golubnjača pit (Podlapac, Lika), pit called "Jama na Kamenitom vršku" (Delnice, Gorski Kotar), Martineza pit (Buje, Istra), Brgud pit (Dragozetići, island of Cres), Vilim pit (Lokvice, Mt. Biokovo), Trogrla pit (Mt. Dinara), Duple pits (Zrnići, Mt. Velika Kapela), Đurinka pit (Kosinj, Lika), Jama u gaju (Kozalj vrh, Kordun), Lukina jama (Hajdučki kukovi, Velebit)...total : 3631 pits.

Their distribution is unequal in different karst areas of Croatia. Pits account for 76% of all speleo-features in the Outer (Adriatic) Karst belt, and for approx. 30% of such features encountered in the Inner Karst belt. On some localities, pits are almost the only speleo-features, i.e. at Štirovača on Mt. Velebit, Mt. Velika Kapela, on the island of Brač. Pirkovača pit (Lađena, Mt. Biokovo) from the Outer Karst belt is presented in Supičić, Ž. (1981) work. According to the shape and distribution of the main and secondary channels, pits can be: simple pits, branching pits, step-like pits and pit systems.

2.1.3. Combined or complex speleological objects

It is sometimes very difficult or almost impossible to define the character (type) of a speleo-feature. An object may be a combination of vertical and horizontal speleo-features where no single feature is predominant (Fenelon, P, 1974, Bogli, A. 1980, Geze, B. 1965, Audetat, M. 1981). For instance, a speleo-feature with a vertical entrance (pit) may be continued as a cave, while a speleo-feature with a horizontal entrance (cave) may be continued as a pit (Trimmel, H. 1968, Trombe, F. 1973). If vertical and horizontal dimensions are more or less equal, it is impossible to define the type of a speleo-feature. In such cases, we are dealing with complex or combined speleo-features. Such objects account for approx. 2% (106) of all objects found in the Croatian karst and they are linked to the Inner and Middle Karst belt. Some examples are: "Mijatova jama" pit (Matečko selo, Kordun), Kojina cave (Furjan, Kordun), Zakičnica VII pit (Mt. Medvednica, Zagreb), "Vrbanova peć" cave

(Lovinac, Lika)... total : 106 caves.

The complex speleological object of Mijatova pit (Mateško selo, Kordun) from the Inner Karst belt is presented in Garašić, M. (1980.).

2.2. Morphological types of speleological objects

Types of speleo-features called morphologic types may be differentiated according to the shape and distribution of channels in speleological objects.

After analysing the distribution of different morphologic types of speleological objects in the Croatian karst, it is possible to conclude that simple pits and caves generally predominate in the Outer Karst belt (Istria, islands, Mt. Velebit, Mt. Biokovo), that branching speleo-features appear at points where several joint system meet (especially in the Inner and Middle Karst belt - Kordun, partly in Mid-highlands of Lika, etc.), and that the level speleo-features are located in the areas of the neotectonic uplift (Mt. Velebit, Mid-hightlands of Lika, Mt. Dinara, etc) in the Inner and Outer Karst belt, that the steplike pits most often appear in areas with the alternation of limestones and dolomites, i.e. in areas with lithologically and sometimes even stratigraphically different units (i.e. Pit of Bunovac on Mt. Velebit) in Triassic limestones and dolomites, Šimunova pit on Mt. Mala Kapela - the alternation of the Jurassic limestones with cherts and dolomites, etc.), that the cave and pit systems are located in the tectonically very active zones where even hydrogeological relations are such that several speleo-features are joined into a single feature (Kordun, Lika, Gorski Kotar).

2.2.1. Simple speleological objects

Simple speleological objects have only one channel (horizontal or vertical) without secondary ones. Although one might think that simple speleological objects are usually of smaller dimensions, it is not always the case: some caves are more than 200 metres deep (Mamet pit, Mt.South Velebit) and might be over 400 m long (Kuruzovićeva cave, Vaganac, Lika) and are still considered to be simple speleo-features.

It can generally be stated that such objects originate in compact rocks, and that their speleogenesis started from one source.

About 20% (1115) of the total number of speleo-features in the karst of Croatia are simple pits and caves (including abris - rock shelters that are formed almost exclusively by the sea or lake wave action). Some examples are: Mamet pit (Štikada, Mt. Velebit), Kuruzovićeva cave (Vaganac,Lika), Podgračišće II pit (Pražnice, island of Brač), Semič pit (Semič, Istria), Vrtlina cave (Visočica cave, Velebit), Kovačevićeva cave (Pražnice, Island Brač), Pećina kod Plasa (Brinje, Lika), Ponor Sušik sinkhole (Drežnica, Gorski kotar), Pražić ponor sinkhole (Zrnići, Mt. Velika Kapela), Mamulna cave (Bunić, Lika), Zelena cave (Bunić, Lika), Karinčica (Karin, Ravni kotari)...total : 1115 caves.

Simple caves and pits are not equally distributed within karst belts: they are most often found in the Outer Karst belt. The simple cave of Vrtlina on Mt. Velebit is presented in Pavličević, D. (1966), whereas the simple pit

Podgračišće II near Pražnice on the island of Brač is shown Garašić,(1974).

2.2.2. Branching speleological objects

Speleo-features with at least one secondary channel of the horizontal or vertical type are considered a branching type. The size of branching speleo-features is variable (i.e. from several tens of meters to several kilometers). Within the total number of speleo-features found in the karst of Croatia, the branching type is represented by about 30% (1526). Some examples are: Cerovačka Lower cave (Cerovac, Lika), Gospodska cave (Cetina river spring, Dalmatia), Rudelića cave (Civljane, Dalmacija), Cave on Gromački vlak (Dubrovnik, Dalmacija), Zala cave (Gornje Dubrave, Kordun), Cave near Veliki Kozarac (Vrbovsko, Gorski kotar), Hajdova hiža cave (Kuželj, Gorski kotar), Bezdan pit in Sadilovac (Mt. South Velebit), Đukić caves (Tušice, Lika), Mačje pits in Medačka staza (Mt. South Velebit), Golubnjača pit (Veliko Rujno, Mt. Velebit), Gajića cave (Gračac, Lika), Bijela voda cave (Karin, Ravni kotari)...total : 1526 caves.

Most caves are characterized by a maximum of 3 different joint systems that are parallel to the cave (pit) channels. Branching speleo-features are most often encountered in the Inner Karst belt, but they are also frequent in the Middle Karst belt. In the Outer Karst belt branching speleo-features are less represented, what is understandable if one takes into account the fact that this type develops mostly in the horizontal speleo-features that are less common in the Outer Karst belt. The branching speleo-feature Barićeva cave (Ličko Petrovo selo, Lika) located in the Inner Karst belt is presented in Čepelak, R. (1965).

2.2.3. Level speleological objects

Level speleological objects are the objects where cave channels are developed in several different levels or floors. Horizontal speleological objects of this sort are by far more numerous than vertical ones. In the karst of Croatia, they account for approx. 9% (474) of the total number of the registered speleo-features. Some examples are: Veternica (Mt. Medvednica, Zagreb), Cave near Luka (Sića, Kordun), Ostojića cave (Štikada, Lika), Pivnica cave (Mt of Žumberak), Babina cave (Lovinac, Lika), Lokvarka cave (Lokve, Gorski kotar), Bibička cave (Trošt Marija, Gorski kotar)... total : 474 objects.

Such speleo-features are the most numerous in the Inner and Middle Karst belt, particularly in the well bedded limestones. Multi-level speleo-features usually exceed 100 meters in length, while some branching level ones are more than several kilometers long.

2.2.4. Knee-formed speleological objects

Knee formed speleological objects are those that have two or more vertical steps. This morphologic type accounts for approx. 40% (2095) of the total number of speleo-features in the Croatian karst and is therefore the most frequent morphologic type. This is due to the fact that they are developed exclusively in the vertical speleo-features (pits) that are more frequent than caves. Some examples are: Pepelarica sink hole (Jadovno, Mt. Velebit), Vilimova pit (Lokvice, Mt. Biokovo), Jama pit near Rašpor (Rašpor, Istra), Sink hole near Klana (Klana, Rijeka), Jama kod Matešić stana (Gornji Humac, Island Brač), Sink hole Ponikva II (Skrad, Gorski kotar), Batluška pit (Batlug, Istra), Balinka pit (Plaški, Lika), Gligina jama (Studenci, Lika), Jama na Vrščiću (Kuselj, Lika), Ćampari pit (Beli, island of Cres)... total: 2095 objects.

Knee-formed speleological objects are most frequently found in the Outer and Middle Karst belt, especially in the areas with the horizontal or slightly inclined bedding, and with distinct lithologic and stratigraphic changes (ie. changes in Triassic limestones and dolomites on Mt. Velebit, or the alternation of the Jurassic limestones, dolomitic limestones and dolomites on Mt. Biokovo). Their size can vary from a few tens of meters to several hundred meters. The knee formed pit located on the Grgin brijeg (Mt. Velebit) is presented in Garašić, M. (1982).

2.2.5. Cave or pit system

This is the most complex morphologic type of speleo-feature of the Croatian karst. This type can briefly be defined as two or more speleological objects joined into a single unit. The system must have at least two entrances. Only 53 cave systems (approx.1%) are registered in the karst of Croatia and only some of them are a few kilometers long. Smaller speleo systems are found in the Outer Karst belt, while the greatest and most complicated systems are located in the Inner Karst belt - more than 15 kilometers long. Some examples are: Đulin ponor - Medvjedica cave (Ogulin, Gorski kotar), Muškinja cave - Panjkova cave (Kršlja, Kordun), Jopičeva cave - Spring Bent (Brebornica, Kordun), Kiceljeve pits (Little and Big) (Ravna Gora, Gorski kotar), Matešića peć cave system (Lađevac, Kordun)...total : 53 objects.

All cave and pit systems found in the karst of Croatia have strong active water streams which leads us to the conclusion that they are still in the second phase of the speleogenesis. These systems are formed in the Cretaceous and Jurassic limestones, partly in the dolomitic limestones. In my opinion, the number of very complicated systems found so far does not correspond to the actual distribution - I belive that these systems are more numerous.

Cave systems are located in the tectonically very fractured rocks with prominent bedding, and powerful active underground water streams. Cave system Muškinja cave - Panjkova cave (Kršlja, Kordun) located in the Inner Karst belt is presented in Garašić, M. (1984b).

SPELEOHYDROGEOLOGICAL CRITERIA

3.1. Speleological objects and karst hydrogeology

The dependence of good understanding of karst hydrogeology on speleological objects has been known for a long time (Castany, G. 1982). Speleological features with a hydrogeological function, i.e. sink holes, ponors, springs or percolating objects belong to the circulation chain of the karst water. Some authors (Jennings, J. 1971, 1985, Gams, I. 1974, Jakucs, L. 1977, Collignon, B. 1989) even explain the Paleo-conditions in various types of karst by establishing a direct relation with speleological features.

The first scientific theories on karst and levels of subsurface waters are based on data derived from the knowledge about speleological features (Grund, A. 1903, Katzer, F. 1909, Cvijić, J. 1925). Recent investigations, (Bahun, S. 1968, 1969, Bahun, S. & Fritz, F. 1971, Bojanić, L. & Fritz, F. 1970, Herak, M & Stringfield,V. 1972, Magdalenić, A. 1971, 1984a, Milanović, P. 1979), using the modern scientific hydrogeological approach, stress the importance of "Subsurface geology" - speleogeology results, that contribute to better understanding of the Croatian karst (Jurak, V. 1984).

In some karst areas of Croatia, especially near the dividing line of Adriatic and Black Sea drainage areas, speleological features can be significant indicators for defining that dividing line (i.e. Kamenak cave near Vodoteč in Lika - Magdalenić, A.(1984b) or Rokina bezdana near Jezerane in Lika - Garašić, M. 1977). Herak, M. & Stringfield, V. (1972), Milanović, P. (1979) and Baučić, I. (1965) analyze some caves located in the Croatian karst area, where the subsurface connections between sink holes and springs had been established by dyeing. These connections were later confirmed by speleological methods - general strike of cave channels in that area with respect to the direction of underground flows (i.e. Imotsko polje, Sinjsko polje). Zotl,J. (1974) also describes the importance of understanding the karst hydrogeology during the tunnel construction in karst. During the excavation of practically all longer traffic or hydrotechnical tunnels in Croatia, caverns, i.e. speleological features without the natural surface exit - were found (Božičević, S. 1983, Malez, M. 1956, Garašić, M. 1988) in Učka tunnel (over 1350 meters long) Vrbovsko - Stubica (17 caverns up to 50 meters long), tunnel for " Obrovac " reversible power plant (caverns longer than 1,5 kilometres and chambers bigger than 100 metres) and during the construction of some other structures. The necessity of hydrogeological and speleological explorations during the construction of such structures is obvious. In the karst of Croatia in urban areas (ie Rijeka, Split, Dubrovnik) or away from them (ie HPP Sklope in Lika), speleological features that might endanger the stability of constructions at those sites were found during the construction works. Speleological explorations helped to gain more knowledge about the hydrogeology of those areas (Bonacci, O. 1987), indirectly about engineering geological characteristics of rocks on particular sites, and about the possibilities for the safe and correct execution of works. It is nowadays widely accepted that full knowledge about the karst hydrogeology is not possible without proper knowledge of the morphology and hydrogeology of speleological features. That is the reason why the speleological features have been treated as an important part of hydrogeological registers (Šarin, A. & Urumović, K. 1980).

3.2. Hydrogeological function of speleological objects

The inseparable relationship between the karst hydrogeology and speleological features that is derived from the verycomes just from the hydrogeological function (rule) of speleo-features is well known, no matter if it relates to the past or present function (Kempe, S. 1972, Bretz, J. 1942).

If we sort speleo-features with permanent or periodical ground water occurrence that can be found in the karst of Croatia, we may differentiate the following types:

a. Periodical Springs (caves or pits)
b. Permanent Springs (caves or pits)
c. Periodical Sink holes (caves and pits)
d. Permanent Sink holes (caves and pits)
e. Estavelas
f. Vruljas (submarine springs)
g. Percolating speleological objects

3.2.1. Periodical springs

Periodical springs are speleo-features from which water rises during the rainy season. There are 3,5% (193) such springs registered in the Croatian karst. Periodical springs are more often caves than pits, but more than hundred meters deep pits, taken as periodical springs have also been registered (ie. near Vrgorac, Župa, Pavlinovići in Biokovo hinterlands and in Imotska krajina). The periodical spring cave Vrelo (Jasenak, Gorski kotar) is presented in Garašić, M. (1986) work. Some of periodical springs (caves and pits) are: Špilj (Polojska kosa, Kordun), Šutina jama (Potok, Kordun), Zagorska Cave (Josipdol, Lika), Mračna pećina cave (Perušić, Lika), Borina pećina cave (Vrbovsko, Gorski kotar), Duća jama (Katići, Kordun), Pits of Betine (Kokorići, Vrgorac), Gospodska cave (Cetina river spring, Dalmacija), Čavle cave (Muškovci, Zrmanja, Dalmacija). Periodical spring caves are most often located along the rims of karst poljes (Ličko, Gacko, Krbavsko, Sinjsko, Ogulinska zavala etc) in the Middle Karst area. Their function as springs directly defines the underground water level in the defined period. The flow duration is different (from a few hours to a few months in a year), and depends on numerous factors (the drainage area, the underground water links, the width and the size of cave galleries, the altitude, lithostratigraphic properties of rocks, hydrometeorological conditions etc.). "Potajica" (intermittent spring), that yields water periodically within strict time intervals also belongs to this group of speleofeatures (Rikavica, Jablanac, Croatian littoral).

3.2.2. Permanent springs

Permanent springs of cave or pit shape are speleo-features from which water springs throughout the year. The quantity outflow may vary even few hundred times, and it depends on the rain and dry seasons of the year. In the karst of Croatia 0,7% (37) such speleo-features are registered. Some examples of permanent springs (caves and pits) are: Bistrac (Gornje Dubrave, Kordun), Crno vrelo (Kordunski Ljeskovac, Kordun), the Kupa river spring (Gorski kotar), the Rječina river spring (Rijeka), Bent (Brebornica, Kordun), Jastrebinja (Frketić selo, Kordun), Cave near Čankovići (Gračac, Lika)...total : 37 objects.

Until present time, more spring caves than spring pits have been registered, but that does not need to be the final conclusion about their distribution. Spring pits can only be explored by diving (ie. the Kupa river spring, the Slušnica river spring, Sinjac spring), but that is still an insufficiently used speleological technique (Burges, P. 1976, Exley, S. 1973, 1980). At the same time, exploration of spring caves is possible by means of very simple methods (ie. walking in rubber boots, by caving boats etc.). Permanent springs appear more often in the Inner Karst belt, but they are also found in the Middle Karst belt: Sources of almost all karst rivers are located in speleological features, but many of them have not as yet been explored (ie. rivers Zrmanja, Una, Mrežnica, Krupa, Krnjeza etc.). The permanent spring cave Jastrebinja (Frketić selo, Kordun) is shown in Garašić, M. (1977) work, while the spring pit Sinjac (Plavča Draga, Lika) is presented in Garašić, M. (1986).

3.2.3. Periodical sink holes

Periodical sink holes are such speleological objects that funnel water from surface to underground, so they (caves and pits) act as sink holes during the rainy period of the year. All together 5% (258) periodical sink holes are registered in the karst of Croatia. Examples: Ponor on Grgin brijeg (Jadovno, Mt. Velebit), Panjkova cave (Kršlja, Kordun), Ponor Jovac (Bročanac, Kordun), Ponor Vratimnice (Ječmište, Mt. Žumberak), Ponor near Ramna kala (Čimuš, Mt. Žumberak), Jelar ponor (Gračac, Lika)...total : 258 objects. These are relatively frequent speleological features; their relation with periodical springs is variable, but periodical sink holes are the more numerous. The cause should be in the quantity of precipitations that reach the karst surface and immediately sink underground by means of periodical sink - caves and sink - holes. The periodical sink cave Tumarna cave (Perjasica, Kordun) is shown in Garašić, M.(1981), while the periodical sink hole Jama u Zelinu (Crni Lug, Gorski kotar) is presented in Garašić, M.(1986) work.

3.2.4. Permanent sink holes

Permanent sink holes are speleo-features into which water sinks all the year round. The water quantity oscillates a few hundred, and even a few thousand times (i.e. Novokračina cave near Rupa in Istria swallows permanently at least 1 to 2 l/sec, but during rainy periods even more than 10 m^3/sec, Pepelarica ponor sinkhole that swallows from 1 l/sec to a few m^3/sec etc.). In Croatian karst 1% (55) such speleological features that act as permanent sink holes have been registered. Examples are : Perinka pit (Švica ,Lika), Sinkhole Ponor on Bunovac (Mt. South Velebit), Tumarna (Perjasica, Kordun), Đulin ponor (Ogulin, Gorski kotar) (permanently in past, and now periodically) Ponor Gusci (Točak, Kordun), Ponor Bele vode (Crni lug, Gorski kotar), Ponorac (Rakovica, Kordun), Pit in Pazin (Pazin, Istria)...total : 55 objects. They are located near superficial water streams, i.e. by the river banks (i.e. Korana, Krka, Zrmanja, Krnjeza, Krupa etc) or lakes (i.e. Peruča lake, Plitvice lakes), or along the rims of karst poljes when they act as main sink holes (ponors) of sinking rivers (i.e. Lika, Gacka, Ričica, Obsenica, Lička Jasenica etc.). The sinkhole Ponor on Bunovac (Mt. South Velebit) that acts as a permanent sink hole is presented in Garašić, M. (1978).

3.2.5. Estavelas

Estavelas are morphologically complex speleo-features (Forti, P. & Cigna, A. 1978), that are hydrogeologically acting as periodical springs and periodical sinks. The water rises from estavelas during high underground water level (rainy season), but with the falling water level, estavelas became sink holes. In the karst of Croatia 7,5% (387) estavelas are registered. They are situated exclusively in the Middle Karst belt. Examples are: Velika pećina (Blata, Lika), Markarova pećina (Stajnica, Lika), Dabar pećina (Dabar, Lika), Pećina kod Tisovca (Lika), Budilovica pećina (Lička Jasenica, Lika), Pećina pod Sitnikom (Dabar, Lika), Crnačka pećina (Jezerane, Lika), Crna pećina (Pazarište , Lika)...total : 387 objects. Garašić, M. (1986) shows the estavela Markarova pećina (Stajnica, Lika) located in the Middle Karst belt.

3.2.6. Vruljas

Vruljas are speleo-features situated under the sea level (Exley, S. & Young, F. 1982) that act as fresh water springs. They may be permanent or periodical depending on the fresh water supply. They are characteristic exclusively for the Outer Karst belt (Alfirević, S. 1969). In the karst of Croatia 9 (0,3%), such speleo-features have to this date been explored. Examples are: vruljas near Ika, Volovsko, Novi Vinodolski, Senj, Jablanac, Makarska...total : 9 objects. Their length varies from 8 to 23 meters, and the depth from 10 to 30 meters, and pits are predominant. The presently available data are insufficient for generalization.

3.2.7. Percolating speleological objects

Percolating speleo-features are those where the active water stream percolates through, but neither come from the surface (sinkholes), nor springs at the entrance (spring cave). Such speleological features are the most numerous in the Croatian karst and 17% (903) such features have been registered. They represent the real treasure of hydrogeological data because the presence of underground water in the particular karst areas can only be determined by their direct explorations. Percolating speleological objects are the most usual in the Inner and Middle Karst belts. Garašić, M. (1986) shows the percolating cave Tamnica (Potok, Kordun). The examples for percolating speleo-features are: Veternica (Mt. Medvednica, Zagreb), Jopičeva cave (Brebornica, Kordun) Tamnica cave (Potok, Kordun), Mijatova jama (Mateško selo, Kordun), Mandelaja

(Oštarije, Kordun), Babina cave (Raduč, Lika), Cave Jama pod Debelom Glavom (Blagaj, Kordun), Rokina bezdana (Jezerane, Lika), Javornica cave (Mt. Medvednica, Zagreb).

3.3. Water in the speleological objects

Analysis of the hydrogeological function of speleological objects in Croatian karst shows that 35% (1842) of the total number of speleo-features have a hydrogeological function (i.e. have active water), and about 65% (3421) speleo-features are dry. However, even among the "dry" speleological objects there are some with dribbling water or moisture, but in negligible quantities. It should be noted that many speleo-features are not speleologically explored so that it is not possible to exactly define the number of permanent spring caves and pits in the Croatian karst. After statistical analysis of 35% (1842) of all speleological objects with water, the following results were obtained: 10,5% (193) periodical springs, 2% (37) permanent springs, 14% (258) periodical sink holes, 3% (55) permanent sink holes, 21% (387) estavelas, 0,5% (9) vruljas and 49% (903) are percolating objects.

The analysis shows that hydrogeologically percolating speleological objects and estavelas are the most frequent in Croatian karst. Most estavelas are located along the rims of poljes (Ličko, Stajničko, Crnačko, Drežničko, Krakarsko, Ogulinsko, Blata, Gračačko etc) in the Middle Karst belt. Estavelas are related to the contacts of permeable and impermeable strata (most often Jurassic and Cretaceous limestones and dolomites with Quaternary clays).

If we consider the water present in speleo-features, we might say that it is most abundant in Mt. Mala Kapela (estavelas and sink holes), i.e. Jasenak, Drežnica, Crnac, Krakar, Stajnica, Glibodol, Dabar, Jezerane, Lička Jasenica, Blata, Plaški, Latin, Josipdol, Musulinski potok etc.,and in Lika region - Mid-highlands of Lika,Vrebac, Mogorić, Ploča, Lovinac, Sv. Rok, Raduč, Štikada, Gračac, Bunić, etc. Percolating speleological objects are also most often found in Lika (Švica, Kompolje, Raduč, Perušić, Pazarište, Korenica etc) and in Kordun (Perjasica, Primišlje, Donje and Gornje Dubrave, Potok, Tounj, Kukača, Slunj, Rakovica, Skradska gora, Polojska kosa, Tržačka kosa etc.). Speleological objects with permanent water are rare in Istria (ie. Pincinova pit near Poreč or in the cavern in the "Učka" tunnel) and on the islands. But, on the islands of Kornati there are 47 registered pits with brackish water (so called bunar pits). In the Bukovica, North Dalmatia and Ravni kotari some speleological objects with water are located near the canyons of the rivers Zrmanja, Krka and Karišnica (Muškovci, Karin, Islam Latinski, Žegar etc), periodical spring caves Bijela voda cave (Karin), Čude cave (Obrovac), Čavle cave (Muškovci). The Krnjeza river spring is significant (the flow estimated in July 1977 was 2 m^3/sec). The speleological objects with water in South Dalmatia are rare (Cave Močiljska, Cave near Gromački vlak near Dubrovnik and Šipun cave in Cavtat (brackish water). The Inner region of Biokovo hinterland has plenty of water in speleological objects, predominantly in pits (i.e. Gvozdenica cave near

Zagvozd, Pit in Pavlinovići, Rebići, Župa, Orah, Kokorići, Vrgorac etc.). In the Northern Gorski kotar there are speleological objects with permanent function as spring (i.e. Trbuhovica cave near Prezid, Tejina pit near Čabar, Zeleni vir spring near Skrad, Pit on the Prezidanski Berinšćek, Cave in Tršće etc.), but the largest number of speleological features in that area function as sinks. Almost always, the sink holes in Gorski kotar are located at the contact between Triassic or Jurassic limestones or dolomites and older Paleozoic clastites (sandstones, micaceous schist and shales etc.).

The quantity of water in speleological objects may in a certain way show even the reserves of underground water in some areas of Croatian karst. For instance, the quantities of water in Rokina bezdana pit near Jezerane (Mt. Mala Kapela) were estimated. On average flow in the dry season was between 0,5 and 2 m^3/sec (from 1971 to 1988, it was measured eleven times in October and November). The flow rises a few dozen times during the rain seasons (estimated by the erosion marks on rocks in the cave and detritus deposited on the higher terraces inside the cave). In Velika pećina near Blata (Lika), there is 10000 to 20000 m^3 of water that does not flow out of the cave during the dry season. In the cave under Sitnik (Dabar, Lika), the steady inflow during July and August (5 measurements in 1976, 1981, 1983, 1987 and 1990) is between 300 and 500 l/sec. In Babina cave, that is located near Opsenica sink hole (Lika), during the summer months the flow ranges from 0,9 to 1,5 m^3/sec, in spite of the smaller volume of water in Opsenica sinking hole during the superficial flow (it even dries out completely). Furthermore, lakes 250 to 650 metres long with some 25000 m^3 of water were found in Panjkova and Muškinja cave. A steady flow in dry months (measured in 1983 and 1987) varies from 100 to 200 l/sec. Even during the big drought in the autumn of 1983, this cave system had plenty of water. Such examples are numerous in the Croatian karst, i.e. Krčić, Crno vrelo, river Radašica spring, river Lička Jasenica spring, river Slušnica spring etc.

In the sink holes of Croatia, I witnessed on several occasions the rapid rise of water and I estimated the quantity, ie. in Novokračina cave (Rupa, Istra) on November 17, 1967 the amplitude of the wave was 1 meter, and length 10 metres, and the speed was 3 m/sec, the flow was approx. 30 m^3/sec. In the Ponor pit on Bunovac (Mt. South Velebit), the flow registered on July 13, 1977 was 2 m^3/sec at the depth of 65 metres, and in Panjkova cave, the flow registered on November 25, 1985 at the cave entrance was 2 - 3 m^3/sec. Garašić, M. (1977, 1981c, 1986, 1990) quotes the data about some speleological objects with water in Croatian karst and specifies the water quantity (flows) for some of them.

CONCLUSION

Based on the data of large number (5263) of researched speleological objects (features) in the Croatian Karst, morphological and hydrogeological classification was made. It is a matter of a large number of objects, the largest accumulated at one place in Croatia up to now. Situation, morphology, hydrogeological function, as well as the genesis type of speleological object show particular regularity in appearances of these phenomena in Croatian karst. Since Croatian karst, due to hydrogeological districts (areas),is divided in Inner, Middle and Outer karst region (zone), incline and form classification of the cave channels (morphologicaly) , and according to hydrogeological function, exactly add and built an additional part to the mentioned hydrogeological districts (areas), for example, in the Outer karst region (zone) vertical speleological objects (shafts and pits) predominate, those of simple or knee type, in Middle karst region (zone) branching or level speleological features predominate, with estavela function, etc.

Speleogenesis, not specialy prominent in this work, but serving as a classification base, caused the appearance of every type of speleological object (feature) in tectonic function (especially neotectonic), in lithostratigraphic and hydrogeological functions and geological processes of erosion, corrosion, abrasion etc.

The orientation of the main channels of speleological objects is closely connected with the appearance of faults, folds, anticline crests in certain areas of the Croatian karst. About 66% (3474) speleological objects are oriented in the direction NW - SE, so called "Dinaric direction", while 16% (842) objects are almost vertical on that direction, and 18% (947) objects are oriented in different directions.

In the Croatian karst, 29% (1526) of the caves (horizontal objects) are registred, which are mostly in the Inner and Middle karst region. Also were found 69% (3631) of the pits and shafts (vertical objects), and they are mostly in the Outer and Middle karst region. In the Inner karst region weer there 2% (106) of speleological objects that are combined or complex, it is difficult to determine wheather they are pits or caves.

According to the form and distribution of the channels in the objects, Croatian speleological features are divided into simple caves and pits 20% (1115), branching objects 30% (1526), multi-level objects 9% (474), knee-formed objects 40% (2095) and cave systems 1% (53).

From the hydrogeological standpoint, speleological objects are divided according to the hydrogeological function - dry objects 65% (3421) and objects with water 35% (1842). Water is always (continually) present in about 19% (1000) of the objects, and in 16% (842) of the objects it depends of the seasons.In the Croatian karst water appears in the speleological objects with following hydrogeological functions : periodical springs (caves or pits) 3,5%

(193), permanent springs (caves or pits) 0,7% (37), periodical sink holes (caves or pits) 5% (258), permanent sink holes (caves or pits) 1% (55), estavelas 7,5% (387), vruljas 0,3% (9) and percolating speleological objects 17% (903).

Percentage maybe slightly differs the relations among occasional classes, but it is confident that all the morphological and hydrogeological classifications will be the basis of further more precise divisions. Using these classifications, every speleological object in the Croatian karst, will be defined in a morphological and hydrogeological sense.

REFERENCES

Alboy, L. (1975) : Initations a la Speleologie. Bonnerman, pp.1-119,Paris.

Alfirević, S. (1966) : Jadranske vrulje u vodnom režimu Dinarskog primorskog krša i njihova problematika. Krš Jugoslavije, vol.6, pp.183-200, JAZU, Zagreb, 1969.

Audetat, M. (1981) : Notions de geologie,geomorphologie et hydrogeologie a l'usage des speleologues. SSH, pp.1-163, Geneve.

Bahun, S. (1968) : Geološka osnova hidrogeoloških odnosa krškog područja između Slunja i Vrbovskog. Geološki vjesnik, vol.21, pp.19-81, Zagreb.

Bahun, S. (1969) : On the formation of karst dolinas. Geološki vjesnik, vol.22, pp.25-32, Zagreb.

Bahun, S. & Fritz, F. (1971) : Hidrogeologija Ličkog polja. Zbornik radova I Simpozija hidrogeol. i inže.geol., Hercegnovi, pp.7-13, Beograd.

Baučić, I. (1965) : Hydrogeological characteristics of the Dinaric Karst in Croatia with special regard to the underground water connections. Naše jame, vol.7, no.1-2, pp.61-72, Ljubljana.

Bojanić, L. & Fritz,F. (1970) : Geološki i hidrogeološki odnosi u području Crnog Luga. I Kolokvij geol. Dinaridov. Ljubljana.

Bonacci, O. (1987) : Karst Hydrology. pp.1-184, Springer verlag, Berlin, New York.

Božičević, S. (1983) : Otkrivanje i proučavanje šupljina pod građevinama u kršu. Mehanika stijena, temeljenje, podzemni radovi. Knjiga 1, pp.53-75, Zagreb.

Bogli, A. (1980) : Karst hydrography and Physical Speleology. pp.1-270, Springer Verlag, Berlin, New York.

Bretz, J. H. (1942) : Vadose and phreatic features of limestone caverns. Journal geol., vol.50, pp.675-811, New York.

Burges, P. (1976) : The cave Divers. pp.1-239, Dodc, Mead Along, New York.

Burke, A. & Bird, P. F. (1966) : A new mechanism for the formation of vertical shafts in carboniferous limestone. Nature, vol.210, pp.831-832

Castany, G. (1982) : Principes et methodes de l'hydrogeologie. pp.1-238, Dunod Universite, Paris.

Collignon, B. (1989) : Speleologie approches scientifiques. pp.1-238, Edisud, Aix-en-Provence.

Curl, R. N. (1964) : On the definition of the cave. NSS Bulletin, vol.22, no.1, pp.66.76, Huntsville.

Čepelak, M. (1978) : Speleološka ekspedicija "Bunovac 77". Naše planine, vol.30, no.1-2, pp.7-9, Zagreb.

Čepelak, R. (1965) : Barićeva pećina. Naše planine, vol.17, no.9-10, pp.199-200, Zagreb.

Čepelak, R. & Garašić, M. (1982) : Tumač Zapisnika speleološkog istraživanja. Komisija za speleologiju PSH, II izdanje, pp.1-48, Zagreb.

Exley, S. (1973) : The enviroment of cave diving. pp.1-19, Miami.

Exley, S. (1980) : Basic cave diving, pp.1-46, Jacksonville.

Exley, S. & Young, F. (1982) : Cave diving manual. National Speleological Society, pp.1-292, Miami.

Fenelon, P. (1974) : Phenomenes karstiques .Ed. Centre National de la Reser. Scien. Analtole, vol.15, pp.1-374, Paris.

Ford, T. D. & Cullingford, C.H. (1976) : The Science of Speleology. pp.1-593, Academic Press, London, New York.

Forti, P. & Cigna, A. (1978) : Grotte e fenomeni carsici. Manuale di speleologia. pp.95-178, Longanesi, Milano.

Gams, I. (1974) : Kras. pp.1-360, Slovenska matica, Ljubljana.

Garašić, M. (1974) : Podgračišće II - najdublja jama u Hrvatskoj. Naše planine, vol.26, no.7-8,pp.127-129, Zagreb.

Garašić, M. (1977) : Neki speleološki objekti s vodom u našem kršu. Diplomski rad, pp. 1-75, V tabl., RGN fakultet, Zagreb.

Garašić, M. (1978) : Istraživanje Bunovca. Naše planine, vol. 30, no.1-2, pp.12-14, Zagreb.

Garašić, M. (1980) : Mijatova jama. Sedmi jugoslavenski speleološki kongres, Herceg Novi, 1976. pp-135-142, Titograd.

Garašić,M. (1981a) : Neki speleološki objekti s vodom i praćenje neotektonske aktivnosti u njima. Magistarski rad, pp.1-93, XI tabl., Sveučilište u Zagrebu.

Garašić, M. (1981b) : Neotectonics in some of the speleological objects in Yugoslavia. Proceedings of 8 th International Congress of Speleology, Bowling Green, pp.148-149, Bowling Green, USA.

Garašić,M. (1982) : Ponor na Grginom brijegu. Naše planine, vol.34, no.11-12,pp-273-275, Zagreb.

Garašić, M. (1984a) : Proučavanje tektogeneze u spiljama. Priroda, vol.73, no.1, pp.21-22, Zagreb.

Garašić, M. (1984b) : Neotektonske aktivnosti kao jedan od uzroka geneze i morfologije jednog od najvećih spiljskih sistema u Hrvatskoj. Deveti jugoslavenski speleološki kongres, Karlovac, Zbornik predavanja, pp.457-465, Zagreb.

Garašić, M. & Cvijanović, D. (1985) : Speleološke pojave i seizmička aktivnost u krškim poljima. Naš krš, vol.18-19, pp.103-109, Sarajevo.

Garašić. M. & Cvijanović, D. (1986) : Speleological phenomena and seismic activity in Dinaric karst area in Yugoslavia. Communicacions ,9 th Congresso International de Espeleologia, vol.1, pp.94-97, Barcelona.

Garašić, M. (1986) : Hidrogeologija i morfogeneza speleoloških objekata u kršu SR Hrvatske. Disertacija, pp.1-155, Sveučilište u Zagrebu.

Garašić, M. (1987) : Dominantan utjecaj geoloških uvjeta na morfološke i hidrogeološke tipove speleoloških objekata u hrvatskom kršu. Naš krš, vol.22, pp.141-150, Sarajevo.

Garašić, M. (1988) : Speleološki objekti u tunelu Vrbovsko - Stubica. I Jugoslavenski simpozij o tunelima, Brioni, no.1, pp.83-90, Zagreb.

Garašić, M. (1989a) : New concept of morphogenesis and hydrogeology of the speleological objects in karst area in Croatia (Yugoslavia) from the geological point of view. 10 th International Congress of Speleology, Proceedings, vol.1, pp.234-236, Budapest.

Garašić, M. (1989b) : Utjecaj podzemne vode na stijene proučavane prilikom speleoloških istraživanja u našem kršu. VII jugoslavenski simpozij za mehaniku stijena i podzemne radove, Zbornik radova, pp.199-204, Beograd.

Garašić, M. (1990) : Jama pod Debelom glavom - speleološki objekt na razvodnici slivova rijeke Korane i Gline. Spelae ologia croatica, vol.1, pp.9-14, Zagreb.

Garašić, M. (1993) : The karstification process and hydrogeological features of the mesozoic rocks in the karst of Croatia (Europe). Proceedings of the XI International Congress of Speleology, pp.1-4, Beijing, China.

Garašić, M. & Kovačević, T. (1990) : Speleohidrogeologija Velike pećine kod Blata u Lici. Spelaeologia croatica, vol.1, pp.15-19, Zagreb.

Geze, B. (1965) : La speleologie scientifique. pp.1-191, Raylon, Paris.

Gvozdeckij, N. A. (1981) : Karst. pp.1-212, Mir, Moskva.

Herak, M. (1976) : Jugoslavenski prilog poznavanju hidrogeologije i geomorfologije krša. Zbornik jug. amer. simpozija, Dubrovnik, pp.1-24, Sarajevo, 1976.

Herak, M. (1984) : Tektonski okvir speleogeneze. Deveti jugoslavenski speleološki kongres, Karlovac, Zbornik radova, pp.111-131, Zagreb.

Herak, M. (1986) : A new concept of geotectonic of the Dinarides. Acta geologica, vol.16, no.1, pp-1-42, JAZU, Zagreb.

Herak, M. & Stringfield, V. T. (1972) : Karst. Important regions of the northern hemisphere. pp.1-551, Elsevier, Amsterdam.

Jakucs, L. (1977) : Morphogenetics of the karst regions. pp.1-387, Academia Budapest, Bristol.

Jalžić. B. (1993):Jama nad jamama: Hrvatski planinar, vol.85, br.9-10,str.196-199, Zagreb.

Jasinski, M. (1966) : La speleologie. pp.1-112, Arts et voyages, Bruxelles.

Jennings, J. N. (1971) : Karst. pp.1-252, MIT Press, London.

Jennings, J. N. (1985) : Karst geomorphology. pp.1-293, Basil Blackwell, Oxford

Jurak, V. (1984) : Hidrogeološka interpretacija krškog područja kao putokaz za speleološka istraživanja. Deveti jugoslavenski speleološki kongres, Karlovac, Zbornik radova, pp.237-250, Zagreb.

Kempe, S. (1972) Cave genesis in gypsum with particular reference to underwater conditions. Jour. Brit. Spel. Asso.,vol.6, pp.1-6, London.

Kyrle, G. (1923) : Grundriss der theoretische Speläologie. pp.1-353, Wien.

Magdalenić, A. (1971) : Hidrogeologija sliva Cetine. Krš Jugoslavije, vol.7/4, pp.89, JAZU, Zagreb.

Magdalenić, A. (1984a) : Hidrogeologija otoka Paga. Krš Jugoslavije, vol.10/6, Zagreb.

Magdalenić, A. (1984b) : Značenje pećine Kamenak za određivanje regionalne razvodnice između Crnomorskog i Jadranskog sliva. Deveti jugoslavenski speleološki kongres, Karlovac, Zbornik radova, pp.261-268, Zagreb.

Malez, M. (1956) : Pećina Drenovac. Speleolog, vol.4, no.3, pp.52-56, Zagreb.

Marbach, G. & Rocourt, J. (1980) : Technique de la Speleologie Alpine. pp.1-352, Milau.

Martinoff, A. (1976) : La speleologie. pp.1-208,Marabout service, Limburg, Belge.

Milanović, P. T. (1979) : Hidrogeologija karsta i metode istraživanja. pp.1-302, Trebinje.

Moore, G. W. & Sullivan,G. N. (1978) : Speleology. The study of caves. pp.1-150, Zephyrus Press, Teaneck, USA.

Pavličević, D. (1966) : Jama Vrtlina na Velebitu. Naše planine, vol.18,no.3-3, pp.61-63,97-98, Zagreb.

Renault, P. (1970) : La formation des Cavernes. Univer. Presse, no.1400, pp.1-126, Paris.

Supičić, Ž. (1981) : Prilog poznavanju speleoloških objekata na području Biokova (Srednja Dalmacija).Osmi jugoslavenski speleološki kongres, Borsko jezero, 1980. pp-113-118, Beograd.

Šarin, A. & Urumović, K. (1980) : Bimorfni hidrogeološki katastar. Zbornik referatov 6. jug. simp. o hidrogeol. i inženjer. geol., Portorož, knjiga 1, pp.79-87, Beograd.

Trimmel, H (1968) : Höhlenkunde. pp.1-300, Vieweg, Braunschweig.

Trombe, F. (1973) : La Spéléologie. Universitas Presse, no.709, pp.1-128, Paris.

Zötl, J. G. (1974) : Karsthydrogeologie. pp.1-291, Springer verlag, Wien, New York

SPELEOMORFOLOŠKA IN SPELEOHIDROGEOLOŠKA KLASIFIKACIJA SPELEOLOŠKIH OBLIK (JAM IN BREZEN) NA HRVAŠKEM KLASIČNEM KRASU

Povzetek

Speleološka in hidrogeološka klasifikacija je napravljena na podlagi velikega števila (5263) raziskanih speleoloških objektov. Avtor deli hrvaški kras na notranji, srednji in zunanji pas. V zunanjem prevladujejo vertikalni objekti, v srednjem pa razvejani oziroma objekti v nivojih, često s funkcijo estavele. Smer glavnih rovov je v tesni zvezi s tektonskimi linijami: 66 % speleoloških objektov je v dinarski smeri, 16 % je pravokotnih na to smer, 18 % pa ima drugačno usmeritev. Po hidrogeološki klasifikaciji deli avtor objekte (od vseh jih ima 35 % hidrološko funkcijo) na 7 skupin: občasni izvir, stalni izvir, periodični ponor, stalni ponor, estavela, vrulja, pretočni speleološki objekt.

SPELEOLOGICAL FEATURES (CAVES AND PITS) AND THE KARSTIFICATION PROCESS OF THE MESOZOIC ROCKS IN THE CLASSICAL KARST OF CROATIA

SPELEOLOŠKE OBLIKE (JAME IN BREZNA) IN ZAKRASEVANJE MEZOZOJSKIH KAMNIN NA KLASIČNEM KRASU HRVATSKE

MLADEN GARAŠIĆ

Izvleček UDK 551.44:551.49(497.13)

Mladen Garašić: Speleološke oblike (jame in brezna) in zakrasevanje mezozojskih kamnin na klasičnem krasu Hrvatske

Analiza in računalniška obdelava preko 7300 speleoloških objektov na Hrvaškem (JV Evropa) kažeta, da je tako veliko število objektov tudi odraz kraških procesov. Predvidoma je na Hrvaškem okoli 17000 jam, kar je veliko število, glede na relativno majhno ozemlje. Hidrogeološki vidiki zakrasevanja kažejo na medsebojno odvisnost med talno vodo in intenzivnostjo zakrasevanja. Meritve kažejo na neotektonsko aktivnost, ki sega vsaj nekaj km globoko v mezozojske kamnine. To dokazujejo tako geofizični poizkusi kot tudi običajna vrtanja. Čeprav je zakrasevanje proces, ki zahteva dolgotrajne raziskave, že predhodne raziskave, predstavljene v tem prispevku, kažejo, da je zakrasevanje na teh območjih tako intenzivno, kot redkokje drugod na svetu.

Ključne besede: speleologija, zakrasevanje, jame, brezna, mezozojske kamnine, klasični kras, Hrvaška.

Abstract UDC 551.44:551.49(497.13)

Mladen Garašić: Speleological features (caves and pits) and the karstification process of the Mesozoic rocks in the Classical Karst of Croatia

The analysis and computer data processing for over 6500 speleological structures found in Croatia (southeast Europe) shows that the formation of a great number of caves and pits discovered in this area is also due to the process of karstification. It is assumed that there are about 17000 caves in Croatia which is a great number considering the relatively limited area in which they have been formed. Hydrogeological aspects of the karstification process point to the dependency between the ground water occurrence and the intensity of karstification. The measurements show neotectonic activity in the Croatian karst which spreads at least several kilometers into the depth of the Mesozoic rocks. This has been proven through geophysical testing, but also through trial boring. Although the karstification process is a phenomenon which will have to be investigated over a long period of time, the initial investigations presented in this paper already show that the karstification in this area is of intensity rarely found in other regions of the world.

Key words: Speleology, Karstification, Caves, Pits, Mesozoic Rocks, Classical Karst, Croatia

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INTRODUCTION

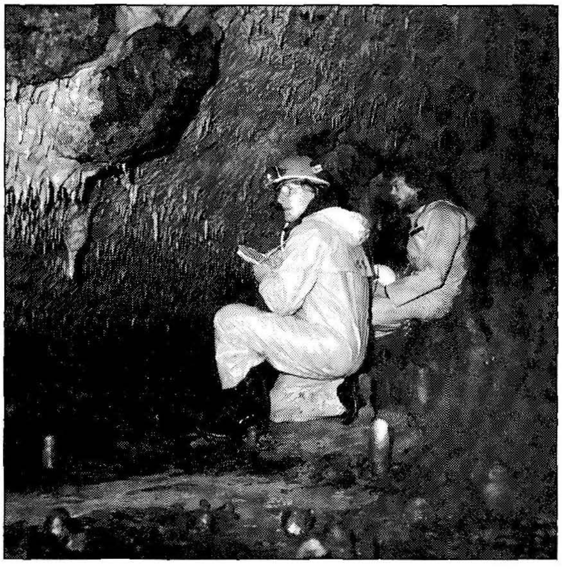
The karstification process has been observed in the speleological structures of Croatia in many localities (Garašić, 1993), but it is most marked in the Mesozoic rocks of the carbonate facies. These rocks are mostly limestones, dolomitic limestones, lime dolomites of the Trias, Jurassic and Cretaceous with all their varieties, from both lithologic and stratigraphic aspects. Among the over 7300 speleological structures that have been explored to this date, about 77% are vertical structures (pits), 22% are horizontal (caves), while the remaining 1% are combined speleological structures (Garašić, 1986,1991). Results obtained by trial boring in the Adriatic karst of Croatia show that karstification processes occur even at depths of over 4 km. Speleothems formations have been found in the Jurassic limestones. It should be noted that the thickness of Mesozoic rocks found in that area amounts to approx. 8 km. However, the best observations of karstification processes have been made in the course of speleological investigations.

THE INFLUENCE OF THE PRECIPITATION, TEMPERATURE AND ALTITUDE ON THE FORMATION OF SPELEOLOGICAL STRUCTURES IN CROATIA

The mean annual (present-day) quantity of precipitation in Croatian karst amounts to approx. 1500 mm/year. The areas of Gorski kotar, Velebit, Biokovo and the region in the hinterland of the Adriatic have over 2000 mm/year of annual precipitation. The coastal area has the Mediterranean precipitation regimen so that it has up to 50% less precipitation in the hot half of the year and is thus characterized by an irregular annual distribution of rainfall. The analysis of speleological structures and the precipitation rate show that speleological structures are more frequent in regions with greater rainfall (annual precipitation from 2500 to 3500 mm) such as in the Delnice area and at the north side of Velebit (Pavić, 1975). This is due to the greater oportunity for the carbonate rock dissolution. There are however some areas (e.g. in Istria) with an average present-day precipitation rate (from 1000 to 2000 mm/year) where the speleological structures are also quite frequent (Rogić, 1975). The reason for that may be sought in an intensive tectonic activity although it is most probably due to paleoclimatic conditions. The analysis shows that some very intensely karstified terrains have been formed in regions that currently do not abound in rainfall, such as in Istria and on the island of Brač (Friganović, 1975), but the precipitation rate in such areas was certainly intensive in the period of primary karstification. It may generally be stated that the majority of speleological structures now at the main or even initial stage of formation are situated on the mountain massifs characterized by high precipitation (Velebit, Dinara, Mosor, Velika Kapela, Mala Kapela, etc.). The present-day precipitation rate on the ground surface does not necessarily constitute the basis for the formation of speleological structures because the paleoclimatic conditions are the most significant factor. These conditions have significantly changed in some areas.

The air temperatures in Croatian karst are quite variable, i.e. on the Adriatic coast the winters are mild with the mean January temperatures ranging from +5.5 to +9.6 C, while the summers are warm so that the mean air temperature in July varies from +22.8 to +26.2 C. In the mountainous regions of the Croatian karst the winters are cold - the mean temperatures in January range from -1.9 to -4 C, while the summers are fresh - with the mean temperatures varying from +14.9 to +20.3 C. The relative humidity of air falls when going from north towards the south, i.e. from 85% in Gorski kotar to 65% in southernmost areas of the Croatian littoral (Dubrovnik) (Šarin, 1983).

Speleological structures situated at higher altitudes in areas with low mean annual temperatures and characterized by specific cave shapes and a particular orientation of cave channels and entrances may have snow and ice on their



entrances throughout the year. Such structures are called ice caves and snow caves. They can be found on Velebit (Garašić, 1981), in the region of Gorski kotar, on Biokovo and Dinara. Channel volumes of such structures are much greater than those of nearby structures not containing snow and ice. This is due to the fact that snow and ice mechanically (by dilatation, breaking) wear the rocks thus widening the spelological structures. This is a specific process of karstification. A former action of ice and snow has been observed in some speleological structures, while today such action is negligible, e.g. in the cave near Bačić kuk in Crni Dabar, and in Lukina jama near Hajdučki kukovi and Veliki Lom on Velebit Mt. This is due to paleoclimatic conditions which were earlier much different than they are today, e.g. in Istria or in the central part of Velebit, where visible traces of the former action of glaciers and moraine materials were discovered in the investigated speleological structures.

The possible relationship between latitude and the occurrence of speleological structures has not been established in the Croatian dinaric karst as the karst area is too small when compared to some greater karst areas situated in other parts of the world.

It may be assumed that the present-day altitude of cave entrances is not relevant for the genesis of speleological structures, as their formation is strongly influenced by the paleogeographic conditions.

In Croatia, most speleological structures are located at altitudes ranging from 450 to 850 m above the sea level. Some areas at these altitudes are characterized by a relatively high quantity of precipitation (Lika, Gorski kotar). Both horizontal (32%) and vertical (68%) speleological structures are found at these altitudes. It is interesting to note that the longest speleological structures in the Croatian karst have been found at altitudes ranging between 300 and 350 meters (Đulin ponor, Medvedica, Panjkova spilja (Garašić, 1991b), Muškinja, Jopičeva spilja) (Garašić, 1989). The deepest speleological structures have been found at altitudes ranging from 1100 to 1500 meters (Garašić, 1986a). The deepest cave in Croatian karst ares is Lukina jama near Hajdučki kukovi on North Velebit Mt. with depth -1355 meters.

The analyses of altitude and speleological structures do not always show the most realistic relationships (Maull, 1938; Gvozdeckij, 1981) with respect to the frequency of occurrence of speleological structures. This is due to the fact that many parts of the Croatian karst, particularly those situated at higher altitudes, have not as yet undergone speleological investigation and that most of the Croatian karst is situated at the higher altitudes. It is however certain that horizontal ground water displacement, and hence the greater number of horizontal speleological structures in Croatia, may today be expected on altitudes not exceeding 300 m (internal karst area), while vertical structures that have reached the main stage of their genesis may be expected on altitudes above 800 meters.

The analysis of the present-time quantity of precipitation, temperature and altitude shows certain regularity in the occurrence of speleological structures. But this analysis does have some limitations which are primarily due to the fact that paleogeographical and paleoclimatic conditions have at some locations been significantly changed since the time of initial formation of speleological structures.

LITHOSTRATIGRAPHICAL DATA SIGNIFICANT FOR KARSTIFICATION

Lithostratigraphical properties of the rocks in which speleological structures may develop are of great significance for the formation and development of speleological structures. These properties have been analyzed in a number of published papers (Swinnerton, 1982; Ford, 1972; Kempe, 1972), and for Croatian karst (Poljak, 1914, 1925; Garašić, 1977; Božičević, 1985).

The karstification is a relatively regular process so that the rocks in which speleological structures are found may be determined through stratigraphic and lithologic analysis. The principal karstification in Croatia occurred in Mesozoic limestones, dolomitic limestones, lime dolomites and dolomites.

About 6% of all speleological structures found in Croatia are situated in the Trias dolomites, dolomitic limestones, lime dolomites and limestones. These structures are of fractured nature, although there is also a number of caves and pits that are quite developed so that some of them are characterized by greater dimensions, such as Veternica, Ponor on Bunjevac (southern part of Velebit), etc. Most structures formed in Trias dolomites are characterized by the constant presence of ground water which can be explained by the relative impermeability of Trias formations with respect to some other formations, such as chalky limestones. In the case of dolomites, which are the most frequently encountered, the rocks are of massive structure, they are characterized by sugary fractures, the bedding is not marked, the shape of caves and pits is fractured, and the access to some parts is often impossible as the channels become too narrow. In areas at the stage of neotectonic elevation, the channels of speleological structures have a specific shape of an elongated letter "I".

Trias limestones are less often encountered in Croatia and the channels of speleological structures found in such formations are wider and more voluminous when compared to channels found in the Trias dolomites. They are usually very fissured and weakly to moderately bedded. On Velebit, we have a number of structures that were formed in the Trias limestones containing chert (Danina pećina, the cave above Bukova glava).

About 14% of all speleological structures found in Croatia are situated in the Jurassic limestones. Despite the fact that the area characterized by the Jurassic limestones and dolomites has undergone a relatively limited speleological investigation, it is interesting to note that a great number of speleological structures has been found precisely in this area comprising a part of Gorski kotar (Garašić,1992), the massif of Velika and Mala Kapela, Velebit and Biokovo. The reason for that should be sought in the great density of occurrence of speleological structures (up to 24 structures per square kilometer), for instance in the area called Samarske stijene and Bijele stijene. In the well bedded Jurassic limestones, the vertical speleological structures are more developed that the horizontal ones, but the presence of water has been registered in only 20% of structures, which is a relatively low percentage. The exceptions are structures formed in the Jurassic dolomites or dolomitic limestones containing cherts where water flows are almost always encountered (e.g. cave near Kučinić selo, Ponor). However, their shape is not so typical if compared to that of structures formed in the Trias dolomites.

From the speleological standpoint, the Cretaceous limestones and dolomites contain the greatest number of structures. Over 65% of all known structures in the Croatian karst have been recorded in these formations. The analysis of Cretaceous formations in speleological structures shows that the most frequent ones are well bedded limestones of the Upper Cretaceous (Senonian). The limestones and dolomites of the Lower Cretaceous are also well represented (approx. 30% of speleological structures found in the Cretaceous formations) as an environment where speleological structures have been formed. Vertical and horizontal structures are almost equally represented in the Cretaceous formations (with respect to their total number) and the water courses are present in such structures in approx. 20% of all cases, which is similar to the water presence information for the Jurassic formations, the only difference being that a much greater number of structures has been found in the Cretaceous limestones and dolomites. Horizontal structures formed in the Cretaceous formations characterized by the neotectonic elevation have a typical "V" shaped cave channel profile.

THE SIZE AND ORIENTATION OF ENTRANCES, THE DIRECTION OF MAIN CHANNELS AND THEIR RELATIONSHIP TO STRUCTURAL TYPES AND KARSTIFICATION

The tectonic predisposition is certainly one of dominant factors in the formation of speleological structures (Garašić, 1984). The practical investigation of a great number of structures has shown that, in their interior, they have rock layers, folds, ruptures, faults and even nappes (overturned folds). M. Herak (1984) provides a geotectonical framework of speleogenesis for the area of Croatian karst which coincides with the results of speleological investigations in the regional sense.

The rock layers may be monitored in almost all speleological structures, but they can best be observed in vertical structures. Limestones are characterized by the most marked bedding and are, in that sense, followed by dolomitic limestones. In most cases, speleological structures follow the orientation and inclination of layers. In such cases, the orientation and inclination of layers corresponds to the orientation and inclination of the main channel of a speleological structure. In addition, speleological structures develop through the process of widening the interstitial fractures in thick-bedded limestones from the Cretaceous or Jurassic period. In structures formed in rocks whose layers are horizontal and not marked (massive dolomites and limestones), the level of rock fracturing dominantly influences orientation of speleological structures.

In speleological structures, it is easier to observe folds in caves than in pits. It has been established that vertical structures most often develop in the crests of anticlines, while horizontal ones usually develop in synclines. The micro-folds have also been discovered but also the wings of some large forms. It may be stated that the formation of speleological structures is sometimes not directly related to the folding of layers as can for instance be seen in the area of Mala Kapela. Here we have a synclinal shape, but the vertical structures are much more frequent that the horizontal ones. This is due to karstification, i.e. to the fracturing of layers, particularly of the Jurassic and Cretaceous limestones.

Ruptures or fractures occur in all speleological structures. They differ in size, orientation, fill, roughness, etc.

The faults are fractures along which there has been displacement of the sides and of individual rock blocks. In addition to fractures, these are the most common phenomena we find in speleological structures, since almost 90% of all structures in Croatia are located in fault zones. The faults that divide different lithostratigraphical members can more easily be observed, but those situated in the same lithologic environment may also be detected quite readily because of the striae and the smooth paraclases. The occurrence of smooth paraclases is more frequent than on the ground surface. The inclination of speleological structures regularly coincides with the inclination of paraclase, while the horizontal displacement or heave of the fault may be determined through differences among several different levels in a structure.

Nappes are in fact overturned folds and, in Croatia, they are one of the causes of genesis of speleological structures and constitute therefore an important part of karstification. The examples of such phenomena have been observed in the Trias formations of Gorski kotar.

The entrances of speleological structures provide in most cases the explanation of the paleo or recent function of a structure (Bögli, 1980). This is due to the fact that they may point to the spring caves and pits, sinkhole caves and pits, intensity of karstification, the way of formation (caving from above, caving from below, inverse karstification, solution from above, etc.).

The basic orientation of the entrance does not necessarily coincide (although that is very often the case) with the general direction of the main channel of speleological structures found in the Croatian karst. Approximately 66% of speleological structures are of northwest - southeast direction or "Dinara spreading", 16% are oriented perpendicularly to that direction, i.e. they are of northeast - southwest spreading, while other speleological structures (18%) are of variable direction.

If we compare the orientation of entrance and main channels of speleological structures with the structural units of the lithosphere in the Croatian karst, we may conclude that direction of speleological structures coincides with that of faults, fold axes and nappes. This is an obvious proof that tectonics is a significant factor in the genesis or karstification of speleological structures.

HYDROGEOLOGICAL FUNCTIONS OF SPELEOLOGICAL STRUCTURES AS RELATED TO KARSTIFICATION

A firm link has been established between the rock karstification and the hydrogeological paleo and recent functions of speleological structures. With respect to hydrogeological function, we may observe in Croatia the presence of perennial and intermittent springs, permanent and occasional ponors, flow structures, estavelles and submarine springs. Their location, orientation, size, morphology and hydrogeological potential are directly dependent on the type and intensity of karstification. There would be no real karstification without the influence of ground water which has been found in approx. 18% of all speleological structures of Croatia. Cases of inverse karstification have been found in Istria, while karstification by direct gravity action has been observed on Velebit (Garašić, 1989,1991).

THE LONGEST AND THE DEEPEST SPELEOLOGICAL FEATURES OF THE MESOZOIC ROCKS IN THE CROATIAN KARST

The longest caves in Croatia:

1. Đulin ponor (Đula) - Medvedica (sustav) .... 16396 m
2. Muškinja - Panjkova spilja (sustav) .... 12385 m
3. Špilja u kamenolomu Tounj .... 8143 m
4. Veternica .... 6804 m
5. Jopićeva spilja - Bent (sustav) .... 6564 m
6. Donja Cerovačka spilja .... 2510 m
7. Klementina I .... 2403 m
8. Mandelaja .... 2326 m
9. Munižaba .... 2300 m
10. Spilja za Gromačkom vlakom .... 2171 m

The deepest pits (shafts) in Croatia:

1. Lukina jama .... 1359 m

2. Stara škola .... 576 m
3. Vilimova jama (A - 2) .... 572 m
4. Ponor na Bunjevcu (Bunovcu) .... 534 m
5. Jama pod Kamenitim vratima .... 520 m
6. Fantomska jama .... 477 m
7. Munižaba .... 448 m
8. Nova velika jama .... 380 m
9. Jama kod Rašpora .... 361 m
10. Biokovka .... 359 m

REFERENCES

Božičević, S. (1985): Morfogeneza speleoloških pojava Istre i njihova zavisnost o geološkim i hidrogeološkim uvjetima. Disertacija, pp.1-166, Zagreb.

Bögli, A. (1980): Karst hydrology and Physical Speleology. pp.1-270, Springer Verlag, Berlin, New York.

Ford, D. (1971): Structures in limestones affecting the initiations of caves. Trans. Cave Res.Group, vol.13, pp.65-71, London.

Friganović, M. (1975): Južno hrvatsko primorje. Geografija Hrvatske, part 6, pp.1-221, Zagreb.

Garašić, M. (1977): Neki speleološki objekti s vodom u našem kršu. pp.1-75, University of Zagreb, Zagreb.

Garašić, M. (1981a): Neotectonics in Some of the Speleological objects in western Yugoslavia. Proceedings of 8th International Congres of Speleology, pp.1-149, Bowling Green.

Garašić, M. (1981b): Neki speleološki objekti s vodom i praćenje neotektonske aktivnosti u njima. Thessis. pp.1-93, University of Zagreb, Zagreb.

Garašić, M. (1984): Proučavanje tektogeneze u spiljama. Priroda, vol.73, pp.20-21, Zagreb.

Garašić, M. (1986a): International Speleological expeditions in Yugoslavia in 1984. and 1985. 9th Congresso International de Espeleologia. Communications. Barcelona, vol.2, pp255-257, Barcelona.

Garašić, M. (1986b): Hidrogeologija i morfogeneza speleoloških objekata s vodom u kršu Hrvatske. Disertacion. pp.1-155, University of Zagreb, Zagreb.

Garašić, M. (1989): New concept of the morphogenesis and hydrogeology of the speleological objects in karst area in Croatia. 10th International Congress of Speleology, Proceedings, vol.1, pp.234-236, Budapest.

Garašić, M. (1991): Morphological and Hydrogeological Classification of Speleological structures (Caves and Pits) in the Croatian Karst area. Geološki vjesnik, vol.44, pp.289-300, Zagreb.

Garašić, M. (1991b): The cave channel karstification behind Green sump and

its hydrogeological role in Muškinja and Panjkova cave system in Kordun. Spelaeologia Croatica, vol.2, pp.5-14, Zagreb.
Garašić, M. (1992): Speleološki objekti okolice Ravnog i Lukova (Gorski kotar). Spelaeologia Croatica, vol.3, pp.77-80, Zagreb.
Garašić, M, (1993):The karstification process and hydrogeological aspects of the Mesozoic rocks in the karst of Crroatia (Europe). Proceedings of XI International Congress of Speleology, pp.1-4, Beijing, China.
Gvozdeckij, N. (1981): Karst. pp.1-212, Mir, Moscow.
Herak, M. (1984): Tektonski okvir speleogeneze. Deveti jugoslavenski speleološki kongres, Karlovac, Zbornik radova, pp.111-130, Zagreb.
Herak, M. (1986): A new concept of geotectonics of the Dinarides. Acta geologica, vol.16/1, pp.1-42, Zagreb.
Kempe, S. (1972): Cave genesis in gypsum with particular reference to underwater condition. Jour. Brit. Spel.Ass., vol.6, pp.1-6, London.
Maull, O. (1938): Geomorphologie. ppl-502, Springer Verlag, Wien.
Pavić, R. (1975):Gorska Hrvatska. Geografija Hrvatske, part 4, pp.1-196, Zagreb.
Poljak, J. (1914): Pećine hrvatskog krša, part 1 and 2. Izvješća o raspr.mat, vol172, pp.117-137, Zagreb.
Poljak, J. (1925): Istraživanje pećina u hrvatskom kršu. Glasnik sr. geogr. druš., vol.11, pp.103-109, Beograd.
Rogić, V. (1975): Sjeverno hrvatsko primorje. Geografija Hrvatske, part5, pp.1-212, Zagreb.
Swinerton, A. (1932): Origin of limestones caverns. Bull.geol.Soc.Am. vol.43, pp.663-694, New York.
Šarin, A. (1983): Hidrogeologija krškog područja. Tumač za hidrogeološku kartu SFRJ, Beograd.

SPELEOLOšKE OBLIKE (JAME IN BREZNA) IN ZAKRASEVANJE MEZOZOJSKIH KAMNIN NA KLASIČNEM KRASU HRVATSKE

Povzetek

Analiza in računalniška obdelava preko 7300 speleoloških objektov na Hrvaškem (JV Evropa) (med njimi je 77 % brezen in 22 % jam) kažeta, da je tako veliko število objektov tudi odraz kraških procesov. Predvidoma je na Hrvaškem okoli 17000 jam, kar je veliko število, glede na relativno majhno ozemlje. Hidrogeološki vidiki zakrasevanja kažejo na medsebojno odvisnost med talno vodo in intenzivnostjo zakrasevanja. Meritve kažejo na neotektonsko aktivnost, ki sega vsaj nekaj km (tudi preko 4 km) globoko v mezozojske kamnine, ki na tem področju dosegajo debelino približno 8 km. To dokazujejo tako geofizični poizkusi kot tudi običajna vrtanja. Čeprav je zakrasevanje proces, ki zahteva dolgotrajne raziskave, že predhodne raziskave, predstavljene v tem prispevku, kažejo, da je zakrasevanje na teh območjih tako intenzivno, kot redkokje drugod na svetu.

KARST REGIONAL PARKS IN SLOVENIA AND THEIR ECOLOGICAL PROBLEMS

KRAŠKI PARKI V SLOVENIJI IN NJIHOVI EKOLOŠKI PROBLEMI

HABE FRANCE

Izvleček UDK 551.44:502.5(497.12)

France Habe: Kraški parki v Sloveniji in njihovi ekološki problemi

Slovenski kras je najbolj onesnažen del Dinarskega krasa. Vedno gostejša urbanizacija, naraščajoča industrija in nove ceste onesnažujejo kraško površje, podzemeljski svet in predvsem bogate kraške vode. V italijanski dobi in za nove Jugoslavije je tod na razdalji dobrih 50 km zraslo na desetine kasarn. Že pred četrt stoletja se je pojavila pobuda za ustanovitev kraških parkov (regijski park Kras in Notranjski regijski park), ki naj bi preprečevala vedno hujše onesnaženje.

Ključne besede: varovanje okolja, kraški park, Slovenija, Kras, Notranjska

Abstract UDC 551.44:502.5(497.12)

France Habe: Karst Regional Parks in Slovenia and Their Ecological Problems

The Slovene Karst is the most polluted part of the Dinaric Karst. Dense urbanization, augmented industry, and new roads pollute the karst surface and the underground world. Karst waters in particular are polluted. In the Italian period and in new Yugoslavia about ten barracks were built in the distance of a good 50 km. Before a quarter of a century ago an intitiative to establish karst parks arose in order to prevent the increasing pollution. (Kras Regional Park, and Notranjska Regional Park).

Key words: environment protection, karst park, Slovenia, Kras, Notranjska

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One third of the Republic of Slovenia, being the westernmost part of Dinaric Mountains, belongs to karst. It includes more than 40% of the Slovene waters between the Soča and Kolpa rivers. Over the shortest part of this part of Kras from Ljubljana Moor to the Trieste Bay an important european road leads. More than ten millions of tourists once travelled towards the sea each year. Between the First and the Second World War the border between Italy and Yugoslavia passed here. This traffic zone is densely populated and along it, due to political conditions numerous barracks were built in the distance of 50 km; without water treatment plants they additionally pollute karst surface, and karst waters in particular. Adding industry, and transport of harmful and inflammable substances the karst, rich with water is additionally endangered.

The idea to protect this area goes back to the beginning of 1920 when the Natural History Museum in Ljubljana issued the first memorandum about the nature protection. Soon afterwards, in 1924 similar memorandum was issued regarding the protection of the Triglav National Park. Since then the idea to safeguard the nature was alive not only among the naturalists but among people too. From 1947 to 1968 by regulative acts about the nature safeguarding 31 regions and objects, covering 9152 ha (it means 0,45% of Slovenia) were protected. By the act about the Triglav National Park protection in 1981 the protected surface reached 93.960 ha or 4,62% of Slovenia (Skoberne 1989, 118).

The karst area where the European road to the sea coast leads is the most karstified, there the speleological objects are the most dense and water richness the most expressed, there are all the karst poljes, from Planinsko Polje, Cerkniško, and Loško Polje and world famous caves as are Postojnska Jama, Predjama, Planinska Jama. All this extreme variety of karst phenomena stimulated the Institute for Protection of Natural and Cultural Heritage of the Republic of Slovenia to foresee in 1966 already the foundation of two karst parks: Karst Regional Park and Notranjska Regional Park (Golob, 1966).

Karst Regional Park should include the region from the state border with Italy, Sežana up to Divača, Kozina and Socerb. The nucleus and the future administrative centre of this park would be at Škocjanske Jame that are the only Euroepan cave, listed in the UNESCO World Heritage since 1986. Severe regime within a Karst Park would be implemented on floristically rich mountain, called Vremščica and on stud Lipica also. More than 500 caves are known within this Karst Park; each tenth cave is polluted and together with industry at Ilirska Bistrica the only karst river of this Park, is additionally polluted. According to Osimo agreement Yugoslavia had to provide that the Timavo springs in Trieste Bay would become more clean. In such a way the karst area on our and on the other side of the border is connected; this is why the members of the International Foundation for Karst Protection in Triest passed to the Italian Parliament a suggestion to found an international karst park; this would enable the Italian side to intervene on the slovene karst landscape which is contaminated by the construction of the research scientific centre Synchrotron near Bazovica close to the border. By such an agreement the natural equilibrium would be endagered in this delicate karst landscape even more than it is today (Rojšek, 1987).

In the area of Notranjska karst poljes the foundation of Notranjska Regional Park was foreseen. According to proposal of R. Golob it would cover about 200 km^2 and include not only the karst poljes but also a part of Pivka basin with Postojnska Jama and Predjama (Berce-Bratko, 1994). Now is being prepared also the foundation of a regional karst park for the area of the Kolpa river, a border river between Slovenia and Croatia and landscape parks Kolpa (Bela Krajina) and Trnovski gozd.

The Slovene government only now started to solve the problems of these two parks. Because of extremely complicated problems of protection the foundation of a project group was submitted, to introduce the proposal which should be taken in account of long-term plan of Republic of Slovenia.

The aim of my paper is to give the initiative for the foundation of protected karst parks in the other republics of Yugoslavia where the areas of important karst phenomena should be protected against pollution by regulative laws.

REFERENCES

Berce-Bratko, B., 1994: UNESCO Biosphere reserve: Notranjski kras as a strategy for conservation and development. Acta carsologica, XXIII, 13-33, Ljubljana

Golob, R., 1966: Predlog za zavarovanje slovenskega krasa. Varstvo narave, 529-538, Ljubljana

Golob, R., 1966/67: Zavarovanje slovenskega krasa. Proteus 29, 9-10, 271-272, Ljubljana

Rojšek, D., 1987: Natural heritage of the classical karst. Karst and man, 255-265, Ljubljana

Habe, F., 1990: Problematika kraških parkov. Lipov list 12, 344-345, Ljubljana

Skoberne, P., 1989: Varstvo naravne dediščine Slovenije. Slovenija 88, 118-121, Ljubljana

KRAŠKI PARKI V SLOVENIJI IN NJIHOVI EKOLOŠKI PROBLEMI

Povzetek

Od vsega Dinarskega krasa je najbolj onesnažen Slovenski kras med Ljubljanskim barjem in Tržaškim zalivom, preko katerega poteka evropska pot na morje. Vedno gostejša urbanizacija, naraščajoča nečista industrija in vedno nove prometne poti leto za letom onesnažujejo kraško površje, podzemeljski svet in predvsem bogate kraške vode, ki pogojujejo življenje na krasu. Redek je primer na svetu, da bi na razdalji dobrih 50 km zraslo v italijanski dobi in za nove Jugoslavije desetine kasarn, ki bi morale čuvati kras pa ga temeljito onesnažujejo. Zaradi tega je že pred četrt stoletja zrasla pobuda za ustanovitev kraških parkov, ki naj bi z zaščitno regulativo preprečevali vedno hujše onesnaževanje. Tako sta že takrat bila predlagana na Divaško-Sežanskem krasu do italijanske meje Kraški regijski park s centrom pri Škocjanskih jamah, ki so že v seznamu naravne dediščine UNESCO (1986) in Notranjski regijski park v območju notranjskih kraških polj, s centrom pri Postojnski jami. Zaradi zelo zapletenih problemov zavarovanja je predlagana ustanovitev projektne skupine za pripravo predloga, ki bo v dolgoročnem planu Republike Slovenije predvideval za razglasitev. Obenem avtor predlaga ustanovitev regijskih kraških parkov v ostalih republikah nekdanje Jugoslavije, kjer bi na območjih številnih važnih kraških pojavov zavarovali kras pred onesnaženjem z regulativnimi zakoni.

PROBLEMS IN RELATION TO THE DEVELOPMENT OF SKI-RESORTS ON THE FRENCH MOUNTAIN KARST

PROBLEMI POVEZANI Z RAZVOJEM SMUČARSKIH SREDIŠČ V FRANCOSKEM GORSKEM KRASU

FABIEN HOBLEA

Izvleček UDK 338.48:551.44(44)

Fabien Hoblea: Problemi povezani z razvojem smučarskih središč v francoskem gorskem krasu

V Franciji je v gorskem krasu okoli 60 smučarskih središč. V zvezi z njihovim razvojem so na krasu specifični problemi, predvsem relief in podzemeljska voda. Cela vrsta dejavnikov je neprimernih za razvoj velikih središč na krasu in veliko napak je bilo storjenih prav zaradi nepopolnega poznavanja kraških značilnosti, ki so pogosto sploh prezrte. Zaradi tega bi morali biti krasoslovci oziroma geomorfologi povabljeni k sodelovanju pri planiranju na kraških področjih.

Ključne besede: kraška morfologija, človekov vpliv na kras, turizem, smučarski turizem, Alpe, Francija

Abstract UDC 338.48:551.44(44)

Fabien Hoblea: Problems in relation to the development of ski-resorts on the French mountain karst

In France about sixty ski-resorts are located on mountain karst. There are specific problems of development in karstic areas, mainly with relief and groundwater. A lot of factors make mountain karst unsuitable for big tourism installations, and a lot of mistakes are made because of incomplete knowledge of characteristics of karst, which are often over-looked. For this reason the karstologist or the geomorphologist should be asked to take part in development planning of karst areas.

Key words: karst morphology, man's impact on karst, tourism, skiing tourism, Alps, France

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AN UNFAVOURABLE GEOGRAPHICAL AND GEOLOGICAL LOCATION FOR BIG SKI-RESORTS SETTLEMENTS

In France, ski-resorts in karstic areas are located in three massifs (Fig. 1):

a) JURA: which is completely a mid-altitude mountain massif with the top at only 1700 m high.
b) PYRENEES: where there are not a lot of ski-resorts in karstic areas, but where we can find an important one: La Pierre-Saint-Martin well known for its famous sytem of caves and shafts.
c) ALPS: where "karstic" ski-resorts are almost all located in the subalpine zone in the western range of the massif, with mainly a mid-altitude environment.

There are of course exceptions in the eastern French Alps, especially in Vanoise where we can find a few big famous ski-resorts on gypsum or marble-limestone. For example Tignes, or La Plagne, with ski-areas of high-mountain. Human impacts in this last kind of ski-resorts have been studied by the geomorphologist Rovera (1990).

But generally, the ski-resorts concerned are small, because of their geological environment, as we can see with two examples in subalpine massifs: Vercors and Bauges (Fig. 2). This figure shows how unfavourable are the lithostructural conditions for downhill ("alpine") skiing:

- Low slopes and low denivelations, with a morphology of "plateau" rather more suitable for nordic ski. But in France, this kind of skiing is not so popular and so profitable than downhill skiing, and it is a must for such ski-resort to offer ski-lifts for their clients; even these ski-lifts often lead to ridiculous ski-tracks.
- Mid-altitudes where the snow is not guaranteed, especially for the last five winters. This bad climatic circumstances for winter sports have put some ski-resorts in a very delicate financial situation.
- But confronted by this new problem, the managers often count on always more development, extension and modernization (like for instance snow-guns); and sometimes, the karst will pay the bill, particularly the karstic landscape...

CONTRADICTION BETWEEN THE SKI-RESORTS DEVELOPMENT AND THE CONSERVATION OF KARSTIC SUPERFICIAL LAND-FORMS AND LANDSCAPE

"High-alpine" or "woody mid-altitude" karsts, give a topography which is naturally very broken with numerous micro-dolines, rock-rills, steep slopes, pits

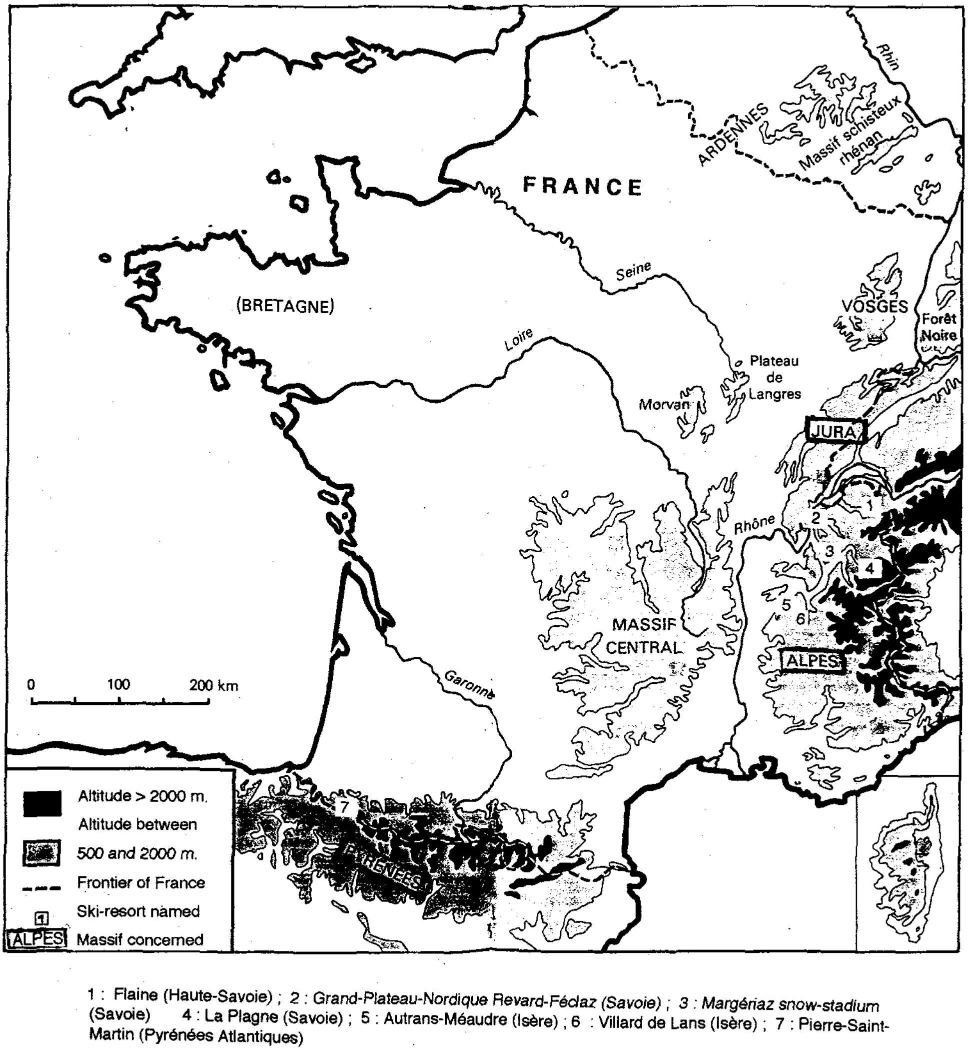

Fig. 1. Place of masiff and ski-resorts named in the text.

and so on... It is a necessity for the manager to eliminate completely shallow landforms not only in the layout of the ski-tracks but also for the building, parking areas etc... Two examples of ski-resorts make us aware of the importance of the destruction: La Pierre-Saint-Martin (Pyrénées), and the Margériaz snow-stadium in the prealpine massif of Bauges, near the savoyen town of Chambéry.

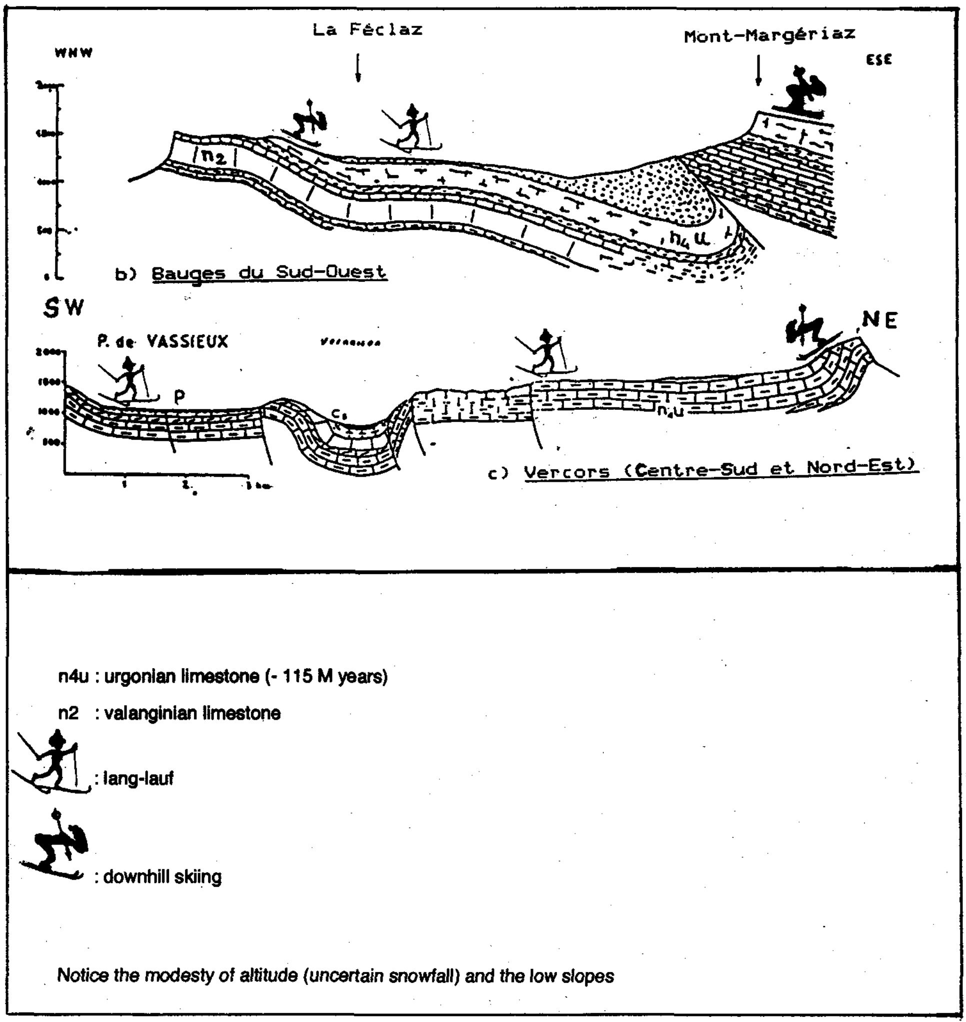

Fig. 2. Examples of lithostructural conditions for ski-resorts in karstic areas.

a) **La Pierre-Saint-Martin: a famous site defaced**

The ski-resort is here established on a remarkable karstic area, not only because of its speleological system, which is 1342 m deep, but also because the shallow karst offers a big scientific interest. The karst of la La Pierre-Saint-Martin is assuredly one of the jewels of the karstic heritage in the world. But the settlement of the ski-resort has led to massive destruction of karstic landforms in a first time in the grass area, and afterwards in the bare karst, where the scars are indelible. In this natural site "without equivalent in the Pyrénées" (Viers 1989), one of the last refuges for the big vulture, drastic measures were used: of course very big caterpillars (bull-dozers, scrapers...) but also specific machines newly conceived to destroy and to crush hard rock and especially reef limestone, like for example a little tracked-vehicle supporting a drilling machine which makes holes to put explosives inside. And these explosives are certainly the main weapon against limestone: the quantity of explosive used by ski-resort working in karstic areas is comparable to that for a dam working or a quarry (related to the lenght of the working).

In the site of La Pierre-Saint-Martin, we can observe an economic impact of the destruction of the landscape around the ski-resort: because the works are recurrent each summer, because the clients want now to frequent the mountain in summertime like in winter, in a beautiful environment without noise, defaced areas and so on, and for other reasons which do not concern our topic (ageing of the buildings...), the market of the building park of the ski-resort in crisis.

And more, safety in the ski-area is a very important problem, because of the presence of very numerous deep shafts. In winter, when the snow obliterates the scars, the pits are covered too, and become fatal traps: already three skiers died like this in the Pierre-Saint-Martin. It is of course not a good publicity for the site.

For all these reasons, the place is now not so attractive for the French side and the management team looks for new clients on the Spanish side nearby. That presupposes making new ski-tracks through the most fragile zone of the karstic plateau; that means new destructions and so on, like a vicious circle...

The same process is going on in our second example, but for other reasons.

b) **The snow-stadium of Margériaz (Savoy)**

The advertisement is clear: this snow-stadium (ski-resort without accomodations), set up on a monoclinal slab of Urgonian limestone, wants to be "the biggest snow-stadium in France" (advert-leaflet 1993). In fact: a ski-area of 45 ha, 400 meters of denivellation between altitudes of 1400 m and 1800 m, 15 km of ski-tracks, 10 ski-lifts and 7500 skiers/h. So, a modest place for skiing in the French scale. But not negligible, because of its location, near big cities (Chambéry-Aix les bains, Annecy, Lyon) and an easy and fast access.

For five years, this site has suffer particularly from lack of snow which is recurrent and general in mid-altitude mountains. In this situation the surface of the ski-tracks must be absolutely smooth for skiing with only 20 cm of snow thickness. All the ski-tracks have been treated with huge quantities of explosives, with tracked-drills and stone-crushers... Artificial embankments have been built when the slope was not adapted for downhill skiing. It results in an artificial landscape which shows large scars on the karstified slab with a very important contrast of colour between the superficial colour of the Urgonian limestone (grey) and the internal one (white or clear beige). This contrast is clear on a vertical aerial view of the site (Fig. 3). In the detail, we can of course observe destruction and disappearance of karstic landforms replaced with banal stony material (fine granulometry), not only on the layout of the ski-tracks, but also partially in the area around, because of the projections of stones by the explosives. We also can see rubbish in dolines, and a symbolic absurdity: a few trees rooted in concrete. Here too, the summer landscape has been sacrified, and such a situation is now the problem

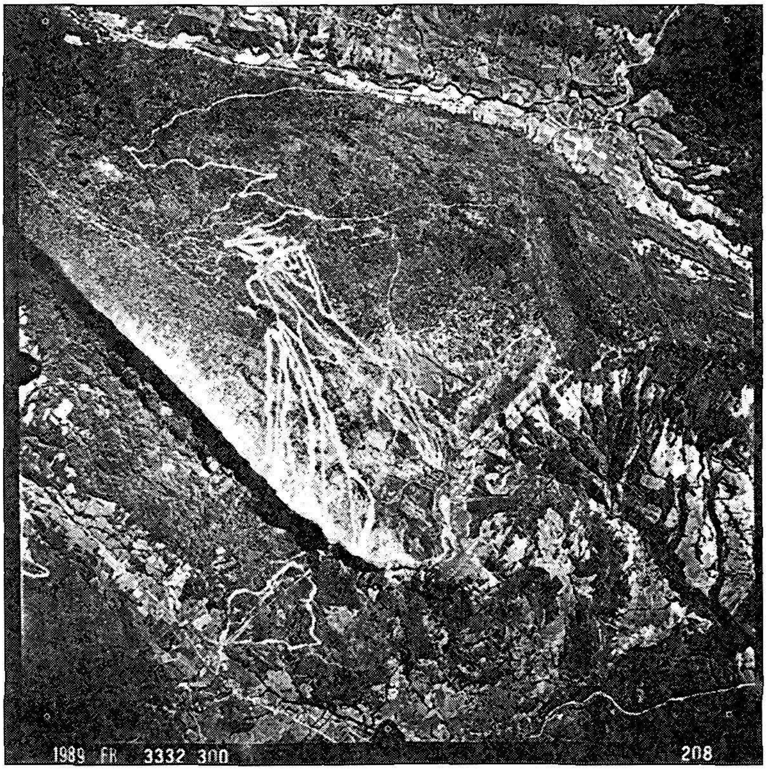

Fig. 3. Vertical aerial view of Mount Margériaz (1845m, Bauges, Savoie)

in the prospective creation of a natural regional park in the Bauges massif. On the Margériaz mount, since the destroying works, tourists run away in the summer season and the rare hikers have negative opinions about such a landscape (survey made in 1989, Hoblea 1990a). It is one of the reasons why some expensive efforts are made to turn the ground green (Daburon 1989).

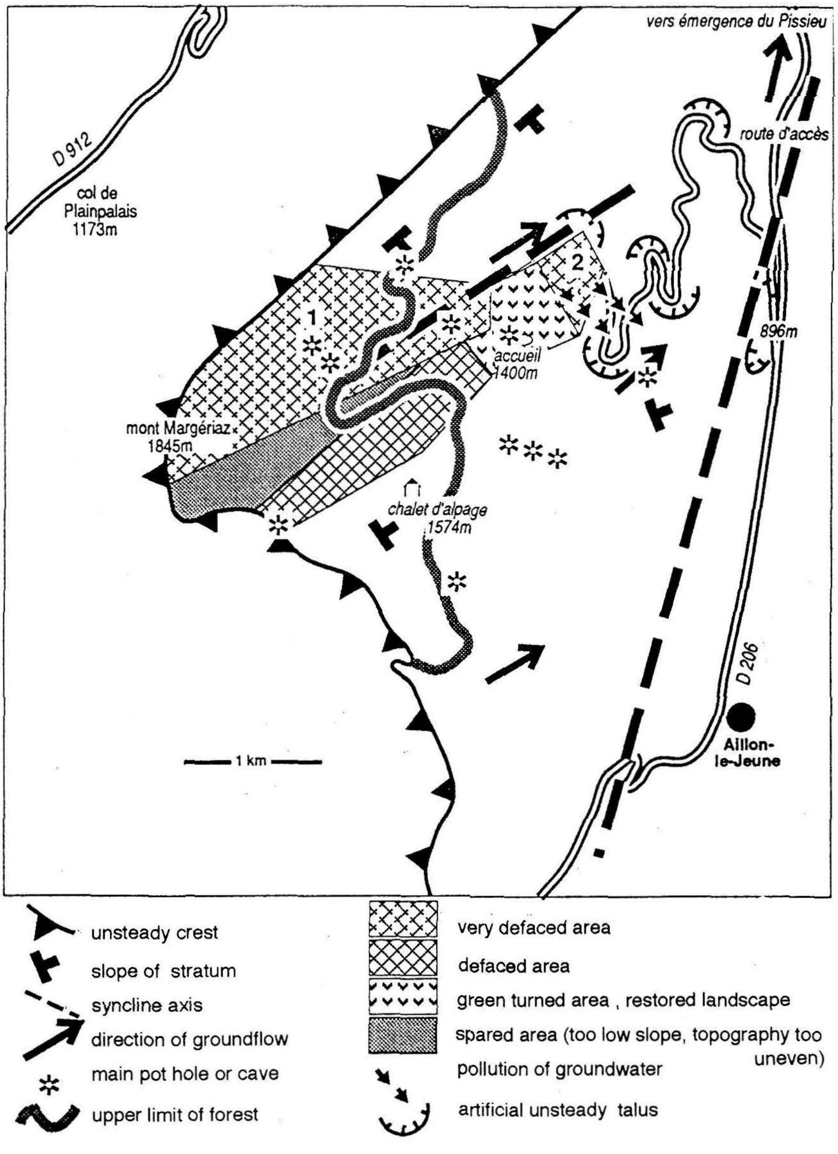

Fig. 4. Margériaz snow-stadium - impacts of dvelopment on the karst.

But on such mountain karstic soil, these efforts are not often sucessful, and only a few plates of brilliant green lawn of clover can subsist (that is not the natural colour and composition of the local vegetation), showing the actual limits of rehabilitating landscape in karstic areas. The karstologists should make an inventory of all these kinds of human impacts on mountain karst and locate them on a map like the one proposed on the Fig. 4 (simplified map because of the small scale necessary for this publication).

Like in the Pyrénéan example, the Margériaz snow-stadium has problems about the safety of the ski-area. We have listed more than ten falls of skiers in pits, luckily without serious injury... And the works in the ski-area or in the roads around usually open new cavities. For two years, after the suggestions of the speleo-rescue and the "civil protection office", the manager of the stadium has agreed to inform the public of the existence of shafts and caves on the massif (there are more than 300 entrances listed by the cavers on a speleological map, and among them, the deepest cave of Savoy: the "Tanne Froide/Tanne aux Cochons" system: -825 m) and more, the staff who work in the ski-area get a training about the technics of speleo-rescue.

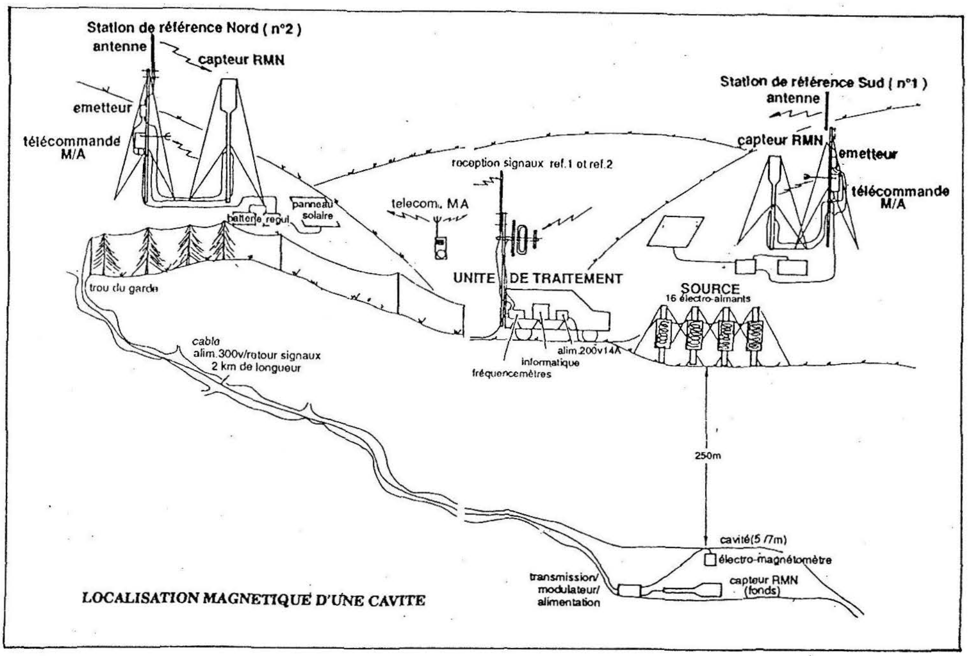

Fig. 5. Method for magnetic location of karstic cave - example of the "Trou du Garde" (La Féclaz, Savoie, France). (LETI laboratory, Grenoble, France)

In spite of the difficulties caused by the karstic topography, and the bad climatic circumstances (lack of snow in winter), an important extension of the ski-area is planned, including a link by ski-lift with the bottom of the valley at an altitude of ... 900 m! A plan for equipment with snow-guns is prepared, which could take the water inside the karst, in spite of a very little flow in winter (around 1 l/sec!). Are this (very expensive) plans very serious? Managers and local elected representative think so...

Anyway, we reach here the problem of the karstic water as resource for touristic development.

WATER RESOURCES AND TOURISTIC DEVELOPMENT IN KARSTIC MOUNTAINS

The lack of shallow water and associated water table, the depth of the underground water streams (in average more than 150/200 meters of hard limestone), which are in mountainous karst canalized in narrow channels without filtration, make the water supply for a big touristic settlement difficult. Until five years ago, it was an insuperable handicap for the development of the capacity of accomodation (the formula of the "snow-stadium" among others is imposed by this natural constraint). But for about seven years, the interest in karstic underground water is woken up by the progress of the magnetic method of location of karstic cavities and by the progress of the deep drilling technique. To bring up water from the depth of the karst became possible. In France, a little old ski-resort of the Bauges massif, called La Féclaz, has been the pioneer to test this methods. The drilling operation was success, but then arose the question to protect and to clean up the water...

a) **The drilling of La Féclaz**

At the end of the 1980s, because of the creation of a big nordic ski-area in the massif around it (operation "Grande Plateau Nordique"), the ski-resort of La Féclaz wanted to develop its capacity of accomodation with 4000 new beds (1700 beds were available at this time). But the precondition to realize this aim was that La Féclaz find more water. The ski-resort is settled above a very important speleological system 25 km long (the "Garde/Cavale"), which offers several underground torrents but more than 200 m deep inside the Urgonian limestone. The solution of drilling was selected, made possible by the discovery of new process for the location of deep cavities by a French laboratory at Grenoble: the LETI (Fig. 5). With the collaboration of the cavers, it was a total success and the 21 november 1987, after 213 m of drilling, the drill reached its target with only 20 cm error! But before pumping up the water (30 m^3/h planned), La Féclaz had still to wait several years because the protection and the cleanness of the water was not guaranteed.

b) **The difficulties of protecting and cleaning up the water**

The construction of a cleaning station and the joining up of each building was of course the priority, because all the dirty waters went directly into the karst through dolines or shafts. So, the inhabitants and the tourists could drink their own used water, as has happened in the past in a settlement of the Jura!. The protection of the underground water resource was therefore a necessity and a priority: but what is the solution to protect un undeground water system sustained by a superficial basin whose boundaries are very difficult to know with the required precision, and that fluctuate according to the seasons and the meteorological circumstances? And more, what kind of measures could be used to protect a basin which corresponds to the ski-area subject of the development, with works, deforestation, and so on? It was the question asked to the mayor of the ski-resort who thought that the best way to protect his drilling was to forbid the caving practice. The intervention of an hydrogeologist, a karstologist, and caving representative made the mayor conscious that it was a derisory and vain solution if in the same time the danger represented by some shallow activities (among which were touristic ones) was not eliminated... Now caving is regulated in the Trou du Garde, but the shallow activities too, especially the management of rubbish collection. A big collapse doline called "Creux de l'Olette" has been (only partially) cleaned up with scrapers, and several tonnes of rubbish, sometimes toxic, have been taken out of this famous hole. And finally, the investigation and the study of this very interesting hydrogeological and speleological system can go on...The drilling of La Féclaz shows how difficult and complex it is (if is now possible in a technical point of view) to use karstic underground water in a growing touristic area. Other examples confirm this fact, like the drilling of Autrans-Méaudre in the Vercors realized through 300 meters of hard limestone in the famous "Trou-qui-souffle".

CONCLUSION

In conclusion, the problem of the touristic development on karstic mountains in France can be summerized in this paradox: small and non-profitable ski-resorts, but maximal natural contraints and big damage to the environment and the landscape, damage which compromise the development of a "soft" or "green" tourism in every season (especially in summertime) that these regions try moreover to attract. There is here a fundamental contradiction.

BIBLIOGRAPHY

CERREP-GREGE, 1986: Aspects environnementaux du développement des stations de sports d'hiver. Rapport au ministere de l'environnement, pp. 123, Grenoble

Daburon, A., 1989: La réhabilitation des surfaces dégradées des domaines skiables: une nouvelle conception de l'aménagement des stations. Cas de l'Isere et de la Savoie. These Doctorat d'Université, Géographie, Université Grenoble 1, pp. 310

Hoblea, F., 1990a: Les aménagements touristiques sur karsts d'altitude: problemes et impacts. L'exemple des Bauges du sud-ouest et de quelques régions de comparaison. Mémoire de DEA interface Homme/Nature, Université Lyon 2, pp. 234

Hoblea, F., 1990b: Problemes d'aménagement sur karsts d'altitude voués au tourisme. Bull. du Laboratoire Rhodanien de Géomorphologie, 25/26, 67-86

Rovera, G., 1990: Géomorphologie dynamique et aménagement des versants en moyenne Tarentaise: une contribution a l'étude de l'érosion naturelle et anthropique. These de Doctorat d'Université, Géographie, Université de Grenoble 1, pp. 465

Viers, G., 1989: Le masif de la Pierre-Saint-Martin. Bull. de l'ARSIP, 16, 11-18

PROBLEMI POVEZANI Z RAZVOJEM SMUČARSKIH SREDIŠČ V FRANCOSKEM GORSKEM KRASU

Povzetek

V Franciji je v gorskem krasu v Juri, Pirenejih in Alpah okoli 60 smučarskih središč, nekatera (Tignes, La Plagne) so celo v visokogorskem krasu na sadri ali marmorjih. V zvezi z njihovim razvojem so na krasu specifični problemi, predvsem relief in podzemeljska voda. To skušajo reševati z obsežnimi tehničnimi ukrepi na površju in z različnimi vodogospodarskimi ukrepi, vključno z globokim vrtanjem do vodonosnih plasti. Posebne težave so z varovanjem podzemeljske vode in s čiščenjem odpadnih voda.

Cela vrsta dejavnikov je neprimernih za razvoj velikih smučarskih središč na krasu in veliko napak je bilo storjenih prav zaradi nepopolnega poznavanja kraških značilnosti, ki so pogosto sploh prezrte. Pojavlja pa se tudi zanimiv paradoks: majhna in nerentabilna smučarska središča povzročajo največje pritiske in škodo okolju. Zaradi tega bi morali biti krasoslovci oziroma geomorfologi povabljeni k sodelovanju pri planiranju na kraških področjih.

THE CRITERIA FOR DEFINING KARST GROUNDWATER PROTECTION AREAS

KRITERIJI ZA DOLOČANJE VARSTVENIH OBMOČIJ KRAŠKE TALNE VODE

JOŽE JANEŽ

Izvleček UDK 556.338.2

Jože Janež: Kriteriji za določanje varstvenih območij kraške talne vode

V kraških vodonosnikih ni mogoče določati varstvenih območij s pomočjo časa razgradnje kateregakoli onesnaženja, tudi bakteriološkega ne. Predlagamo, da bi ranljivost različnih delov hidrološkega zaledja določali s časom, ki je na voljo za intervencijo ob odkritju onesnaženja, oziroma časom za preprečitev vstopa nevarne snovi v vodonosnik in v vodovodni sistem. Na obseg varstvenih območij bistveno vpliva poleg hidrogeoloških značilnosti hidrološkega zaledja tudi njegova raziskanost. Kriterij za določanje površine varstvenih območij so razmere ob visokih hidroloških stanjih (največje hitrosti, najvišja gladina, največja površina hidrogeološkega bazena).

Ključne besede: krasoslovje, hidrologija krasa, varstvo kraške talne vode

Abstract UDC 556.338.2

Jože Janež: The criteria for defining karst groundwater protection areas

It is not possible to define the karst aquifers protection areas by using the parameter of degradation time of any kind of pollution, including bacteriological contamination. We suggest that the demarcation of the protection areas is based on the vulnerability of the aquifer, which is determined as the time interval between the moment when pollution started and the moment when it is already too late to intervene (to prevent the admittance of dangerous material into an aquifer or water supply system). The extent of protection areas depends on hydrological characteristics of hydrological background as well as on the degree to which it is discovered. The extent of protection areas has to be defined at conditions of high hydrological situations (the highest water-speed, the highest water-level, the greatest extent of hydrogeological basin).

Key words: karstology, karst hydrology, karst groundwater protection

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INTRODUCTION

The article deals with the professional difficulties regarding preventive protection i. e. defining karst water resource protection areas. We consider the criteria for defining protection areas have not been studied sufficiently. We think, in future, these criteria must receive greater attention to be quantified to the greatest extent possible. In the article, four different criteria are discussed: the water stay-time interval, the extent to which the hydrological catchment area has been researched, the degree of danger for groundwater pollution and the time interval available to prevent ground water pollution.

CRITERIA

Water flow-time interval

The catchment area is the ground area from which all the water streams, on the surface as well as underground, flow off towards a certain spring. When defining protection areas in intergranular aquifers the catchment area of the karst springs is mostly divided into different degrees of danger for groundwater pollution, regarding "the time interval of water-flow within the limits of the protection area and the spring". The time interval necessary for the degradation of bacteriological contamination is used as the basis, i. e. the time interval sufficient for the microorganisms to lose their pathogenic characteristics. An extremely large span has been quoted or used for this time interval by different authors. The time interval of one to two months was used by Breznik (1976) to divide between the first and the second protection area in intergranular aquifers. It was quoted by Lacković (1986) that bacteria lose the pathogenic characteristics within 50 to 60 days, while 200 days with the bacteriological contamination of lower intensity and 400 days with intensive and permanent bacteriological contamination were cited by Filipović & Vujasinović (1982). According to Fritz & Pavičić (1986) the time interval necessary for the water to flow from the contamination infliction to the spring is one of the most important parameters for the karst springs as well. Surely the transfer time interval for the dangerous material is one of the basic physical factors to be taken into account with hydrological research. Nevertheless, it has limited applicability in karst underground water protection as the water speed in the karst is so great as not to allow adequate degradation of even the quickest degradable organic materials in the aquifers of natural size when the water level is high.

The 0,4 - 3,1 cm/s (14,4 - 111,6 m/h) apparent water speed levels of the tracing tests in Switzerland were quoted by Zupan & Gospodarič (1980). The results of tracing tests in Slovenia establishing apparent speed values (V_f) between 0,01 and 24,8 cm/s (0,36 - 893 m/h) were collected by Novak (1985), the average being 2,1 cm/s (75,6 m/h). In the Dinaric karst V_f is in the span between 0,002 and 55,2 cm/s (0,07 - 1987 m/h), the most frequent class being 1 - 2 cm/s (36 - 72 m/h) (Milanović, 1979). At $V_f > 0,5$ cm/s a distance of nearly 13 km is reached by water within 30 days, at $V_f > 1$ cm/s (according to Milanović (1979) 88,7 % of all cases) a distance of 26 km.

In the contamination degrading time interval such distances are reached by the groundwater as to make this criterion only one among the possible additional criteria to distinguish between the farthest and least threatened areas and the areas with the higher degree of danger for pollution, with the karst aquifers as well as fissure aquifers. It would be a reasonable choice to have, as suggested by Fritz & Pavičić (1986), definite criteria for each protection area, which should be the same ones for all the water springs in the karst.

THE CRITERION OF THE PROVED CATCHMENT AREA OF A KARST SPRING

According to the criterion of the catchment area of a karst spring established through research the following areas can be divided:

- proved catchment area of the karst spring (through the tracing test or other hydrological or geological proof),
- not proved but possible catchment area,
- proved out-of-catchment area (fig. 1).

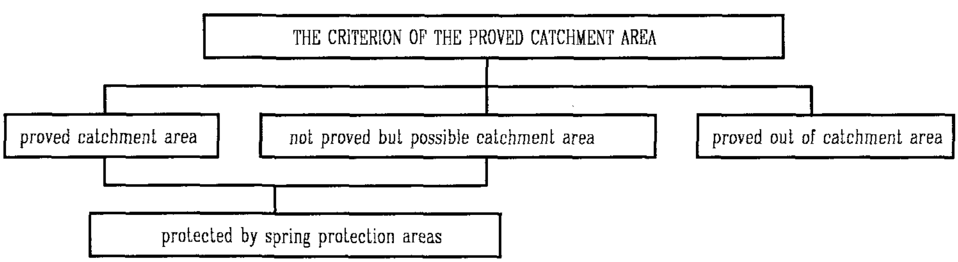

Fig. 1. The criterion of the proved catchment area

It appears to be reasonable to attribute to the not proved catchment areas of the karst spring the degree of pollution danger possible, regarding the existing hydrological circumstances, in case of the proved connection. If there are sinking streams with possible direct connections in such an area, it must be ranged among the areas of high pollution danger, otherwise among the medium or less endangered areas. Through further, more detailed research, the not-proved catchment area of the karst spring can be eliminated from the protected area or it can be appointed a milder protection regime.

Among the particular protection areas inside the whole protected area, the priority principle of the inner protection area is in force, which means the more rigorous protection regime is in force for the areas not clearly distinguishable as belonging to either one or the other degree of pollution danger.

POLLUTION DANGER AND THE TIME INTERVAL AVAILABLE TO INTERVENE

The pollution danger of the karst water depends on the burdening of the environment and the natural vulnerability of the aquifer (fig. 2).

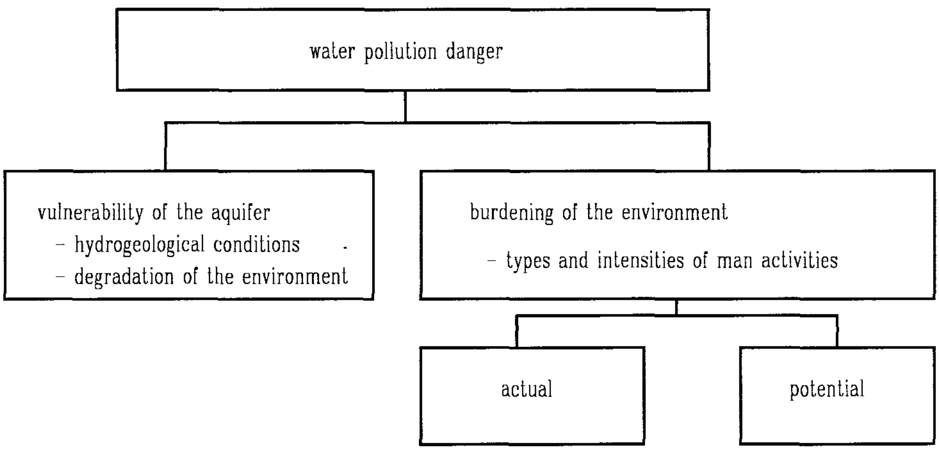

Fig. 2. Pollution danger of a karst aquifer

The burdening of the environment is caused by various types and intensities of human activities, latent and active. The natural vulnerability of the karst aquifer depends on the surface infiltration and hydrogeological conditions in the aquifer (way and time of underground water flow, water quantities, degree of dilution) and on the already reached degree of environmental degradation.

The vulnerability of the aquifer is used as the main criterion to classify the catchment area of the karst spring into protection areas. It is divided into four degrees: areas of catastrophic vulnerability, areas of great vulnerability, areas of medium vulnerability, and areas of little vulnerability (fig. 3).

This division corresponds almost fully with Šarin's (1986) area division, according to the pollution danger, into the following kinds of areas: the highly threatened ones (= great vulnerability), the endangered ones (= medium vulnerability), the partly threatened ones (= little vulnerability), and the non-threatened areas.

Through this division into the above four degrees of aquifer vulnerability we are able to prescribe the necessary criteria or conditions respectively as well as the corresponding protection area for each degree.

As the criterion of the parameter of degradation time for dangerous materials does not allow the differentiation of different degrees of pollution danger, and through that the protection areas, the degree of aquifer vulnerability is defined by the time interval available to intervene.

Intervention is required in the case of a sudden accidental or intentional release of dangerous material onto the surface. Usually the admittance of dangerous material at a certain spot is the problem, taking place once and only lasting a short time. Most frequently, it is caused by an unconventional permanent pollutant. Intervention can also be required in the case of conventional pollution (e.g. unexpected fertilisation, road construction in the catchment area of a karst spring), but also in the case of heavy rainfall after a longer dry period, when the washout of dangerous materials, which have been accumulating onto the surface or aquifer more or less continually, is increased.

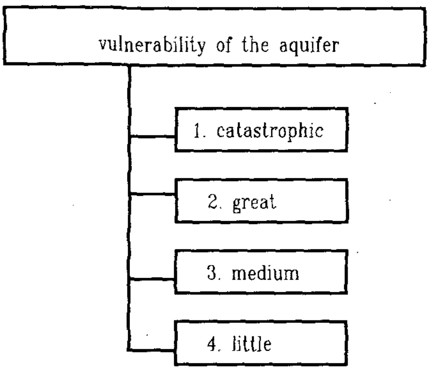

Fig. 3. The vulnerability of the aquifer

It is the intervention aim:

- to prevent the spread of dangerous material across the surface and its irruption into the aquifer,

- to prevent admittance of dangerous material into a spring, a well or into the water supply system (to the consumer).

Usually, accidental events take place and can be expected in the production, transport, storage, processing and usage of dangerous materials (Kokol, 1980), which we have to take account of when organising preventive activities in protection areas.

When defining protection areas, we will not be interested in the sanction activity mode, contents or scope but in the time interval at disposal to intervene. The time interval available to intervene depends only on characteristics of the aquifer and of the dangerous material:

- the permeability of the surface and aquifer,
- the hydrological parameters (flow, stream speed, stream direction),
- the distance between the pollution point and the spring,
- climatic and hydrological circumstances,
- characteristics of the dangerous material.

From the point of view of protection, the karst spring catchment area can be divided into:

- the areas inside which there is practically no time to prevent the admittance of dangerous material into the water supply system after the pollution event,
- the areas inside which there is practically no time to prevent the admittance of dangerous material into the aquifer after the pollution event, but there is a certain time interval to prevent the admittance of the material into the water supply system,
- the areas inside which there is a certain time to prevent the admittance of dangerous material into the aquifer after the pollution event (fig. 4).

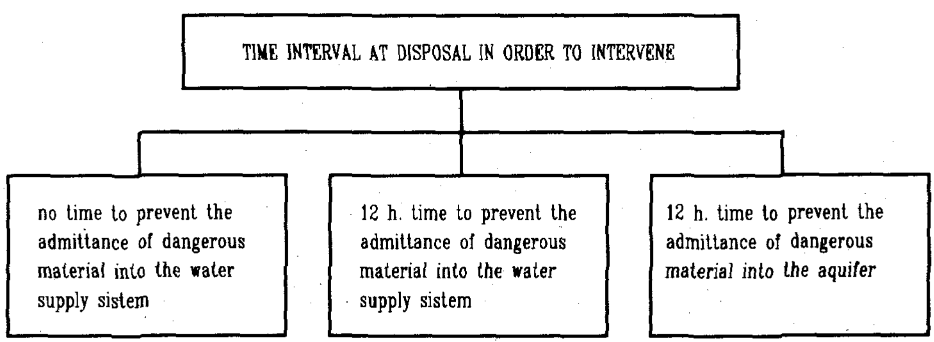

Fig. 4. Time interval available in order to intervene in case of pollution

Defining the time interval available to prevent the admittance of dangerous material into the water supply system or the aquifer should be based on the speed of water flow through the aquifer and the time interval necessary to degrade or absorb the non-lasting dangerous materials. However, as already stated, the water speed levels in the karst aquifers and fissure aquifers are such as not to allow any of the dangerous materials infiltrated into the hydrological basin to be degraded or absorbed sufficiently as far as the spring or well. This is why the time available to intervene should be based on the convention taking into account also the actual time interval during which the water supply system management or any other service can intervene in case of emergency. The time interval during which the intervention is feasible depends upon the state of the water supply service organisation as well as upon the characteristics of the place in which the disaster has occurred. Therefore the time available to intervene (12 hours) is presented as the proposal taking both conditions into account.

The catastrophic vulnerability of the aquifer applies for the areas inside which there is practically no time (up to 4 hours) to prevent the admittance of dangerous material into the water supply system after the pollution has occurred.

The great vulnerability of the aquifer applies for the areas in which there is practically no time to prevent the admittance of dangerous material into the aquifer after the pollution taking place; there is, however, a certain time interval (12 hours, a suggestion) in which the admittance of dangerous material into the water supply system can be prevented.

The medium degree of danger for groundwater pollution applies for the areas inside which there is a certain time interval (more than 12 hours) to prevent the admittance of dangerous material into the water supply system after admittance of dangerous material into the aquifer has taken place.

The little vulnerability of the aquifer applies for the areas:

- inside which there is a certain time interval (12 hours, a suggestion) to prevent the admittance of dangerous material into the aquifer after the pollution taking place, or
- where the concentration of the dangerous material in actual potential quantity is lowered below the maximum allowed concentration level defined by law, within the distance from the admittance point to the spring (fig. 5).

Above all, vulnerability in a certain area is affected by the hydraulic permeability of the aquifer. Regarding hydraulic permeability from the standpoint of defining protection areas, too, there can be distinguished: the karst aquifers and areas (limestone, chiefly), the fissure aquifers and areas (dolomite, mostly) and the poorly permeable and non-permeable areas (e.g. flysch). Each of the degrees of danger for groundwater pollution can be described additionally, applying characteristics defining the aquifer permeability.

The areas of great vulnerability are defined by exceptionally great permeability, the areas of medium vulnerability by medium permeability, and the areas of little vulnerability by low permeability. Naturally, when defining the danger for aquifer pollution, figures other than hydraulic permeability must also be considered (the depth to the groundwater piezometric level, the stated groundwater speed, the distance from the pollution source to the karst spring etc.).

It is possible but difficult to define the degree of danger for groundwater pollution according to the water quantity contributed to the total spring flow by the different parts of the catchment area. Usually, there are not sufficient data for such a definition (the not sufficiently dense ombrographic net, the lack of data about hydraulic permeability etc.). It is possible to estimate the degree of danger according to the sinking stream flow, though.

The extent of protection areas has to be defined at conditions of high hydrological situations (the highest water speed, the highest water level, the greatest extent of hydrological basin).

A certain protection area with the corresponding protective regime applies for each degree of aquifer vulnerability (fig. 5).

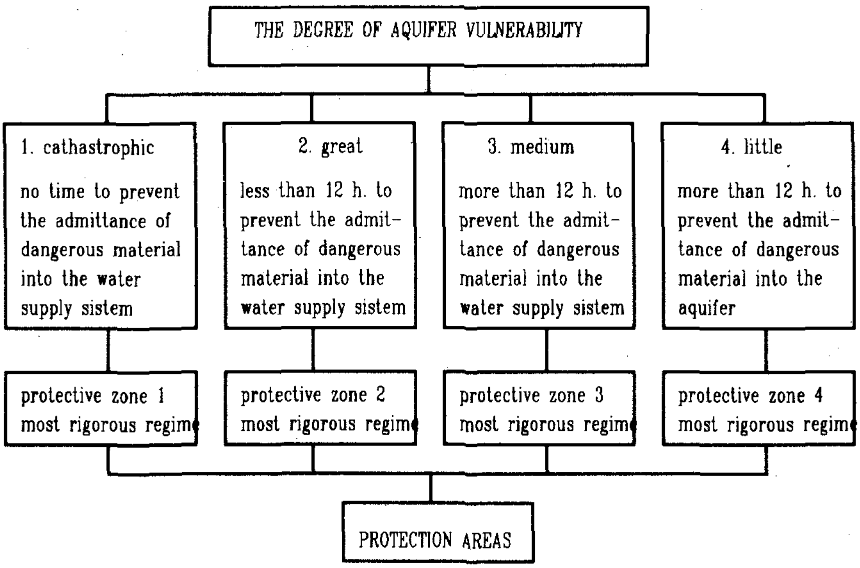

Fig. 5. The connection between the vulnerability of the aquifer and karst spring protection areas

REFERENCES

Breznik, M., 1976: Metodologija zaščite podzemne vode ter določitve varstvenih območij in pasov. Zasnova uporabe prostora. Vodno gospodarstvo. 176 str. Zavod SR Slovenije za družbeno planiranje. Ljubljana.

Filipović, B. & S. Vujasinović, 1982: Zaštita podzemnih voda. 358 str. OOUR Grupa za hidrogeologiju Rud. geol fakult., Univ. u Beogradu.

Fritz, F. & A. Pavičić, 1986: O problemu zaštitnih cona u kršu. Zb. jug. sav. Zaštita izvorišta voda za vodoopskrbu, Split 1986, 255 - 263. Zav. za tehn. izobr. Ljubljana.

Kokol, J., 1980: Ukrepi za zaščito voda in vodnih virov v slučaju nezgodnih dogodkov. Tipkopis, 131 str. VGP Hidrotehnika TOZD Hidroinženiring Ljubljana. Arhiv Zv. vodnih skupnosti Slovenije, SŠ 27. Ljubljana.

Lacković, M., 1986: Problematika zaštite temeljnih voda aluvialnih naslaga s osvrtom na crpilište regionalnog vodovoda Varaždin. Zb. jug. sav. Zaštita izvorišta voda za vodoopskrbu, Split 1986, 331 - 339. Zav. za tehn. izobr. Ljubljana.

Milanović, P., 1979: Hidrogeologija karsta i metode istraživanja. 302 str. HE na Trebišnjici. Inst. za korištenje i zaštitu voda na kršu. Trebinje.

Novak, D., 1985: Metodologija zaščite kraške podzemeljske vode. Naš krš, XI, 18 - 19, 11 - 15. Sarajevo.

Šarin, A., 1986: O karti ugroženosti vodonosnika od zagadjenja. Zb. jug. sav. Zaštita izvorišta voda za vodoopskrbu, Split 1986, 55 - 61. Zav. za tehn. izobr. Ljubljana.

Zupan, M. & R. Gospodarič, 1980: Sledenje s fluorescenčnimi barvili v švicarski Juri. Tipkopis, 68 str., 13 pril. Zv. vodnih skupnosti Slovenije, IZRK ZRC SAZU Postojna.

KRITERIJI ZA DOLOČANJE VARSTVENIH OBMOČIJ KRAŠKE TALNE VODE

Povzetek

V praksi običajno naletimo na velike težave pri določanju varstvenih območij kraških vodnih virov, saj temu problemu doslej ni bilo posvečeno dovolj pozornosti. Pri medzrnskih vodonosnikih najbolj pogosto privzamemo kriterij časa toka vode znotraj meja varstvenega območja. Za osnovo je uporabljen čas, ki je potreben za degradacijo bakteriološkega onesnaženja. Ta kriterij ima v krasu omejeno uporabnost, saj zaradi prevelike hitrosti toka ob visokih vodah ni možen ustrezen razkroj niti najhitreje razgradljivim organskim snovem. Bolj smiselna se nam zato zdi kombinirana raba 4 različnih kriterijev: časa toka vode skozi vodonosnik, stopnje raziskanosti hidrogeološkega zaledja, stopnje nevarnosti onesnaženja podzemne vode ter časa, ki je na voljo za preprečitev onesnaženja podzemne vode.

Kriterij časa toka vode skozi vodonosnik uporabljamo v krasu le kot pomožni faktor za ločevanje najmanj in najbolj ogroženih območij. Glede na stopnjo raziskanosti so lahko območja v zaledju kraških izvirov: dokazano znotraj zaledja, možno, a ne dokazano znotraj zaledja ter dokazano izven zaledja. Smiselno je, da območjem, ki jih sicer uvrščamo v zaledje, a za to nimamo zadostnih dokazov, priredimo tako stopnjo nevarnosti onesnaženja, kot da bi bile zveze dokazane. Če pa se ne moremo odločiti za primerno stopnjo nevarnosti onesnaženja, izberemo možnost strožjega režima.

Nevarnost onesnaženja kraških vod je odvisna od obremenjenosti okolja in naravne ranljivosti vodonosnika. Glavni kriterij za klasifikacijo zaledij v varstvena območja je ranljivost, ki je lahko katastrofična, velika, srednja in majhna. Kriterij za razvrščanje v te razrede je čas, ki je na voljo za intervencijo ter je odvisen od karakteristik vodonosnika in lastnosti nevarnih snovi, ki povzročajo onesnaženje. Pri katastrofični ranljivosti ni časa za preprečitev vstopa nevarnih snovi v sistem vodooskrbe, zato taka območja uvrščamo v 1. varstveno območje z najstrožjim režimom. V 2. varstvenem pasu so območja velike ranljivosti, kjer je za intervencijo na razpolago manj kot 12 ur. Za srednjo ranljivost je značilno, da imamo več kot 12 ur časa za preprečitev vstopa nevarnih snovi v sistem vodooskrbe in jih uvrščamo v 3. varstveno območje. Pri majhni ranljivosti je za preprečitev vdora nevarnih snovi v vodonosnik na voljo več kot 12 ur, zato imajo ta območja znotraj 4. varstvenega pasu najmanj strog režim zaščite. Izbiro intervala 12 ur predlagamo na osnovi ocene stopnje organiziranosti službe za nadzor vodovodnega sistema in karakteristik območja, v katerem se onesnaženje pojavi.

VREME BEDS AND THE GENESIS OF THE KARST CAVES IN THEM IN WIDER SURROUNDINGS OF ŠKOCJANSKE JAME (ŠKOCJANSKE JAME CAVES, SLOVENIA)

VREMSKE PLASTI IN RAZVOJ KRAŠKIH JAM V TEH PLASTEH V ŠIRŠI OKOLICI ŠKOCJANSKIH JAM

MARTIN KNEZ

Izvleček UDK 551.44(497.12)

Knez, Martin: Vremske plasti in razvoj kraških jam v teh plasteh v širši okolici Škocjanskih jam

Vremske plasti (maastrichtij) sestavljajo predvsem drobnoplastnati temni apnenci, ki so ponekod močno bituminozni, redkeje laporni apnenci in premogovi skrilavci ter ponekod vložki premoga. Po strukturi je apnenec biomikrit tipa wackstone-packstone. Med omenjenimi plastmi se pojavljajo tudi breče, ki so najverjetneje singenetskega nastanka. Fosilni ostanki kažejo, da se je večji del vremskih plasti sedimentiral v plitvem morju. Na obravnavanem ozemlju je v vremskih plasteh samo 6,2% vseh jam oziroma komaj 0,3 jame/km^2, kar je dve tretjini pod povprečjem.

Ključne besede: krasoslovje, geologija, paleoekologija, litostratigrafija, vremske plasti, Škocjanske jame, Slovenija

Abstract UDC 551.44(497.12)

Knez, Martin: Vreme beds and the genesis of the karst caves in them in wider surroundings of Škocjanske jame (Škocjanske jame caves, Slovenia)

The Vreme beds (Maastrichtian) are composed mainly of dark thin bedded, sometimes strongly bituminous limestones and rarely marly limestones and coal shales and inliers of the coal. According to structure the limestone is biomicrite of wackstone-packstone type. Among the mentioned beds there are the most probably the syngenetic breccias too. Fossil remains and sedimentological data show that the major part of the Vreme beds was deposited in a shallow sea. On the treated area there are in Vreme beds 6,2% of all the caves only, or 0,3 cave/km^2 respectively, which means two thirds below the average.

Key words: Karstology, Geology, Paleoecology, Litostratigraphy, Vreme beds, Škocjanske jame (Škocjanske jame caves), Slovenia

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INTRODUCTION

Out of 6000 karst caves registered on the Slovenian karst which covers about 40% (8800 km2) of the country we have chosen the area of the wider surroundings of Škocjanske jame (102 km2) where 113 speleological objects are registered. The region is built by Cretaceous and Paleogene rocks which are the most common in the area of the Classical Karst of southwestern Slovenia. The statistical data processing was done in order to find out the given regularities in the appearance of the karst caves. As already inferred by M. Garašić (1986; 1989; 1991) the geological conditions dominantly control the karst objects formation. The influence of temperature or altitude, for example could be considered after thought for both paleoclimatic and paleogeographic influences on the formation of the cave objects during their genesis which have not yet been studied in detail.

Before the karst caves statistical processing on the mentioned area we anticipated from the Cave Register that the Liburnian beds are poor regarding the speleological objects. It is known that the Cretaceous beds are generally much richer. This is why I tried to establish in which conditions the Vreme beds, the beds of Liburnian formation respectively, have been deposited.

PALEOECOLOGICAL AND LITHOSTRATIGRAPHICAL PROPERTIES OF THE LIBURNIAN FORMATION AND OF VREME BEDS IN THE WIDER VICINITY OF ŠKOCJANSKE JAME WHERE ONLY FEW SPELEOLOGICAL OBJECTS DEVELOPED

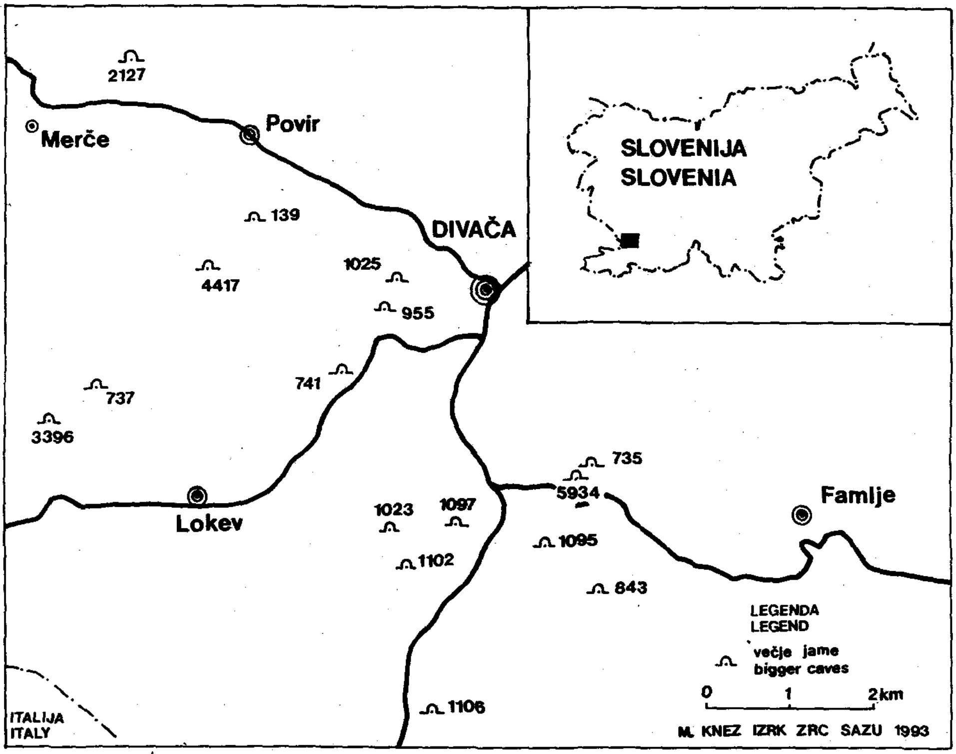
The least number of all speleological objects were identified in the upper part of the Liburnian formation, in the Vreme beds (upper part of the Upper Cretaceous - Maastrichtian). A lot of stratigraphic, biostratigraphic, lithological, sedimentological and other researches were carried out in the Vreme beds. Most of them were done from one aspect only. Just a few of them offer a conclusion in form of synthesis from various points of view. None of them includes the karstological or speleological viewpoint. Therefore the connection of lithological, petrological, stratigraphical and biostratigraphical statements with speleological findings and speleological development in past is surely interesting.

Lithostratigraphical properties of the rock where the speleological object could potentially develop (M. Garašić, 1986) are undoubtedly the most important for the origin and development of the speleological objects. The karstification of the rock is a relatively regular process and according to stratigraphy and lithology the beds, where the speleological objects developed, could be defined.

In 1872 G. Stache denominated the Liburnian formation or Protocene as prevailingly carbonate sediment occuring in southwestern Slovenia and Istria among Rudist limestones and limestones with Alveolina and Nummulites.

Today the lower part of the Liburnian formation is called the Vreme beds; they are of Maastrichtian age, the central part are Danian Kozina beds and the upper part limestones with Milliolidae of Thanetian age (R. Pavlovec & K. Drobne, 1991).

M. Pleničar, A. Polšak and D. Šikić (1973) wrote that the region of the

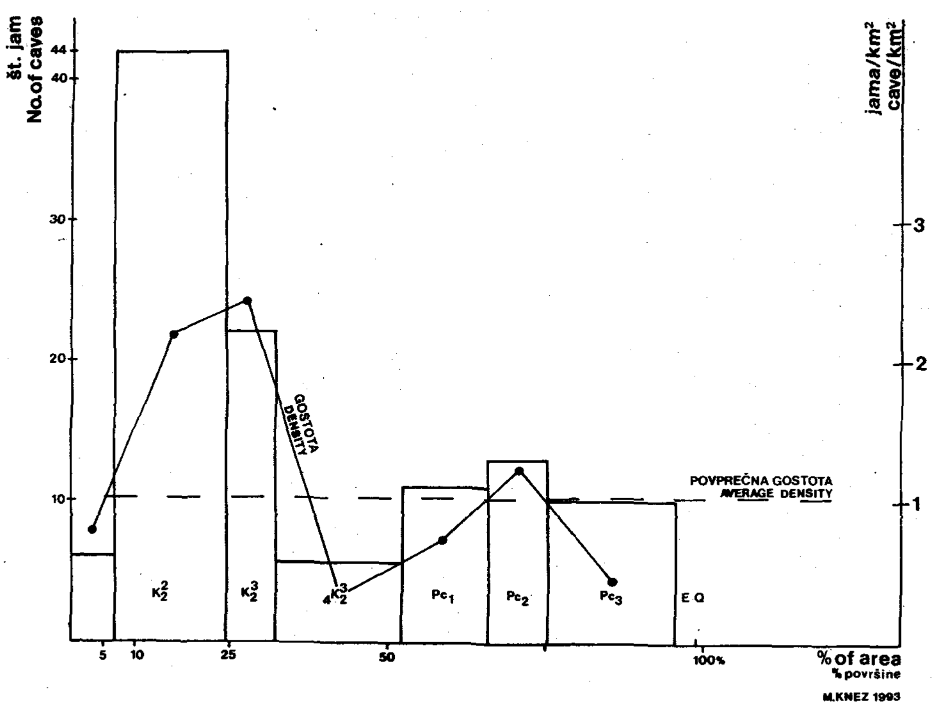


Slika 1. Skica ozemlja med Merčami in Lipico na vzhodu, Senožečami in Barko na zahodu ter Kačičami na jugu, z označenimi večjimi jamami.
Fig.1. The sketch of the region between Merče and Lipica on the east, Senožeče and Barka on the west and Kačiče on the south with bigger caves drawn in.

Slovenian Littoral was taken by Laramian folding at the end of the Cretaceous. In Danian and in Paleocene the sea transgressed into formed sinklines. According to D. Šikić and M. Pleničar (1975) there are the signs of general uplifting of the territory at the end of Cretaceous. On the passage of Cretaceous to Tertiary the sea bottom oscillated several times.

Similar is the description of the history of this part given by S. Buser (1973). In upper Senonian some parts of the Trieste Komen plateau were uplifted out of the sea. In Senonian and Paleocene the marine, brackish and fresh water conditions of sedimentation alternated frequently.

The breccias and bauxites of the Liburnian formation found on many places in Primorska indicate the then sea regression which is supposed to be shallow with local patches of land. In the sea lagoons and partly in the fresh water lakes the Liburnian formation sedimentation proceeded without any important intermediary tectonic movements (M. Pleničar, 1961). The uplifting



Slika 2. Grafični prikaz razporeditve jam na obravnavanem ozemlju.
Fig.2. Graphic presentation of the caves distribution on the treated area.

occured at the end of Cretaceous but it had the character of epirogenetic and not orogenetic process (M. Pleničar, 1970).

After the sedimentation of the beds with rudists the regression followed to which the Vreme beds are owed (R. Pavlovec & M. Pleničar, 1981).

In Slovenia the Maastrichtian beds developed in limestone and marly facies. Within the marly development they occur as the marine sediments, while in the limestone one as marine, brackish and fresh water beds. J. Pavšič (1976, 1979) wrote about the marly development of the Maastrichtian and about the marly sandstone development (flysch). In southwestern Slovenia the limestone development was defined only (M. Pleničar & R. Pavlovec, 1981).

The Vreme beds are composed mainly dark thin bedded, sometimes strongly bituminous limestones and rarely marly limestones and coal shales and inliers of the coal (M. Pleničar, 1956; M. Hamrla, 1959, 1960; R. Pavlovec, 1965). According to structure the limestone is biomicrite of wackstone-packstone type. Among the mentioned beds there are most probably the syngenetic breccias too (K. Drobne & R. Pavlovec, 1991), where Burnonians are found on some places (K. Drobne et al., 1989). On some places thin gastropoda and thin shelled shells and small micritic plasticlasts appear. Micritic base indicates frequent signs of bioturbation and is washed out in places. In some horizons there are numerous shells (M. Pleničar, 1961) of Gyropleura and Apricardia genus (M. Pleničar, 1993), Rhapydionina liburnica foraminifera, Montcharmontia appenninica and milliolids (K. Drobne, 1981; R. Pavlovec & K. Drobne, 1991). The Rudists and Gyropleura shells were subdued to intensive activity of endolites (K. Drobne et al., 1988).

Fossil remains and sedimentological data show that the major part of the Vreme beds was deposited in a shallow sea (M. Hötzl & R. Pavlovec, 1981; R. Pavlovec, 1981) on a quiet and leeward shelf with the energy index 1-2 (K. Drobne et al., 1989), near the coast and partly in shallow lagoons (K. Drobne & R. Pavlovec, 1991) which were the most probably seasonally bordered by the rudist bioherms (R. Pavlovec & M. Pleničar, 1983). Such environment should exist uniformly on wider region of the Slovenian part of the Outer Dinarides (K. Drobne et al., 1989).

KARST PHENOMENA IN SLOVENIA AND IN WIDER VICINTY OF ŠKOCJANSKE JAME

In Slovenia karst phenomena developed in the Paleozoic limestones, in the limestones and dolomites of the Mesozoic and in the Tertiary limestones, in the limestone sandstones, in the marly limestones and in the conglomerates. The karstification extent and depth depend on thickness, extension and frequency of appearance of porous and permeable carbonate rocks on a given area. The biostratigraphical age of the rocks influences to the origin of the karst phenomena too. Till now it is not yet explained why there is on the

Classical Karst the best developed superficial and underground karst just in the Upper Cretaceous rocks (R. Gospodarič, 1986). It is possible that these rocks are more subdued to karstification as they are primary and secondary more permeable as the mantle Paleocene limestones are; maybe they were tectonically deformed at the passage from Cretaceous to Tertiary already and exposed on temporary land to the first effects of karstification.

From the point of view of karstification the lithologic-petrological setting of the Cretaceous beds is interesting as well. In micritic and sparitic limestones there are included dolomitized and silicified limestones which impede the karstification on the surface and in the undergroubnd due to weak solubility. In the same manner different bedding and connected different fissures within the limestone blocks are interesting, influencing the morphology of the underground passages and the shapes of the superficial karst.

The most widespread and at the same time the most favourable rocks for the karstification in Slovenia are Jurassic and Lower and Upper Cretaceous rocks. In these rocks Postojnska jama, Škocjanske jame, Planinska jama and Križna jama developed and these are our the biggest cave systems.

For a more complex review of the Škocjanske jame problematics in the wider vicinity of the cave system all 113 caves, registered in the Cave Register were statistically processed; they are situated between Merče and Lipica on the east up to the Senožeče and Barka on the west and Kačiče on the south (Fig. 1). Treated were 15 maps in the scale 1:5.000, namely Sežana from 23 to 27, 33 to 37 and 43 to 47. The surface of the entire territory amounts to 102 km^2.

To define a particular lithostratigraphic unit on the studied area I used the basic geological maps, sheets Gorica (S. Buser, 1968), Postojna (S. Buser, K. Grad & M. Pleničar, 1967), Trst (M. Pleničar, A. Polšak, & D. Šikić, 1969) and Ilirska Bistrica (D. Šikić, M. Pleničar, & M. Šparica, 1972). I set apart the following units: Lower Cretaceous and Cenomanian, Turonian, Senonian, Maastrichtian, Danian, Thanetian, Illerdian, Eocene (flysch) and Quaternary.

Cretaceous

In the Lower Cretaceous and Cenomanian limestones and dolomites, covering 7.08 km^2, there are 6 caves or 5.31% of all the caves of the treated area (Fig. 2). One km^2 only is of limestones and 6.08 km^2 of dolomites; in dark grey bituminous limestones of this unit there are no caves.

Dark grey and sometimes snow white fine grained Turonian limestones alternating with grey rudist limestone cover 18.20 km^2, which is 17.84% of the surface. In this unit there are 44 or more than one third of all cave objects included into the study.

On 8.20 km^2 (8.04%) built by Senonian pale grey limestone with numerous rudists 22 caves (19.47%) are registered.

In grey to dark grey bedded Maastrichtian limestones (Vreme beds) there are on the treated area 7 caves, which is 6.20%. Maastrichtian beds cover about 19.72 km^2 or 19.33%.

Tertiary

Characteristic compact, black or brown, sometimes silicified, sometimes crystalline and bituminous Danian limestones cover 13.99 km^2 (13.72%). 11 cave objects or 9.73% were discovered in them.

Thanetian milliolid limestones (the upper part of the Liburnian formation) with 13 caves cover a bit less of the territory (9.52 km^2 or 9.33%).

In spite the fact that the rather compact, mostly granular alveoline-nummulitic limestone covers the biggest amount of the territory 20.89 km^2 or 20.48%) only 10 caves (8.85%) were registered in it.

In flysch rocks (2.88 km^2 or 2.83%) there are no caves.

Quaternary

Quaternary deposits cover altogether 1.52 km^2 (1.49%). No karst caves have yet been found in them.

CONCLUSION

I have calculated from the cited data that the average cave density on the entire area amounts to 1.01 cave/km^2 (Fig. 2). For Lower Cretaceous and Cenomanian this factor is 0.77, for Turonian 2.18, for Senonian 2.42, for Maastrichtian 0.32, for Danian 0.71, for Thanetian 1.23 and for Illerdian 0.43 For Maastrichtian, Danian and Thanetian together, for the Liburnian formation respectively it is 0.75 which is for one quarter below the average.

Summing up the cited lithostratigraphical data of the treated territory where the speleological objects developed I can conclude that the most objects are formed in the Cretaceous rocks, with the greates density in the Senonian limestones. In the area including lithostratigraphic links from Lower Cretaceous to Quaternary there are only no cave objects found in Eocene flysch and Quaternary sediments.

According to the previous knowledge of the Vreme beds the answer to question why there are the least caves in the Maastrichtian Vreme beds, which is without doubt an interesting date by itself, the answer must be probably searched in rather specific conditions in the basin during the sedimentation of the Liburnian formation. By the manner and by the in the introduction mentioned starting points this problematics was not yet studied in detail this is why it is without doubt necessary to continue with petrological, sedimentological and chemical researches beside the paleoecological and lithological ones.

LITERATURE

Arhiv IZRK ZRC SAZU, Postojna. Jamski kataster (Cave Register).

Buser, S. 1968, Osnovna geološka karta SFRJ Gorica 1:100 000.- Zvezni geološki zavod Beograd, Beograd.

Buser, S., 1973, Tolmač lista Gorica. Osnovna geološka karta SFRJ 1:100 000.- Zvezni geološki zavod Beograd, 50 str., Beograd.

Buser, S., Grad, K. & Pleničar, M. 1967, Osnovna geološka karta SFRJ Postojna 1:100 000.- Zvezni geološki zavod Beograd, Beograd.

Drobne, K. 1981, Značilne foraminifere in njih združbe v podlagi danijskih plasti.- Simpozij o problemih danija v Jugoslaviji, Zbornik referatov, Proceedings, 2, 85-97, Ljubljana.

Drobne, K. & Pavlovec, R. 1991, Paleocene and Eocene Beds in Slovenia and Istria.- Introduction to the Paleogene, SW Slovenia and Istria, Field-Trip Guidebook, IGCP Project 286-Early Paleogene Benthos 7-17, Ljubljana.

Drobne, K., Ogorelec, B., Pleničar, Barattolo, F., Turnšek, D. & M., Zucchi-Stolfa, M. L., 1989, The Dolenja vas Section, a Transition from Cretaceous to Paleocene in the NW Dinarides, Yugoslavia), Mem. Soc. Geol. It., 40, (1987), 73-84, 2 ff., 6 tavv. n. t., Roma.

Garašić, M., 1986, Dominantan utjecaj geoloških uvjeta na morfološke i hidrogeološke tipove speleoloških objekata u hrvatskom kršu.- Naš Krš, 12, 21, 57-63, Sarajevo.

Garašić, M. 1989, New concept of the morfogenesis and hydrogeology of the speleological objects in karst area in Croatia (Yugoslavia).- Proceedings, 10th International Congres of Speleology, 1, 234-236, Budapest.

Garašić, M. 1991, Morphological and hydrogeological classification of speleological structures (caves and pits) in the Croatian karst area.- Geol. vjesnik, 44, 298-300, Zagreb.

Gospodarič, R., 1986, O geološkem razvoju klasičnega krasa.- Acta carsologica, 14/15, 19-29, Ljubljana.

Hamrla, M. 1959, O pogojih nastanka premogišč na krasu.- Geologija, 5, 180-264, tab. 1-6, Ljubljana.

Hamrla M. 1960, K razvoju in stratigrafiji produktivnih liburnijskih plasti Primorskega krasa.- Rudar. - metal. zbornik, 3, 203 - 216, Ljubljana.

Hötzl M. & Pavlovec R., 1981, Vremske plasti kot podlaga danijskim plastem v Zahodnih Dinaridih.- Simpozij o problemih danija v Jugoslaviji, Zbornik referatov, 133-136, Ljubljana.

Pavlovec, R. 1965, Regionalni obseg liburnijskih plasti.- Geologija, 8, 135-138, Ljubljana.

Pavlovec R., 1981, Nekaj primerjav s plastmi liburnijske formacije izven jugoslovanskega ozemlja.- Simpozij o problemih danija v Jugoslaviji, Zbornik referatov, Proceedings, 2, 167-174, Ljubljana.

Pavlovec, R. & Drobne, K., 1991, The Vremski Britof Profile, Upper

Maastrichtian.- Introduction to the Paleogene, SW Slovenia and Istria, Field-Trip Guidebook, IGCP Project 286-Early Paleogene Benthos 43-45, Ljubljana.

Pavlovec R. & Pleničar M., 1981, The boundary between Cretaceous and Tertiary in the limestone beds of the West Dinarides.- Rudar.-metal. zbornik, 28/1, 25-31, Ljubljana.

Pavlovec R. & Pleničar, M., 1983, Der ältere Teil der Liburnischen Formation in den NW-Dinariden.- Zitteliana, 10, 195-199, München.

Pavšič, J., 1976, Zgornjekredne in paleocenske foraminifere ter nanoplankton Slovenije.- 8. jugoslovanski geološki kongres, 2, 249-262, Ljubljana.

Pavšič, j., 1979, Zgornjekredni in paleocenski nanoplankton v Posočju.- Geologija, 22, 225-276, Ljubljana.

Pleničar, M. 1956, Razvoj paleocena in eocena v Sloveniji.- Prvi jugosl. geol. kongres, Bled, Predavanja in poročila, 45-46, Ljubljana.

Pleničar, M., 1961, Startigrafski razvoj krednih plasti na južnem Primorskem in Notranjskem.- Geologija, 6, 22-145, Ljubljana.

Pleničar, M., 1970: Tolmač lista Postojna. Osnovna geološka karta SFRJ 1 : 100.000.- Zvezni geološki zavod Beograd, 62 str., Beograd.

Pleničar, M. 1993, Apricardia pachiniana Sirna from lower part of Liburnian beds at Divača (Triest-Komen Plateau).- Geologija 35, 65-68, Ljubljana.

Pleničar, M. & Pavlovec, R., 1981, Novi pogledi na razvoj maastrichtija pri nas.- Rudar.-metal. zbornik, 28/4, 383-386, Ljubljana.

Pleničar, M., Polšak, A. & Šikić, D. 1969, Osnovna geološka karta SFRJ Trst 1:100 000.- Zvezni geološki zavod Beograd, Beograd.

Pleničar, M., Polšak, A. & Šikić, D., 1973: Tolmač lista Trst. Osnovna geološka karta SFRJ 1:100 000.- Zvezni geološki zavod Beograd, 68 str., Beograd.

Stache, G., 1872, Geologische Reisenotizen aus Istrien.- Verh. geol. R. A., 215-223, Wien.

Šikić, D. & Pleničar, M., 1975, Tolmač lista Ilirska Bistrica. Osnovna geološka karta SFRJ 1 : 100.000.- Zvezni geološki zavod Beograd, 51 str., Beograd.

Šikić, D., Pleničar, M. & Šparica, M. 1972, Osnovna geološka karta SFRJ Ilirska Bistrica 1 : 100 000.- Zvezni geološki zavod Beograd, Beograd.

VREMSKE PLASTI IN RAZVOJ KRAŠKIH JAM V TEH PLASTEH V ŠIRŠI OKOLICI ŠKOCJANSKIH JAM

Povzetek

Veliko stratigrafskih, biostratigrafskih, litoloških, sedimentoloških in drugih raziskav je bilo opravljenih v vremskih plasteh. Nobena od njih pa ne vključuje krasoslovnega oziroma speleološkega vidika. Zato je nedvomno zanimiva povezava litoloških, petroloških, stratigrafskih in biostratigrafskih ugotovitev s speleološkimi raziskavami.

Že pred statistično obdelavo kraških jam na omenjenem področju, se je glede na podatke Katastra jam dalo slutiti, da so plasti liburnijske formacije revne s speleološkimi objekti. Da so kredne plasti v splošnem z njimi mnogo bogatejše je znano že dalj časa.

Za kompleksnejši pogled v problematiko Škocjanskih jam je bilo na širšem območju Škocjanskega jamskega sistema, med Merčami in Lipico na vzhodu do Senožeč in Barke na zahodu in Kačičami na jugu (slika 1), statistično obdelanih 113 v Katastru jam identificiranih kraških jam. V obdelavo je bilo tako zajetih 15 kart v merilu 1:5000.

Najmanj jamskih objektov je identificiranih v zgornjem delu liburnijske formacije oziroma v vremskih plasteh (vrhnji del zgornje krede - maastrichtij).

Izračunal sem, da je povprečna gostota jam na celotnem ozemlju 1,01 jame/km^2. Za spodnjo kredo in cenomanij je ta faktor 0,77, za turonij 2,18, za senonij 2,42, za maastrichtij 0,32, za danij 0,71, za thanetij 1,23, ter za ilerdij 0,43 (slika 2). Za maastrichtij, danij in thanetij skupaj, oziroma za liburnijsko formacijo pa 0,75, kar je za četrtino pod povprečjem.

SOME EXAMPLES OF THE KARST WATER POLLUTION ON THE SLOVENE KARST

PRIMERI ONESNAŽEVANJA KRAŠKIH VODA NA SLOVENSKEM KRASU

KOGOVŠEK JANJA

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Izvleček UDK 556.38(497.12)

Janja Kogovšek: Primeri onesnaževanja kraških voda na slovenskem krasu

Prispevek podaja primere, ko se onesnaženje na kraškem površju odraža v kvaliteti *prenikle vode*. Obravnavana je onesnažena prenikla voda z območja slovenskega krasa in sicer v Postojnski (Kristalni rov) in Pivki jami, Ponikovski dragi in v Škocjanskih jamah. Določena je bila vrsta in izvor onesnaženja, v primerih Postojnske in Pivke jame pa smo podrobneje več let spremljali posamezne parametre, kar je pokazalo tudi na postopno večletno čiščenje karbonatnega masiva po odstranitvi izvora onesnaženja.

Ključne besede: krasoslovje, kraške vode, prenikla voda, ponikalnice, kvaliteta, onesnaževanje, slovenski kras

Abstract UDC 556.38(497.12)

Kogovšek Janja: *Some Examples of the Karst Water Pollution on the Slovene Karst*

The paper gives some examples of karst surface pollution reflected in the quality of the percolation water in the caves. The cases of Postojnska Jama (Kristalni Rov), Pivka Jama, Ponikovska Draga and Škocjanske Jame are dealt with. Type and origin of the pollution are determined; in the case of Postojnska Jama and Pivka Jama several parameters of the pollution were monitored during many years and we assessed gradual, several years lasting cleaning up of the carbonate massif after the pollution source was removed.

Key words: karstology, karst waters, percolation water, sinking river, water quality, pollution, Slovenia

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INTRODUCTION

The study of the percolation water corrosion in the caves of the Slovene karst, in Postojnska Jama, Planinska Jama, Taborska Jama, Divaška Jama, Jama at Predjama, Vilenica, Dimnice and Škocjanske Jame yielded us the notion about the water quality. Fig. 1 presents the underground caves where our researches were carried on.

In several caves, lying below the uninhabited areas that are not intensively cultivated, no signs of pollution were registered in the percolation water as it was expected. In the course of researching infiltrating water, polluted water was encountered. This was the reason for analysing the polluted infiltration water in Pivka Jama, in Ponikovska Draga, in the Kristalni Rov of Postojnska Jama and in Tiha Jama, Mahorčičeva, Mariničeva Jama, the latter three forming part of the Škocjanske Jame system.

In all the cases studied, pollution from communal waste waters was present. In the Kristalni Rov alone there was a once-off spillage of some other pollutants which left dark stains on the flowstone.

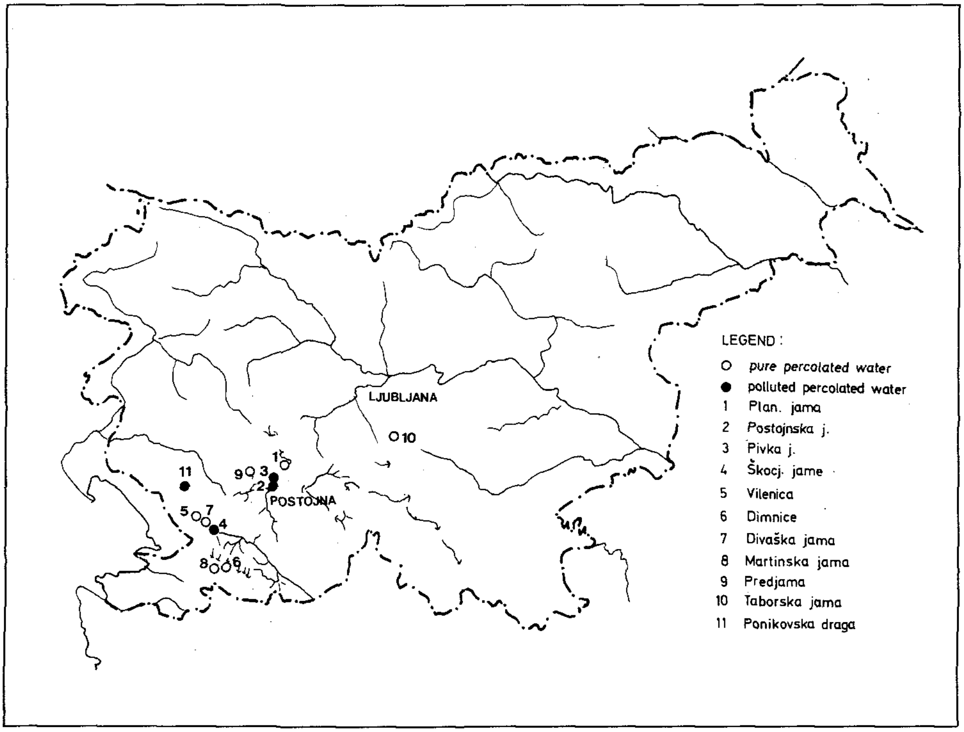
THE EXAMPLES OF POLLUTED PERCOLATION WATER

Pivka Jama

While monitoring the trickles and drippings in Pivka Jama, a narrow area of polluted water was detected, indicated by the increased level of nitrate, phosphate, chloride, and characteristically augmented specific electric conductivity and chemical oxygen demand. A lot of questions arose and we started detailed researches. We were in particular interested what was the source of the pollution, and how quickly the trickles react as it gives the velocity of the pollution transport into the karst interior, what a degree of self-purification exists during the percolation of pollutants through the cave roof and how the pollution is washed out of the cave roof, it means how long it may be retained in the carbonate rocks.

The pollution did not appear in all the trickles at the same extent due to different infiltration mode in various conduits. The reason for the polluted percolation water was waste water from showers and toilets of the camping site at the surface. It was point pollution reappearing in the cave in a radius of about 10 m after it passed through 40 m of fissured carbonate rocks. The trickles in the cave that were the most abundant during dry summer period when, on the other hand, there were most visitors in the camping, evidenced that the trickles represent an additional source of the water from the surface. Obviously this water bothered the visitors of the cave as it was falling to the tourist foot-path and the administration built a roof to protect the tourists against the drops. Hence, while planning the buildings on karst one must urgently examine the terrane and ascertain that there are no underground objects nearby.

Later adaptations of the lavatories within the camping site included blasting and as a result the pollutants have been washed off the cave roof and changed circulation occurred; some trickles almost dried up while the others increased. Obviously intensive works at the surface, blasting of upper rock layers for instance, can essentially impact on water circulation from the surface to the underground; in the mentioned case the works deepened the doline's bottom and we all know that the area of dolines intensively drains the water to the underground.



Sl. 1. Podzemeljske jame v Sloveniji, kjer smo spremljali kvaliteto prenikle vode.
Fig. 1. The underground caves in Slovenia where the quality of percolation water was measured

The results of many year researches have shown (Kogovšek 1987) that the settling of solid organic impurities in a cess-pool and their regular removal eliminate a major part of pollution from the waste water. After such sedimentation the water percolation through karstified carbonate massif is subdued to self-purification processes which are variously efficient due to percolation mode of different trickles. The chloride and phosphate level decreased to half after being filtrated through 40 m thick limestones, chemical and biochemical oxygen demand diminished by 95%. The purification is due to oxidation processes and dilution effects. With higher recharge, or when there are no sedimented solid organic impurities (that happens at direct outlet), the self-purification considerably diminishes and water remains much more polluted.

Kristalni Rov

The researches of percolation water in Kristalni Rov were provoked by visual pollution; dripping from the cave roof over the flowstone left well visible dark stains. This was a once-off spillage of some unknown pollutant obviously, as later this pollution was no more observed. The pollution was reported by the cavers and noticed by Gams (1983) who mentioned that fortunately the pollution did not spread through 100 m thick limestone roof in a bell-shape. Visible pollutions are noticed soon afterwards but most of these that we perceived till now were neither visible to eye nor smelt. Such was the case of water in Kristalni Rov near the place where black stains appeared.

The analyses showed that the water within an area of 20 m is polluted. Increased specific electric conductivity and higher levels of nitrate, phosphate, sulphate and chloride, and chemical oxygen demand (COD) were recorded. The pollution derived from the military object at the surface. Again different degree of pollution at various trickles was stated. Different conductivity of single conduits is controlled by different percolation velocity which influences the purification effect during the percolation and finally reflects in the quality of the percolation water.

I. Gams (1967) reported about different reactions of the percolation water drainage to the rainfall. Later detailed researches of the percolation water in Planinska Jama evidenced that at single trickles considerable differences occur during a year. In wet spring and autumn period the trickle reactions were quick, after half an hour after the rainfall even. In dry summer months the sporadic rainfall does not cause the recharge increase. When the recharge area of trickles is filled up, or when the total rainfall quantity reaches a defined value, in Planinska Jama this is 70 mm (Kogovšek & Habič 1981) the recharges of the trickles in the cave increase. At tiny drippings the reaction to the rainfall is very suffocated this is why the trickles react to the rainfall with considerable time lag. We got similar values at water tracing test from the surface into Kristalni Rov. Through well permeable conduit the tracer has taken an hour to reappear through 100 m thick roof, while badly permeable conduits required almost three months although in this time 240 mm of rain has fallen. By such a way one may presume the movements of pollution, dissolved by water and also non-degradable pollution that is washed off the cave roof. The tracer reappeared on a narrow area due to 100 m thick roof; in Pivka Jama, where the roof is 40 m thick, the pollution spreading was much wider.

These facts may become very useful at accidental spills of harmful substances or some other pollutants at the karst surface; one may assume when the pollution will reappear in the underground (Kogovšek 1982).

Ponikovska Draga

The pollution generated by the village above the cave appears in Ponikovska Draga rather quickly on several places. Of course, certain dilution occurs. During dry periods drippings prevail indicating relatively small or diffused quantities of waste water; probably partial evaporation occurs at the surface, the pollution concentrates and accumulates in the cave roof. During the first rainfall, at the beginning in particular when the dilution is small, the pollution in the underground is the most distinctive; after abundant and intensive rain the pollution is washed off.

Škocjanske Jame

The percolation water in Škocjanske Jame is also polluted. The increased value of nitrate in the trickle at Golgota, Tiha Jama, Škocjanske Jame reached 30 $mgNO_3\ l^{-1}$ may be explained by intensively cultivated field at the surface. In other parts of Tiha Jama, in Hankejev Kanal and in Tominčeva Jama the pollution was not recorded.

Extremely polluted percolation water was detected in Mariničeva and Mahorčičeva Jama. The level of nitrate, sulphate, and chloride and chemical and biochemical oxygen demand (Kogovšek 1994) as well as increased specific electric conductivity indicated the pollution in water. The percolation water constituents were similarly as in Pivka Jama, Kristalni Rov of Postojnska Jama and Ponikovska Draga due to communal waste water.

The roof thickness is from 50 to 80 m. During and after rain more or less abundant trickles appear, providing at the same time considerable dilution and washing the pollution off the surface and off the cave's roof. The degree of pollution among the trickles varies. In dry period in the cave there are single drippings only, similar as was stated in Ponikovska Draga. At such occasions the recharge area of the trickles is not filled and inflow water remains there. Thus the concentrated pollution occurs after the first washing of the recharge area, that means during the first heavy, and in particular intensive rain.

SINKING STREAMS

Karst underground and karst waters are endangered by sinking rivers that, more or less polluted, disappear into the karst underground, some of them several times even. The springs may even be captured for water supply. Also from this point of view the protection of sinking river quality is urgent.

Due to numerous cases when the waste communal waters are not treated the sinking streams receive during their superficial flow a certain amount of pollution. During low waters the conditions are usually critical and at this time the water is even more sensitive for any additional pollution, as could be some accidental spills of waste industrial waters or traffic accidents.

During dry summer months Pivka river gradually disappears in its medium flow already and frequently the water coming to Postojnska Jama is only that of Nanoščica, its tributary. In this time the water and the pollution disappear into karst by other ways, of course. Monitoring Pivka quality at its swallow-hole to Postojnska Jama during low waters indicated increased values of the parameters, in particular chemical and biochemical oxygen demand and at the same time decrease of the dissolved oxygen level that lowered to critical 1.1 $mgO_2\ l^{-1}$ at 6 a.m. But, due to water vegetation, a considerable increase of oxygen during the day was perceived. This production does not work during the night when oxygen is consumed due to assimilation and thus the critical conditions appear early in the morning. At low water level in summer when the temperatures are high, the water treatment is very important, but more and more urgent becomes the need to treat the waste waters of other villages along the Pivka and industrial waste waters.

Table 1 Pivka quality along its flow, August 20, 1992

	T	SEC	Cl^-	NO_3^-	PO_4^{3-}	SO_4^{2-}	COD	BOD	COD/BOD
Postojnska J.	22	505	27	1,4	1,45	19	22,3	2,6	8,6
Pivka Jama	15	405	12	4,2	0,73	12	11,2	1,0	11,2
Planinska J.	12	359	8	8,0	0,40	11	8,1	1,7	4,8

T - *temperature (°C)*
SO_4^{2-} - *sulphates*
SEC - *conductivity (μS/cm)*
COD - *chemical oxygen demand*
Cl^- - *chlorides*
BOD - *biochemical oxygen demand*
NO_3^- - *nitrates*

Monitoring the Pivka quality in Planinska Jama, where the water cools during the summer and is enriched by the oxygen in the underground, recorded rather good quality. Later this water is joined by Rak tributary and the mixture is still more favourable. The Table 1 represents the Pivka river quality at low summer waters at its swallow-hole to Postojnska Jama, in Pivka Jama and in Planinska Jama. The improvement was registered with the exception of the nitrate level that increased along the flow.

For a long time the Reka river was highly polluted due to waste waters of Organic Acids factory. When the factory was closed its quality at the swallow-hole to Škocjanske Jame was gradually improving when the sedimented pollution from the bottom of the riverbed was slowly decomposed and removed. Obviously this factory of organic acids was the main pollutant but others are still present. Relatively high ratio between slowly degradable and non-degradable organic matters indicates that slowly degradable organic pollution increases. Table 2 represents the mean values of cited parameters of the measurements done from 1992 to 1995 and the values at low water level in June 1993.

Table 2 The Reka quality

	SEC	Cl^-	NO_3^-	PO_4^{3-}	SO_4^{2-}	COD	BOD	COD/BOD
Average values 1992-95	345	3,7	4,5	0,03	14,5	6,6	1,8	3,7
June 1993	341	4,0	5,3	0,01	12,0	12,0	2,0	6,0

CONCLUSION

It was stated that the pollution of the percolation water is always due to the pollution at the surface. In most cases these are direct outlets from the houses or villages (cess-pools without bottom) without sewage system and waste water treatment plants. The pollution of karst underground and karst waters is due to waste disposal sites washed by rainwater, and to accidental spills of various liquids at traffic accidents as well as to pollutants being washed off the roads.

How such pollution is reflected deeper in the karst underground, in the karst caves and in the quality of karst water depends on type and quantity of pollution, on rock structure through which the water percolates, as the rocks control the mode and velocity of infiltration and the possibility of oxidation degradable processes which again control the self-purification of these waters which can be done by nature. We assessed that in up to 100 m thick rock oxidation processes helped by dilution effects by the rainwater may be successful; however, the pollution must be enough small and degradable.

Our researches indicate that somewhere the conduits from the surface to the karst interior are very direct and well permeable and the water passes through 100 m thick limestones in an hour already. However, such canals are frequently combined by less permeable conduits where water and liquids may be retained up to three months, in particular during the period of less intensive rain. In such cases the heavy and intensive rain is deciding as it presses the retained pollution.

REFERENCES

Gams, I., 1967: Faktorji in dinamika korozije na karbonatnih kamninah slovenskega dinarskega in alpskega krasa. Geografski vestnik, 38, 11-63, Ljubljana

Gams, I., 1983: Onesnaženje v Postojnski jami. Proteus, 46, 2, 89, Ljubljana

Kogovšek, J. & Habič, P., 1981: Preučevanje vertikalnega prenikanja vode na primerih Planinske in Postojnske jame.- (The Study of Vertical Water Percolation in the Case of Postojna and Planina Caves). Acta carsologica, 9 (1980), 129-148, Ljubljana.

Kogovšek, J., 1982: Vertikalno prenikanje v Planinski jami v obdobju 1980/81. Acta carsologica, 10, 107-124, Ljubljana

Kogovšek, J., 1994: Impact of human activity on Škocjanske jame. Acta carsologica, 23, 73-80, Ljubljana

PRIMERI ONESNAŽEVANJA KRAŠKIH VODA NA SLOVENSKEM KRASU

Povzetek

Človek, ki živi na krasu, s svojo vsestransko aktivnostjo pogosto tudi ogroža kras in kraške vode. Tako srečamo najrazličnejše oblike onesnaževanja kraškega površja, od kjer padavine lahko spirajo topne komponente skozi prepustne karbonatne kamnine globlje v kras, kjer pa so tudi zaloge pitne vode, osnovne človekove surovine. V kras ponikajo tudi reke ponikalnice, ki na svojem površinskem toku sprejemajo odpadne vode naselij, ki v večini primerov še nimajo čistilnih naprav, kot tudi odpadne industrijske vode.

V okviru raziskav prenikajoče vode na slovenskem krasu smo naleteli na onesnaženo preniklo vodo v Pivki jami, v Kristalnem rovu Postojnske jame, v Ponikovski Dragi, v Škocjanskih jamah pa v Mariničevi in Mahorčičevi jami. V Pivki jami in Kristalnem rovu smo podrobneje preučevali prenos onesnaženja skozi 40 m oziroma 100 m debel jamski strop.

Ugotavljamo, da ima onesnaženje prenikle vode vedno izvor v onesnaževanju na površju, v naših primerih so bili to direktni izpusti iz hiš oz. naselij (greznice brez dna), ki nimajo urejene kanalizacije in čiščenja odpadnih voda ali pa so odpadne vode odtekale v kras po predhodni sedimentaciji trdnih nečistoč.

Kako se tako onesnaženje odraža globlje v krasu, v kraških jamah, v kvaliteti kraške vode, pa zavisi tako od vrste in količine onesnaženja, kot tudi od zgradbe kamnin, skozi katere prenika, saj le-ta pogojuje način in hitrost prenikanja ter možnost poteka oksidacijskih razgradnih procesov, od katerih pa

zavisi samočiščenje teh voda, ki ga lahko opravi narava. Ugotavljamo, da v do 100 m debeli kamnini lahko potekajo uspešni procesi oksidacije ob spremljajočih efektih razredčevanja s padavinami vendar le ob dovolj majhnem in razgradljivem onesnaženju. V primeru, ko je vir onesnaženja odstranjen, pa ocenjujemo, da je v primeru manjšega izvora onesnaženja potrebno vsaj nekaj let za vzpostavitev prvotnega stanja.

Naše raziskave kažejo tudi na to, da vodijo s površja v kraško notranjost ponekod zelo direktni in dobro prepustni kanali, ko voda premaga 100 m debele apnence že v dobri uri. Pogosto pa tako prepustne vodnike spremljajo znatno slabši vodniki, kjer se voda in morebitne druge tekočine posebno v obdobjih manj intenzivnih padavin, zadržujejo tudi do tri mesece, kar smo ugotavljali tako za območje Planinske kot Postojnske jame. V takih primerih so odločilne izdatne in intenzivne padavine, ki iztisnejo zastalo onesnaženje.

ON THE PROBLEMS OF THE ICE FILLING IN THE DOBŠINA ICE CAVE

O PROBLEMATIKI LEDU V DOBŠINSKI LEDENI JAMI

MARCEL LALKOVIČ

Izvleček UDK 551.32:551.442(437.6)

Marcel Lalkovič: O problematiki ledu v Dobšinski ledeni jami

Z vprašanjem spreminjanja ledenih oblik v Dobšinski ledeni jami se je v letih 1981 - 1990 ukvarjal Slovaški muzej varstva narave in jamarstva iz Liptovskega Mikulaša. Pojavili sta se dve skupini problemov: naraščanje ali nazadovanje ledu na opazovalnih točkah, razporejenih po jami oziroma prostorsko spremljanje teh sprememb v posameznih delih jame in preučevanje kinetičnih sprememb talnega ledu. Sedanje stanje poznavanja je rezultat meritev, osredotočenih na statične pojave vzdolž turističnih poti v nekaterih delih jame. V določenih delih jame se je talni led zdebelil. Največje spremembe so bile zabeležene v Veliki dvorani. Opazujemo tudi kinetične pojave v ledenem polju, ki se pomika proti spodnjim delom jame.

Ključne besede: speleologija, speleoklima, ledena jama, Slovaška, Dobšinska ledena jama

Abstract UDC 551.32:551.442(437.6)

Marcel Lalkovič: On the problems of the ice filling in the Dobšina Ice Cave

In the years 1981 - 1990 problems concerning the changes of ice forms in the Dobšina Ice Cave were investigated through the Slovak Museum of Nature Protection and Caving from Liptovský Mikuláš. There were two main problems: increase and decrease of ice filling in the observation points scattered in the cave or space pursuing of these changes and investigating of kinetic manifestations of the floor ice. Actual knowledge is the result of observations focused on static manifestations along the touristic pathways. There is an increase of the floor ice. The greatest changes have been recorded in the Great Hall. Kinetic manifestations are observed in the ice field moving towards the kower parts of the cave.

Key words: speleology, speloclimatology, ice cave, Slovakia, Dobšina Ice Cave

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The Dobšiná Ice Cave is from the point of view of its opening for public one of the oldest caves in Slovakia. Thank to its unique ice decoration it has been attractive for scientists since its opening in 1870. This scientific interest remains up today. Ice decoration in the cave is presented in various forms and as the floor ice in all parts open for public. The amount and character of ice formations have made it one of the most frequently visited Slovak caves. The cave has been systematically studying by many experts for a longer time. The aim of these studies is to help preserving the present state of ice decoration and filling.

Problems of ice filling changes have been studied by present Slovak Museum of Nature Protection and Speleology in Liptovský Mikuláš during the period 1981 - 1990. The necessity of similar program resulted from the conclusions of scientific conference held in Slovakia in 1970 on the occasion of 100 years anniversary of the discovery of the cave.

Problems of changes of ice filling are twofold. The ***first*** group of problems includes studies of ice filling increase and decrease at the measuring points distributed in cave and areal observations of the changes in its selected parts. The observing points have been located with respect to character of cave spaces and ice filling into Malá sieň (The Small Hall) - points 1 and 2 , Vel'ká sieň (The Large Hall) - points 3, 6, 9 and 15, into Vel'ká opona (The Large Curtain) surroundings and Ruffiny corridor. Areal studies have been carried out in Malá and Vel'ká sieň and in the space near Vel'ká opona. Later, the measurements have been extended also on Vstupné schodište (the Entrance Stairway) and the passage between Vel'ká and Malá sieň on current excursion route. Some orientation measurements have been done with the same purpose.

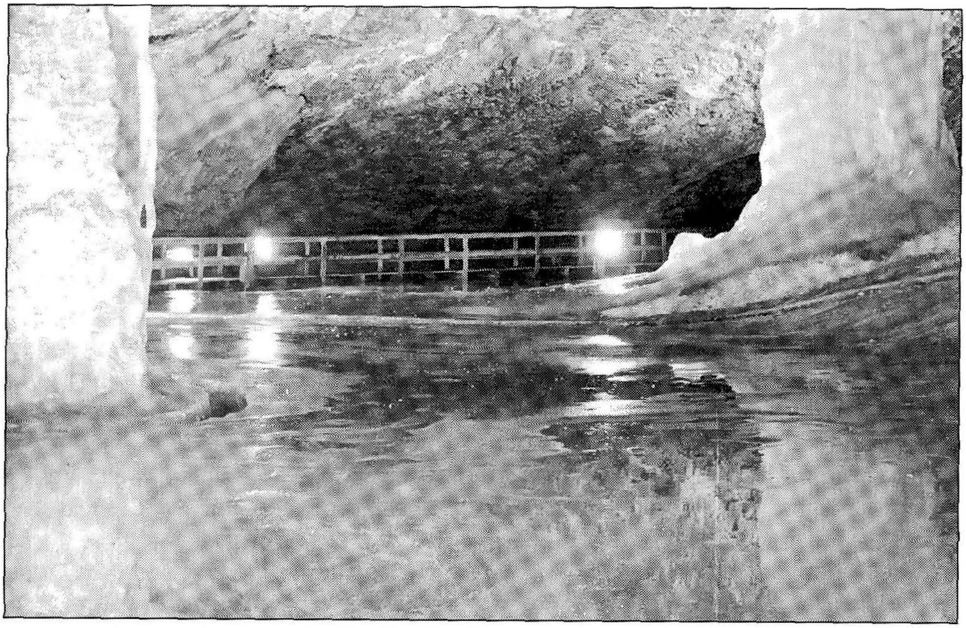
The ***second*** group of problems connected with the study of ice filling changes comprises observations of kinetic manifestations of the ice filling. The studies were based on periodic measurements of observing points located on the floor of those cave's parts covered with ice (Malá and Vel'ká sieň, Vel'ká opona surroundings) and in the ice wall of Ruffiny corridor. The measurements were aimed at determination of horizontal and vertical components of the displacement. Later observations of the excursion pavement deformations in Malá sieň, at Vel'ká opona and in Ruffiny corridor have been connected with the previously achieved knowledge.

It should be noted that there was no methodology before that would allow us to predict effective solutions or adequate results. Therefore, in the beginning it was necessary to verify some components used by particular measurements experimentally (observing points, consoles, etc.). Only longer observations in the cave's environment allowed for modifications of measuring procedures or corrections of their extent and character. Another handicap resulted from the character of the environment in the cave. Utilization of some methods was simply excluded due to shape of cave's space. It has led to original constructions and their experimental verification. The ice filling acted as a negative factor as well. Some observing points have been covered with ice in course of measurements or have lost their functionality for another reasons.

Despite the above mentioned problems the ten years observation period has provided valuable data on our tasks. It helped us to know the course of some processes and answered many, previously only accidentally expressed assumption. Unfortunately, the extent of this paper does not allow more complex presentation of this topic.

METHODS AND ACCURACY OF MEASUREMENTS

In order to understand the processes taking place in the environment of the cave as well as possible, the ice filling changes have been observed by



The Large Hall (Photo M. Eliaš)

means of the following methods :

a) geodetic - method of in front intersect

The position of observing points was measured with the aim to determine the horizontal component of their displacement. Position of the points was calculated from particular number of combinations. The method was supplemented by elevations measurements (method of geometric levelling) that were oriented onto determination of vertical component of displacement

b) geodetic - method of numerical tachymetry

This method was used to reveal volume changes of the floor ice. In case of volume changes of ice in vertical direction it was supplemented by lengths measurements aimed at determination of differences used then by calculation of volume changes.

c) geodetic - method of measurements of small lengths at observing points with specially constructed equipment with the aim to determine ice increase or decrease at measured points

d) photogrammetric - methods of single - snap photogrammetry and ground stereophoto-grammetry

The methods have been used by evaluation of shape and volume changes of selected part of ice field and ice formations.

Specific conditions in the cave had influence on the accuracy of measurements. Therefore, the accuracy of position of particular points is characterized by average error of ± 5 mm. Geometric levelling was affected by mean error of determination of the observing point elevation $m_z = \pm 0.6$ mm. The magnitude of ice increase and decrease at particular observing points is characterized, with respect to technical parameters of used equipment by mean error $m_x = \pm 1.0$ mm.

RESULTS

The observation results can be divided into several groups. The first includes increase and decrease of the floor ice as determined by measurements on observing points (Malá sieň, Veľká sieň, Veľká opona surroundings) It comprises also volume changes evaluated by numerical tachymetry.

Second group of results is created by volume changes of the vertical ice walls (Vstupné schodište, passage between Malá and Veľká sieň) and changes on the observation points in vertical ice wall of Ruffiny corridor.

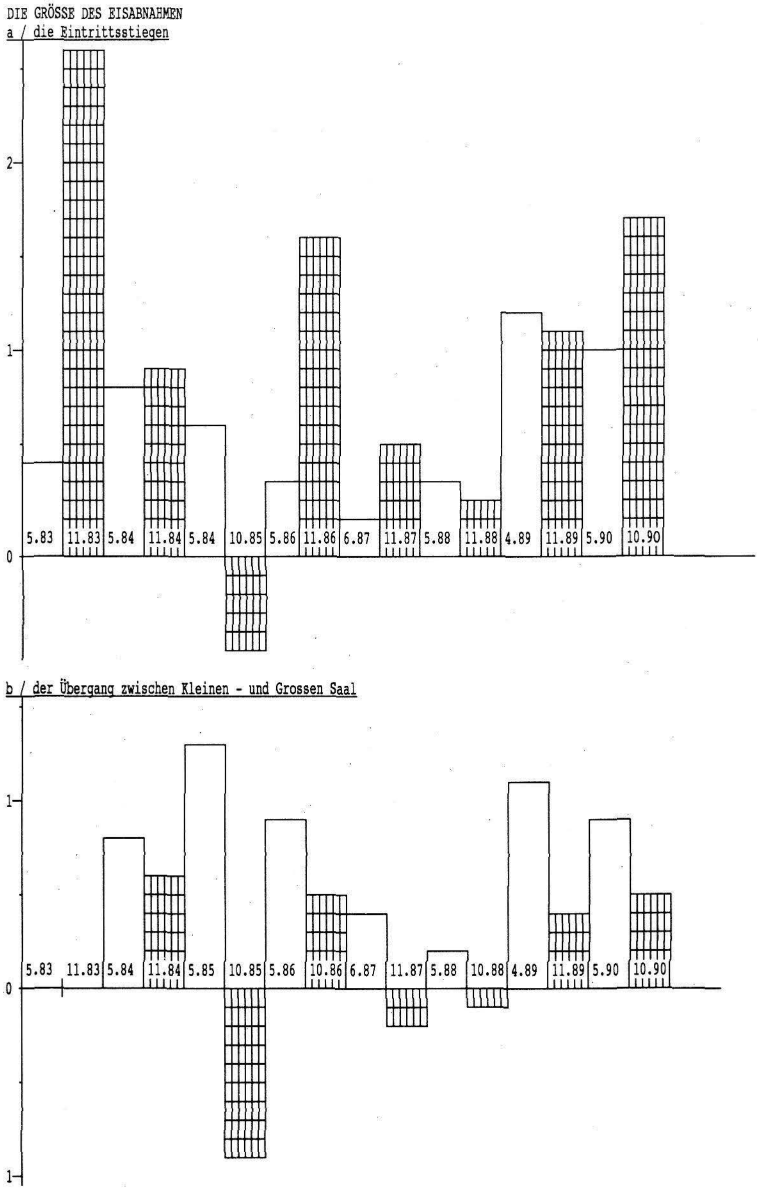
Third, and from the viewpoint of this contribution the last group includes kinetic manifestations of ice filling and related deformations of the excursion pavement.

a) Ice filling increases and decreases

Quantitatively the largest increases on the observation points have been recorded in marginal part of Malá and Veľká sieň. Surroundings of Veľká opona seemed to be a promising area as well. The intense draining of water resulted into covering of the observing point with ice in 1984 already.

Decrease of ice

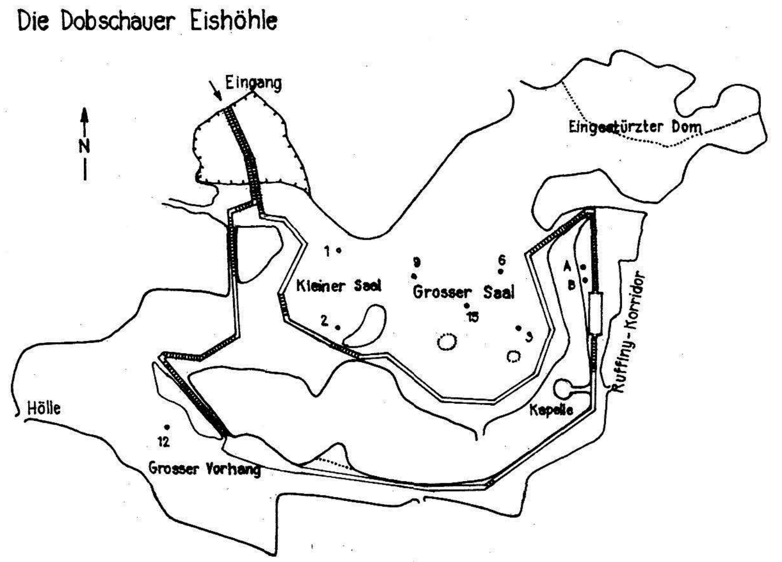
a) Entrance Stairway



b) Passage between Large and Small Hall

Punkt	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
	Die Angaben in mm									
1-Kleiner Saal	0	12	3	19	10	32	115	vereisigt		
2-Kleiner Saal	0	-9	10	-8	-4	-5	-6	7	beschädigt	
3-Grosser Saal	8	0	-14	24	7	7	-27	60		
9-Grosser Saal	50	111	26	64	vereisigt					
15-Grosser Saal	27	30	-22	-13	7	13	-36	12		
6-Grosser Saal	-13	12	beschädigt							
12-Grosser Vorhang	-	83	95	vereisigt						
A-Ruffiny-Korridor	-	-8	-9	-6	-5	-4	-3	-4	-7	-1
B-Ruffiny-Korridor	-	-7	-4	-2	-5	-5	-6	1	-6	-7
+ die Eiszunahmen - die Eisabnahmen										

Increase and decrease of ice at observation points



Dobšina Ice Cave

Consequently, it was not possible to evaluate the increase of the floor ice. Decreases of ice filling have been reported only in passage between Malá and Vel'ká sieň. Such tendency is connected with volume changes of vertical ice walls proved by measurements at these places (Table 1).

The floor ice has been increasing during the observed period as a result of human technical interventions. This fact is documented by increases determined by numerical tachymetry in Malá and Vel'ká sieň and Vel'ká opona surroundings. The largest uplift of the floor ice is in Vel'ká sieň and the largest re-groupment has been recorded in surroundings of Vel'ká opona. It is the lowest part where the water flowing from higher parts gradually freezes and creates new ice layers.

b) Volume changes of vertical ice walls

Decreases of ice filling prove that the profile of corridor in the entrance part of the cave is being permanently wider. The decrease in Vstupné schodište is approximately 12 cubic meters for the period of eight years, while in passage between Malá and Vel'ká sieň it has reached the value of 4 cubic meters approximately. Supposed this process is not stabilized, its negative consequences can became evident after some time in forms that are only hardly predictable yet.

Neither Ruffiny corridor is without problems. Small changes represented by decreases of ice filling have been observed there, too. This tendency is confirmed also by decreases of ice on the observing points. The decrease of ice wall for the given period (1982 - 1990) was 41 - 47 mm with annual decreases within 1 - 9 mm.

The course of volume changes with respect to particular seasons is interesting as well. Measured data indicate that the course of volume changes (decreases) in the beginning and end of season (with respect to their magnitude) follows a sinusoid. Frequency or the extremes of the curve are situated within the range of two to four years. Volume changes measured in the beginning of season have greater phase shift. Volume changes at the end of season are characterized by higher values.

Volume changes in the passage between Malá and Vel'ká sieň showed similar course. The shape of curve expressing volume changes variations at the beginning and end of season is rather similar. Season beginning is characterized by higher values of decreases than its end. Frequency is within the range of two to four years as well. Lower value of the phase shift is typical for the volume changes at the end of season. Its higher value is connected with changes recorded in the season beginning again.

c) Kinetic changes

As it follows from the evaluation of observing points position, their displacement is pronounced in direction Malá sieň - Vel'ká sieň and only partially in direction Malá sieň - Vel'ká opona. The values of the displacement reach up to 37 mm in the x axis direction and up to 31 mm in the y axis direction during the period of three years. The data are relevant to points situated in Malá and Vel'ká sieň. Movement velocity of particular points in horizontal component of displacement varies. In case of points in Malá Sieň (points 1 and 2) it is 10.7 - 14.9 mm/year. Movement velocity of points in Vel'ká sieň (points 3, 9 and 15) is characterized by values between 5.4 and 18.1 mm/year. The greatest changes have been observed in central part of Vel'ká sieň (points 3 and 15) which correspond to volume changes of the floor ice in this part of the cave.

Vertical components of measured displacements vary between 1.5 and 78.5 mm. Maximum has been reached in passage between Malá and Vel'ká sieň (point 2). The downward tendency has been observed during the given period by all observing points although there were some uplifts in particular periods. However, the uplifts were recorded at points located at places with pronounced horizontal bedding of the floor ice.

Ruffiny corridor is characterized by lower horizontal component of displacement velocities of the observing points. The reason is that the observing points are set in vertical ice wall. Vertical displacement is 6.7 mm/year on average. Also these points are typical for downward movement during the observed period.

Changes expressed either as depressions or deformations of the excursion pavement in the area of Malá sieň are the evidence of destruction typical for the entrance parts of the cave. Measurements carried out during the period of five years showed that there has been a marked drop of the left and right sides of the pavement. The drops recorded by 26.5 m long pavement were 49 mm on average at the left side and 28 mm at the right side. Such results are partially connected with some unwise human activities (drainage channels). At the same time they give evidences of kinetic manifestations of the ice field taking place in the direction Malá sieň - Vel'ká opona.

Pavements depressions have been found out also in Vel'ká opona surroundings and on stairway at Kaplnka in Ruffiny corridor. Near Vel'ká opona they are more pronounced only in the front part (in the direction of excursions) and are connected with the state of bedrock underlying the bearing constructions. The depressions of the right side of stairs at Kaplnka result from situation indicated by changes on observing points A and B and volume changes of the wall ice of Ruffiny corridor in its near surrounding.

CONCLUSIONS

It is neither possible to give the detailed description of ice filling changes in this paper nor analyze the reasons of the changes. However, it seems that it is necessary to re-evaluate some of human interventions in the environment of the cave. It is not only problem of draining channels that should be solved with higher consideration than before.

The consequences of digging the new entrance corridor through the ice field in the vicinity of Malá sieň in 1974 became evident just during the observed period. They were confirmed by other works, too. And, it is the status that must be carefully analyzed if also the future generations are to find in the cave that what made it well known among their present visitors.

O PROBLEMATIKI LEDU V DOBŠINSKI LEDENI JAMI

Povzetek

Z vprašanjem spreminjanja ledenih oblik v Dobšinski ledeni jami se je v letih 1981 - 1990 ukvarjal Slovaški muzej varstva narave in jamarstva (Slovenské muzeum ochrany prirody a jaskyniarstva) iz Liptovskega Mikulaša. To delo je bilo rezultat znanstvenega srečanja leta 1970, ki je bilo ob stoletnici odkritja jame. Glede vprašanja, ki bi ga bilo treba rešiti, sta se pojavili dve skupini problemov. V prvo sodi opazovanje naraščanja ali nazadovanja ledu na opazovalnih točkah, razporejenih po jami, oziroma prostorsko spremljanje teh sprememb v posameznih delih jame. V drugo skupino sodi preučevanje kinetičnih sprememb talnega ledu. Sedanje stanje poznavanja problema je rezultat meritev, osredotočenih na statične pojave vzdolž turističnih poti v nekaterih delih jame.

Na osnovi preučevanja lahko sklenemo, da se je, zaradi določenih tehničnih ukrepov, talni led zdebelil. Največje spremembe debeline ledu so bile zabeležene v Veliki dvorani. To potrjuje tudi odebelitev ledu na določenih posameznih opazovalnih točkah. Na drugi strani pa lahko opazujemo kinetične pojave v ledenem polju, ki se pomika proti spodnjim delom jame (Velika in Mala dvorana). Vrtenje opazovalnih točk v Ruffinijevem rovu je posledica pritiska ledene stene.

THE RESEARCHES ON KARST OF MARIO BARATTA, 1868-1935

RAZISKAVE KRASA MARIA BARATTE, 1868-1935

LAMBERTO LAURETI

Izvleček

UDK 551.44(450):929
Baratta M.

Lamberto Laureti: Raziskave krasa Maria Baratte, 1868-1935

Prispevek opisuje delo, predvsem povezano s krasom, na splošno malo znanega geografa in geofizika Maria Baratte (1868 - 1935), ki je preučeval kras v tedanji Julijski krajini. Poleg drugega je izdal več kart in vodnik po Šocjanskih in Postojnski jami. Baratta je na univerzi v Pavii v okviru geografije predaval krasoslovje, najbrž ko prvi na kaki univerzi v Italiji.

Kljuène besede: krasoslovje, Baratta Mario, Italija, Slovenija

Abstract

UDC551.44(450):929
Baratta M.

Lamberto Laureti: The researches on karst of Mario Baratta, 1868-1935

Papers deals with the work connected to karst of less known geographer and geophysist Mario Baratta (1868 - 1935), who investigated the karst in that time's province of Venezia Giulia. Beside others he published some maps and the guides of Škocjanske jame and Postojnska jama caves. At the University of Pavia Baratta was teaching karstology in the frame of geography thus being probably the first in Italy.

Key words: karstology, Baratta Mario, Italy, Slovenia

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L'ATTIVITA SCIENTIFICA DI MARIO BARATTA

Fra due anni, nel 1995, ricorreranno sessanta anni dalla scomparsa di Mario Baratta, figura di studioso molto nota in Italia, soprattutto per le sue ricerche nel campo della sismologia.

Nato a Voghera nel 1868, si laureo a Pavia (allora l'unica universita lombarda) in Scienze Naturali dopo aver frequentato le lezioni di Torquato Taramelli, celebre geologo del tempo, a sua volta allievo di Antonio Stoppani, uno dei padri della geologia italiana.

Dopo la laurea il Baratta fu assunto come Assistente presso l'Ufficio Centrale di Meteorologia e Geodinamica di Roma dove si occupo prevalentemente di studi e ricerche di carattere geofisico e sismologico che gli consentirono di redigere un aggiornatissimo catalogo dei terremoti verificatisi in Italia nel corso dell'era volgare (dalla nascita di Cristo fino a tutto il XIX secolo). La pubblicazione di questo catalogo (1901) rappresento una tappa fondamentale per la ricerca sismologica in Italia e a tuttoggi (grazie alle pazienti e accurate ricerche storiche e archivistiche dell'autore) e un'opera di grandissima utilita. Le ricerche sismologiche del Baratta si svolsero anche sul campo, con l'osservazione degli effetti del terribile terremoto di Messina (1908) sul quale lo studioso ci ha lasciato una grossa memoria redatta per conto della Societa Geografica Italiana. Prima della sua prematura scomparsa (1935) egli curo anche la compilazione di una grande carta sismica d'Italia in cui sono riassunte tutte le sue precedenti osservazioni.

Dopo aver ottenuto la libera docenza in geografia fisica (1903) presso l'Universita di Pavia, occupo nello stesso ateneo, dal 1911 fino alla morte, la cattedra di Geografia nella Facolta di Lettere e Filosofia.

Spirito di grande cultura ed umanita, il Baratta ebbe vasti interessi e si occupo di altri settori delle discipline storico-geografiche. A tale riguardo si devono ricordare i suoi studi sull'opera geografica e cartografica di Leonardo da Vinci e sui mutamenti ambientali in epoca storica nella Pianura Padana, per i quali si avvalse della collaborazione di storici pavesi come il collega ed amico Plinio Fraccaro. Insieme con questi curo la redazione di un grande Atlante Storico realizzato dall'istituto Geografico De Agostini di Novara ed attualmente ancora ristampato. Il particolare interesse per la cartografia, sia sotto il profilo applicativo che didattico, si estrinseco con la realizzazione (nel 1922) di un Grande Atlante Geografico, sempre per l'Istituto Geografico De

Agostini, in collaborazione con Luigi Visintin che ne dirigeva il settore cartografico. Per quasi mezzo secolo le tavole di questo atlante, diffuso in tutto il mondo, furono ristampate nelle numerose edizioni e nelle opere didattiche e divulgative dell'Istituto novarese. Da uno zio, che combatté nell'esercito garibaldino, eredito un profondo spirito patriottico e nazionalista che lo spinse a parteggiare per l'intervento dell''Italia nella Prima Guerra Mondiale. Amico e ammiratore di Cesare Battisti, uomo politico e geografo, il Baratta cerco di giustificare, anche sotto l'aspetto geografico, le ragioni dell'intervento italiano nel conflitto e i motivi per cui i confini del Paese dovessero allargarsi verso est fino a coincidere con la linea dello spartiacque alpino. In cio egli non si differenziava dalle idee del tempo (derivate, del resto, da quelle del geografo tedesco Fredrich Ratzel) in fatto di geopolitica e che cioe uno Stato dovesse avere dei confini appoggiati preferibilmente su linee naturali. La sua onesta intellettuale, al di la della passione politica e dell'enfasi patriottica, gli faceva riconoscere come all'interno di questi confini naturali non tutta la popolazione fosse di lingua italiana, in cio concordando con lo stesso Battisti.

GLI STUDI SUL CARSISMO E SUL CARSO DELL'ITALIA NORD ORIENTALE

E' proprio assecondando il suo spirito patriottico che il Baratta, negli anni della Prima Guerra Mondiale, ritenne di dare un suo personale contributo di studioso dedicandosi ad illustrare le caratteristiche geografiche dei territori reclamati dall'Italia ed a studiarne i piu tipici aspetti naturali, in cio favorito dalla sua solida preparazione geologica. Del resto aveva gia una certadimestichezza con i tipici fenomeni del Carso, in quanto nelle vicinanze della sua citta natale, Voghera, le colline dell'Appennino settentrionale ospitavano discreti affioramenti di rocce gessose (apartenenti al complesso delle evaporiti messiniane che si ritrovano lungo tutto il versante padano dell'Appennino) e con essi anche un piccolo bacino chiuso sul cui fondo si apriva l'ingresso di una grotta di attraversamento, del genere che i francesi chiamano "percée hydrologique". Infatti egli racconta di averala percorsa tutta, per circa 600 metri, dall'ingresso fino all'uscita, quando era ancora ragazzo. Questa grotta, ricordata in studi della fine del secolo XVIII, e citata anche dal Marinelli nel suo classico lavoro *sul carsismo nei gessi della penisola italiana* (1917). Oggi i due ingressi della cavita (gia nota come Grotta del Camera) sono completamente ostruiti in seguito a materiali franati lungo i versanti che li sovrastavano. Il principale contributo del Baratta alla illustrazionei dei fenomeni carsici della Venezia Giulia e del resto d'Italia, frutto di conoscenze dirette acquisite nel corso dei suoi numerosi viaggi e sopralluoghi (compiuti soprattutto nell'ambito delle sue ricerche sismologiche, come nel caso della regione marsicana) in varie parti del Paese, e certamente costituito dai due corsi accademici, svolti negli anni

1916-17 e 1917-18, che egli dedica interamente alle forme e ai fenomeni carsici e alle caratteristiche del carsismo nella Venezia Giulia.

Per rendersi conto della completezza di queste due trattazioni, ci sembra sufficente elencarne il sommario, ricavato dalle dispense litografate che furono pubblicate in quegli stessi anni da parte dell'Ateneo pavese, e che e allegato al presente contributo. Naturalmente i contenuti, al di la della struttura formale, evidenziano il grado di conoscenze che a quei tempi si avevano del fenomeno carsico, e che erano gia notevoli, almeno sotto l'aspetto strettamente morfologico (non si dimentichi che i ricercatori dell' epoca erano dei forti camminatori e degli acuti e precisi osservatori) piu che sotto quello morfogenetico.

L'interesse di queste due opere, anche se ovviamente datate, sta proprio nella loro articolazione: una come quadro panoramico del carsismo italiano, l'altra come esempio di monografia regionale tutta incentrata sul carsismo di una regione, quella che il Baratta chiama, con un neologismo tipico dei geografi, la "Carsia Giulia", fondendo due distinti toponimi, quello relativo al Carso (del resto anche oggi, in Italia, sì usa dire la "Padania" per indicare la regione padana, costituita cioe dalla Pianura Padana) e quello relativo alla Venezia Giulia e alle Alpi Giulie (in questo caso il termine Giulia, che il Baratta scrive accentato, e semplicemente un appositivo). In pratica l'espressione "Carsia Giulia" (noi possiamo anche permetterci di non usare gli accenti) verrebbe a significare non tanto che la regione del Carso appartiene al territorio giuliano, quanto che quella considerata dall'Autore, cioe dal Baratta, e solo quella parte del Carso (che in realta e molto piu esteso) che si trova entro il territorio giuliano (della Venezia o delle Alpi Giulie).

Prof. Mario BARATTA - Univ. di PAVIA
anno acc. 1917-18
LA CARSIA GIULIA

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TAV. 1 - Sommario del Corso monografico relativo alla regione carsica giuliana.

Prof. Mario BARATTA - Univ. di PAVIA
anno acc. 1916-17
MORFOLOGIA E FENOMENI DEL CARSO

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TAV. 2 - Sommario del corso monografico relativo al carsismo in generale.

Gli altri scritti del Baratta relativi al carsismo riguardano un approfondimento di quanto contenuto in questi due corsi oltre che un supporto alla dimostrazione della giustezza delle rivendicazioni italiane nel settore orientale delle Alpi, per le quali si considera anche l'importanza che puo avere la stessa circolazione idrica sotterranea. Numerose sono anche le esemplificazioni cartografiche relative sia agli aspetti del Carso che ai confini orientali d'Italia, curate con ottime rappresentazioni dall'Istituto Geografico De Agostini con il quale il Baratta ebbe un costante rapporto di collaborazione. L'ultimo suo lavoro su questo tema e costituito, nel 1920, da una piccola ma succosa guida (distribuita in occasione di un convegno) delle grotte di S. Canziano e di Postumia. Dopo di allora, assolto il suo contributo di studioso alle fortune del suo Paese, il Baratta non si occupera piu di carsismo per tornare ai suoi studi di cartografia e di sismologia.

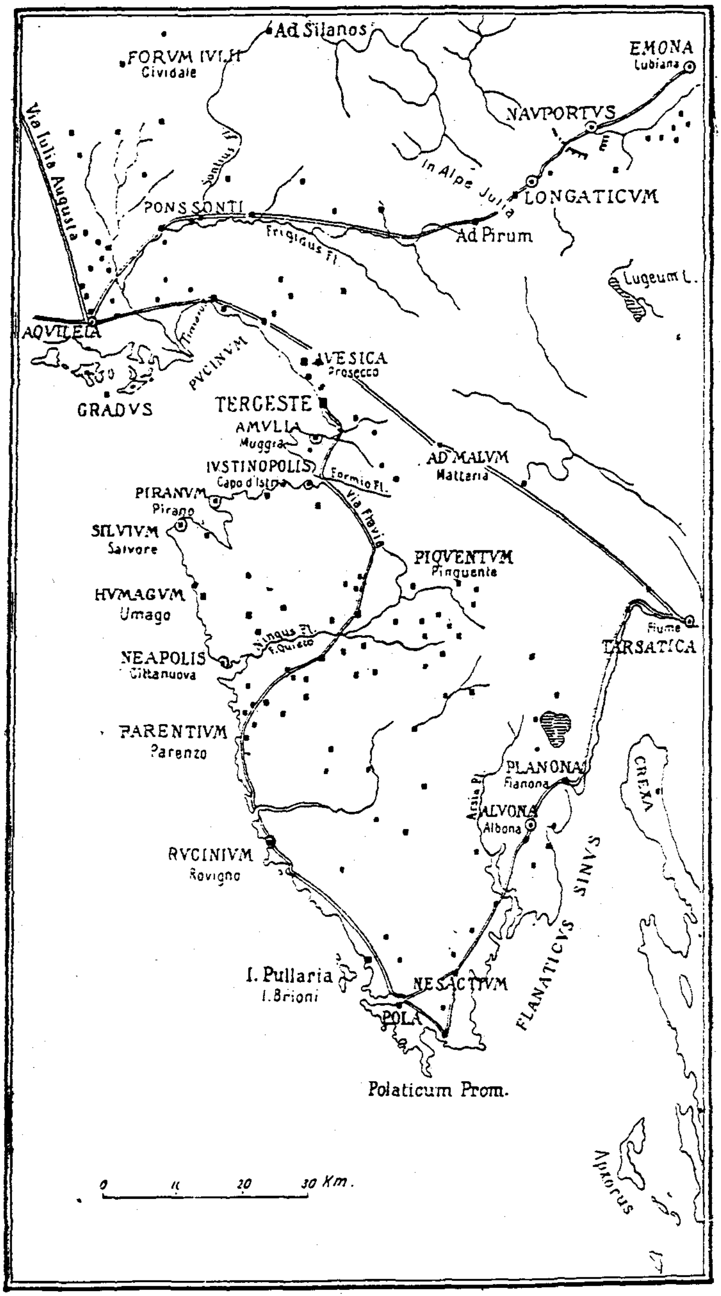
Il profondo senso della storia che era proprio della cultura umanistica del Baratta, lo aveva sempre indotto ad inquadrare i fenomeni naturali da lui studiati in un piu ampio contesto spazio-temporale e soprattutto a collocarli in un contesto dialettico incentrato sul rapporto uomo-ambiente. Come interesse per i fatti storici impressi nel territorio ci sembra indicativo riportare una sua cartina relativa all'antica toponomastica della Carsia.

BIBLIOGRAFIA

Scritti sul carsismo di M. Baratta (Karst bibliography of M. Baratta)

1916-17 - Morfologia e fenomeni del Carso, R. Univ. degli Studi, Pavia, sunto delle lezioni del Corso di Geografia, Litografia tacchinardi e Ferrari, p. 238, tavv. 34.

1917-18 - La Carsia Giulia, R. Univ. degli Studi, Pavia, sunto delle lezioni del Corso di Geografia, p. 340, tavv. 38 e 2 carte geografiche.



TAV. 3. Toponomastica antica dell'Istria e del Carso (da BARATTA M., "Il Carso", 1917, cit.).

1917 - Il Carso, in BARATTA M. et Al., "Pagine geografiche della nostra guerra", Soc. Geogr. Ital., Roma, pp. 97-122.

1918 - Carta del grande altipiano della Carsia Giulia (carso triestino-goriziano) alla scala 1:100 000 e testo esplicativo illustrato, Istituo Geografico De Agostini, Novara, p. 24, con una cartina degli altipiani della Carsia alla scala di 1:500 000.

1918 - Confine orientale d"Italia, in "Quaderni Geografici", I, 3, Ist. Geografico De Agostini, Novara, p. 43, con 2 cartine corografiche a colori e quattro tavole in nero.

1919 - Le Alpi Giulie meridionali, carta alla scala 1:250 000 e testo esplicativo, Ist. Geogr. De Agostini, Novara.

1919 - Le Alpi Giulie meridionali e il confine orientale d'Italia, in "La geografia", VII, pp. 129-61, Ist. Geogr. De Agostini, Novara.

1920 - Le grotte di S. Canziano e di Postumia. Planina-Nauporto. La Foiba di Pisino, Convegno nella Venezia Giulia, Soc. Geogr. Italiana, Roma, p. 55, con 4 tavole e una carta della Venezia Giulia alla scala 1:500 000.

1920 - La circolazione interna delle acque ed il confine orientale d'Italia, in "La geografia", VIII, Ist. Geografico De Agostini, Novara.

RAZISKAVE KRASA MARIA BARATTE, 1868-1935

Povzetek

Mario Baratta, rojen 1868 v Vogheri in študiral naravoslovje v Pavii, je znan italijanski učenjak, predvsem kot seizmolog. Na univerzi v Pavii je 1903 dosegel stopnjo docenta za fizično geografijoin predaval na tamkajšnji katedri za geografijo od 1911 do svoje smrti 1935. Razen potresov so ga zanimale številne veje geografije, predvsem še kartografija in zgodovina geografije. Kot pristaš Ratzelove geopolitične teorije o "naravnih" mejah držav, se je zavzemal za "naravno" mejo Italije na alpskih razvodnicah, čeprav je priznaval, da vse tamkajšnje prebivalstvo ne govori italijanskega jezika.

Njegovo poznavanje krasa je prišlo najbolj do izraza v dveh serijah njegovih univerzitetnih predavanj, 1916-17 in 1917-18, o kraških pojavih in značilnostih zakrasevanja v Julijski krajini, pri čemer je uvajal tudi nov pojem "Carsia Giulia". Predavanji sta v rokopisu shranjeni na univerzi v Pavii in obsegata skupaj skoraj 600 strani. Izdal je tudi več kart, med drugimi tudi tri o krasu v Julijski krajini: Carso triestino-goriziano 1:100 000, le Alpi Giulie meridionali 1:250 000, Venezia Giulia 1:500 000.

ON THE MECHANISMS AND KINEMATICS OF DRIFT DOLINES FORMATION

MEHANIZMI IN KINEMATIKA NASTAJANJA VRTAČ V MORENSKEM GRADIVU

JERZY LISZKOWSKI

Izvleček UDK 551.442(438)

Jerzy Liszkowski: Mehanizmi in kinematika nastajanja vrtač v morenskem gradivu

Pri nastajanju vrtač v morenskem gradivu sodelujejo različni mehanizmi, ne samo sufozija. Glavni dejavniki so: litologija ter fizikalne in geomehanske lastnosti prekrivnih sedimentov, geohidrološke razmere ter način močenja stika med kamnino in nanosom ter stopnja zakraselosti matične kamnine. V zvezi z nastajanjem vrtač sta le dva načina sprememb na površju: počasno, a stalno posedanje in hitri, posamični udori.

Ključne besede: geomorfologija, kraška morfologija, pokriti kras, vrtača, sufozijska vrtača, Poljska

Abstract UDC 551.442(438)

Jerzy Liszkowski: On the mechanism and kinematics of drift dolines formation

Different mechanisms and processes, not only suffosion, operate in the development of drift dolines. The main factors which control both the mechanisms and kinematics of drift dolines formation are: the lithology, and the physical and geomechanical properties of the cover deposits; the geohydrologic conditions and the nature of wetting at the bedrock/cover deposits interface; and the degree of karstification of the limestone bedrock. But there are only two modes of ground surface displacements related to them: slow, continous subsidence and rapid, discontinous collapse dolines.

Key words: geomorphology, karst morphology, covered karst, doline, drift doline, Poland

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INTRODUCTION

Closed topographic depresions called dolines or sinkholes are the most common and characteristic landform of karst terranes. Dolines differ in shape, dimensions, spatial distribution, tectonic setting and age and may be formed by diverse physical processes. In most recent text-books, monographs and papers on karst, three or four main types of dolines are distinguished: 1) solution dolines, 2) collapse dolines, 3) subsidence dolines and 4) suffosion dolines (Jennings 1971, Sweeting 1973, Ford & Williams 1989), although it is evident that these are the end member types only (Ford & Williams 1989, 399). Solution and collapse dolines are end member topographic depressions of bare karst terranes: the processes and/or mechanisms involved in their formation are clearly defined (Cramer 1941) and generally accepted. The types 2), 3) and 4) cited are listed as characteristic for covered (mantled) karst terranes. But from a review of many papers it is evident that a true understanding of the mechanisms and/or processes involved in doline formation and development of covered karst terranes has not been achieved. This is reflected in the rather free, discretionary and often wrong usage of such terms as suffosion, (internal) erosion, piping, subsidence, settlement, sagging, etc. Note also that in case, i.e. of covered karst, the terms collapse- and subsidence doline refer to the nature of ground surface displacement and not to the mechanisms of mass loss at the bedrock/cover deposits interface and thus are nongenetic terms.

Dolines are potential or real hazards owing to possible vertical displacement, either continous (subsidence) or discontinous (collapse, fracturing) of the ground-surface. Since risk or hazard evaluation related to ground-surface displacement be achieved only if the mechanisms and kinematics of the processes involved are exactly specified, identification and classification of different types of dolines will be a very important geologic and engineering-geological research problem.

The paper presents a contribution to this problem from the engineering-geological point of view. The main objectives of this contribution are as follows: a) to define the different processes and mechanisms of doline formation, b) to determine the controls of doline formation and define the basic geologic, geohydrologic and geomechanic models of their development and c) to determine and quantify to some degree the magnitude (amount) and kinematics (rate) of ground surface displacement related to them.

The considerations below will be limited to dolines of covered karst terranes: the broad, nongenetic term "drift dolines" will be used for these. Moreover the considerations will be limited to carbonate karst terranes although they are true for gypsum and/or anhydrite karst terranes too. As most of the results and considerations presented are based on the author's experiences and engineering-geological studies in several karst areas from Poland, only a very limited number of references will be cited in the text.

MECHANISMS OF DRIFT DOLINE FORMATION

Drift dolines are a particular group of natural and/or induced localized vertical mass movements restricted to covered karst terranes. The superficial expression of downward directed vertical mass movements are called subsidence in geomechanics, unaffected by their origin, radius, amount and rate.

It is convenient in engineering-geological practice to recognize different *types of subsidence on the basis of the primary cause of disequilibrium.* The primary cause of subsidences sensu lato is in every case the mass deficit or loss at a given depth below the groundsurface. For dolines the primary cause of subsidence is per definito the solutional mass loss within the bedrock, expressed as solutionally widened joints and fissures, solutional cavities, passages, etc., which act as main strain nuclei. However, in the case of drift dolines the strain nuclei are separated from the centres of solutional mass loss and shifted to the base of the overlying cover deposits. The strain nuclei are now - with only one exception - located along the bedrock/cover deposits interface.

All processes of mass loss operating at this interface are triggered by hydrodynamic forces and belong to the group of seepage (hydrodynamic) deformations of soils (Liszkowski 1973, 1979).

No universally accepted classification of this group of processes exist. However, a more frequently used classification (Ziems 1967, Liszkowski 1973, Busch & Luckner 1974, Witt 1986) divides this group of seepage deformations of soils into two categories according to the general direction of the force potential (hydraulic head) or of the seepage force. If these forces are directed downward they may initiate either suffosion, internal erosion or fluidization. If directed upwards, they may initiate eiher hydraulic penetration or breakthrough, hydraulic-heave or liquefaction.

Suffosion is defined as the selective transport and removal of fines from poorly sorted, noncohesive unconsolidated granular deposits by downward percolating infiltration or downward seeping groundwater. The process develops as a grain-by-grain transport phenomenon. Suffosion changes the texture and permeability of soils but does not lead indispensably to structural failures. But if the process develops progressively, more and more grains of successively greater diameters are entrained in the process and suffosion changes into **progressive suffosion** which affects the structure of the soil and results in its failure.

Internal erosion is the general (involving rather the whole of the soil than individual grains) transport and removal of soil particles by downward moving groundwater. The process leads immediately to volumetric deformations of a part of the soil mass. If the soil involved by the process possess some cohesion, like clayey or loamy sands, tunnel-like channels are formed within the soil mass. For this subtype of internal erosion a very appropriate geomorphic term is **tunnelling**. If the soil is a true noncohesive one, like clean, well sorted sands, a cylindrical body of loose soil particles suspended in the groundwater stream will occur (this is a form of localized fluidization). Internal erosion develops almost exclusively backwards (retrogressive), i.e. from the source of particle removal (strain nucleus) towards the soil mass interior.

Fluidization is the process of volumetric changes from the solid to fluid (suspended) state of noncohesive soils in a rapidly downward flowing groundwater stream. The fluidized granular material flows as a whole. This type of seepage deformation of soils is a very scarce one since fluidization needs very high groundwater flow velocities.

Hydraulic penetration or **break-through** is the process of localized liquefaction of granular (soil) material acompanied or succeeded by the transportation and removal of particles in an upward directed groundwater stream. The process results in the formation of upwards migrating cylindrical zones of suspended soil particles (within noncohesive soils) or pipes (within cohesive soils); that is why the process is commonly called **piping**.

Note that between tunnelling and piping noticeable geometric similarities exist: within cohesive soils both process result in the formation of tube-like subterranean voids. But they differ in sense of the causal seepage forces and this justifies the use of different terms for them. In most geomorphic and geologic publications and monographs both processes are incorrectly called piping. A noteworthy peculiarity of piping in mantled karst terranes is that the sense of particles transport is against the upwards directed seepage forces.

Hydraulic heavy is the process of a really large scale heave of a cohesive, impermeable soil layer as a whole by the buoyant effect of upward directed seepage pressures. As this means that the hydraulic head should exceed the overburden pressure of the overlying soli column, the process occur rather infrequently under natural conditions. However, hydraulic head fluctuations resulting in repeted increase and decrease of bouyant support lead to repeated wetting and drying and hence to repeated swelling and shrinkage. This leads then to cracking, strenght softening etc. which favor disintegration, breaking, shattering and settling out of soil pieces and aggregates.

Liquefaction is defined as the sudden large decrease of shearing resistance of water-saturated fine-grained, silty, cohesionless soils, caused by seismic shocks or strains, and asociated with a sudden but temporary increase of the pore water pressure which transforms the soil into a fluid mass. However, the primary cause of increase of the pore water presure may be a drastic increase or decrease of the hydraulic head unrelated to any seismic event, too.

None of the listed types of seepage or hydrodynamic deformations of soils are restricted to karst terranes. On the contrary, they are common in many other geoenvironments. However, the commonly high secondary solution porosity of limestone bedrock forms extermely favorable conditions for removal and delivery of particles eroded from the overlying cover deposits.

As mentioned above, the strain nuclei of most drift dolines are located along the bedrock/cover deposits interface. At this interface an abrupt, stepwise change of lithologies and pore structures occur: from lithifield, jointed and karstified rock masses below to loose, unconsolidated, porous surficial deposits above the interface. It is this interface which controls and favors the development of seepage deformations of soils. For this particular variety of seepage deformation of soils the adjective "**contact**" meaning: "caused or activated by contact" is used in soil mechanics and engineering geology. Hence, the seepage deformations of soils cited and briefly defined could be in this case exactly named: contact suffosion, progressive contact suffosion, (subterranean) contact erosion, contact hydraulic penetration or break-through. For the process of fluidization, hydraulic heave and liquefaction, as well as for tunnelling and piping, the usage of the adjective "contact" seems to be meaningless.

The last-listed processes define the true origin of drift dolines but not necessarily the modes of ground surface displacements which are only the final expressions of the processes operating within the soil column. For complex, e.g. stratified and inhomogenous drift sequences of great thickness (>25 m), the near-surface mechanisms of deformation, which directly define the modes of ground surface displacements, may be almost completely decoupled from the initial processes of seepage deformations of soils which developed at the interface.

THE GEOENVIRONMENTAL MODEL (SYSTEM) OF DRIFT DOLINES FORMATION

To recognize and/or slarify the mechanisms of drift dolines formation it is necessary to identify the main controlling factors of their development from the intial to final phases in a manner which offers their forecast or prediction and/or calculation. In our case there are three main controls (Liszkowski 1979):

1) the lithology, thickness and physical properties of the cover deposits;
2) the (geo-)hydrologic conditions at the bedrock/cover deposits interface;

3) the structure and degree of karstification just below the bedrock/cover interface.

The first factor controls partly the category of seepage deformations of soils which may develop at the bedrock/cover deposits interface, i.e., the initial processes (mechanisms) of deformation, the likely superposition of different types of deformations and the nature and partly geometric and kinematic characteristics of subsidence of the ground surface. Lithologies of cover deposits may be divided into two broad end-member categories: I - unconsolidated, noncohesive, permeable soils, II - unconsolidated, cohesive, impermeable soils. The first category of cover deposits include gravels, sands and silty sands, the second - clays and loams. Noncohesive soils deform by grain-to-grain displacements, their strenght is the function of normal stresses and the friction angle only and - over their high hydraulic conductivity - pore water pressures within them are quickly dissipated. In contrast, cohesive soils deform as a whole; their shearing strenght is the function of cohesion and friction resistance, effective normal stresses and the complete stress history and - over their tightness - high pore water pressure may be built-up and stored within them.

The second factor circumscribes the nature and location of the potentiometric surface of ground-waters relative to the bedrock/cover deposits interface and therefore the wetting conditions at this interface. These control the continuity of mass loss processes initiated at this interface, the values and sense of the seepage force vector and thus the category and rates of seepage deformations of soils which probably will start at the bedrock/cover deposits interface. For the category of noncohesive cover deposits we may assume that the groundwater will form a free water table. Then three cases may occur: IA - the water table is located much below the top of bedrock, i.e., the bedrock/ cover deposits interface is only exceptionally wetted; IB - the water table lies at the top of bedrock, i.e., the interface is intermittently wetted; IC - the water table lies much above the top of bedrock within the noncohesive cover soils, i.e., the interface is permanently wetted. For the category of cohesive cover deposits three cases of (geo-)hydrologic conditions may occur, too: IIA - the groundwater is unconfined; the water table lies much below the top of bedrock (bedrock/cover deposits interface only exceptionally wetted); IIB - the groundwater is confined; the pressiometric surface lies at the top of bedrock (interface intermitteny wetted); IIC - the groundwater is confined; the pressiometric surface lies significantly above the top of bedrock, within the cohesive cover deposits (interface permanently wetted).

The third factor circumscribes the degree of jointing and karstification of the limestones bedrock. Two cases are of special interest: 1 - the bedrock is jointed but there are no open solutional voids in contact with the overlying cover deposits; 2 - the bedrock is jointed and karstified and there are some open solutional voids in contact with the overlying cover deposits. It should

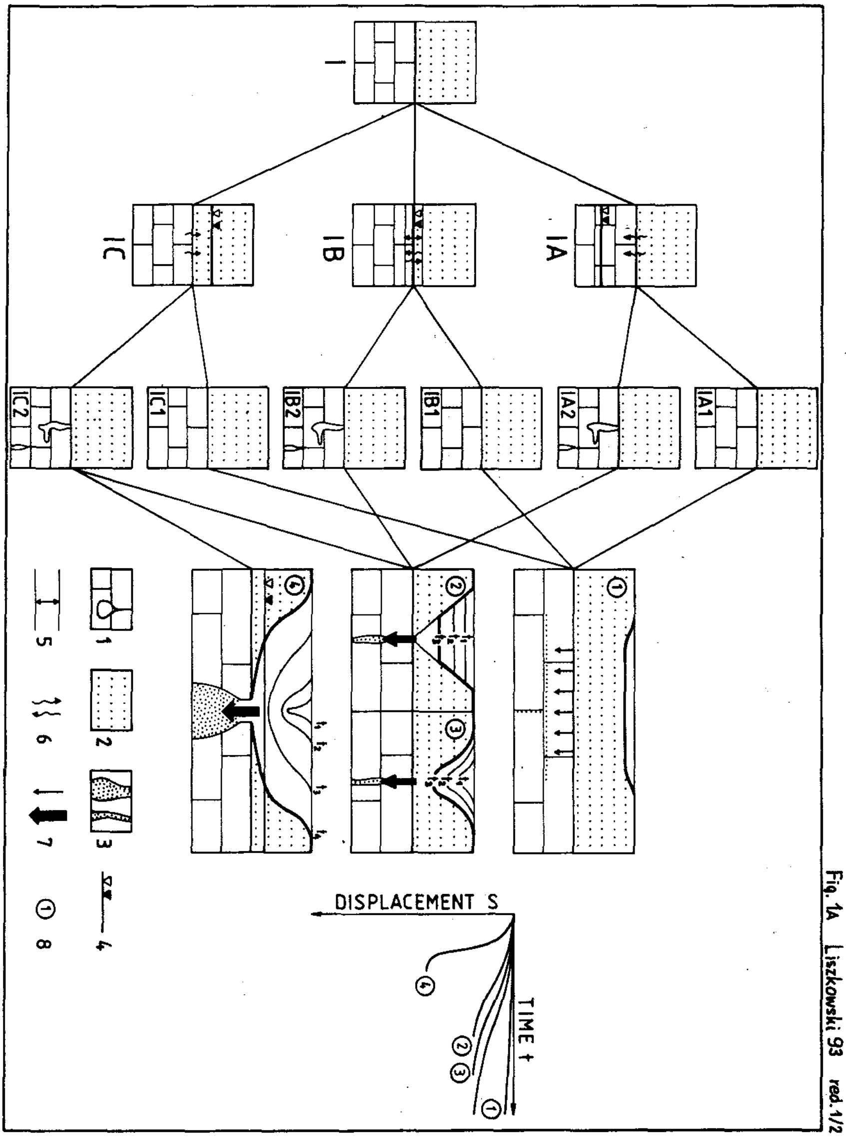
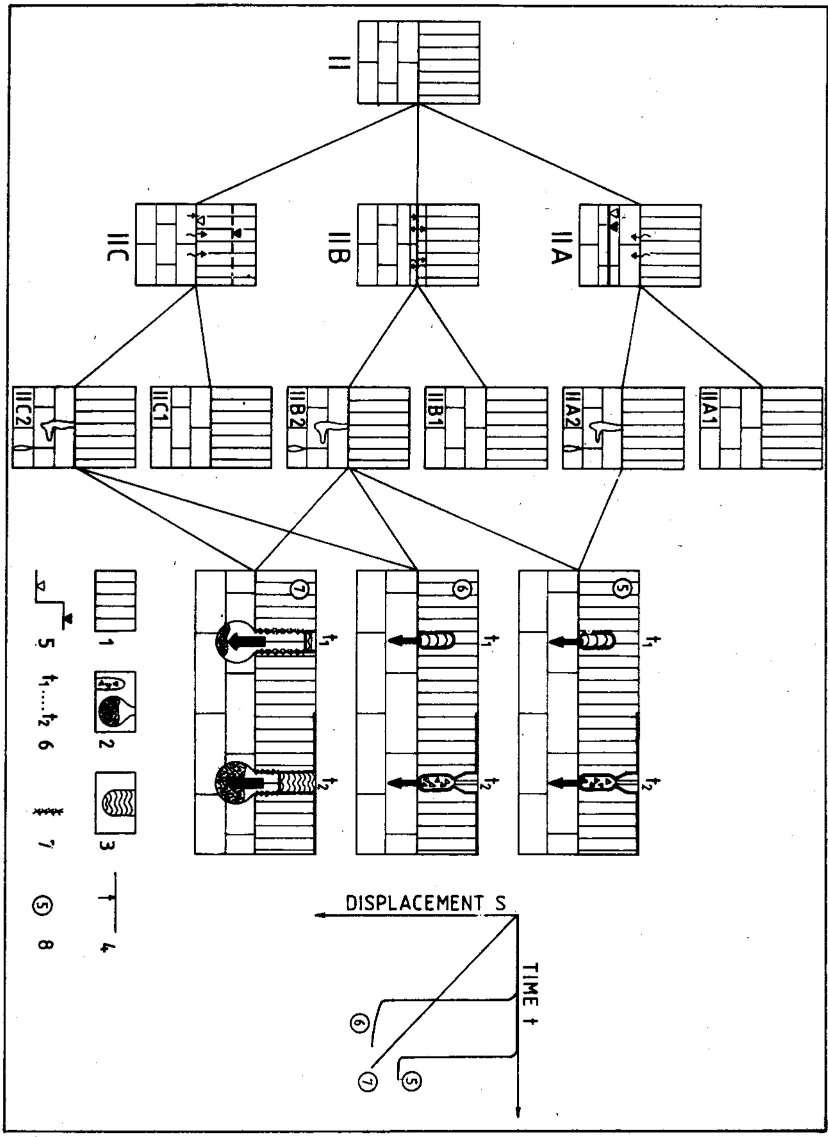


Fig. 1. Models of drift doline formations in mantled karst terranes A/Case I: Noncohesive, permeable cover deposits.

1 - limestone bedrock, with or without solution voids, 2 - noncohesive soils (e.g. sands), 3 - filled solution voids, 4 - ground water table, 5 - range of ground water table fluctuations, 6 - general direction of seepage forces, 7 - mass loss resulting from seepage deformations of cover deposits; thickness of mark indicate mass flux intensity, 8 - types of seepage deformations of soils: 1 - contact suffosion, 2 - progresive contact suffosion, 3 - internal (subterranean) contact erosion, 4 - fluidization.



B/Case II: Cohesive, impermeable (and semipermeable) cover deposits.

1 - cohesive soils (e.g. loams), 2 - voids filled with collapsed (a) and suspended (b) particles, 3 - drift dolines filled immediatly after their ocurrence with limnic and organic sediments, 4 - pressurized ground water table, 5 - pressiometric head, 6 - phases of drift dolines formation from intial (t_1) to final (t_2) ones, 7 - planes of shearfailure, 8 - types of seepage deformations of soils: 5 - tunneling, 6 - piping, 7 - hydraulic haeave. Other symbols are explained in the text.

not be stressed that the degree of karstification controls the likely rate of removal of soil particles from the overlying cover deposits across the interface and the likely volume of deposits which may be stored within solution voids of the bedrock. The degree of karstification controls also partly the geometry of ground-surface dislocation, especially in the case of thin (<5m), homogenous, noncohesive cover deposits (Liszkowski 1975).

It seems to be questionable to limit the controlling factors of drift dolines formation and development to three only. But note that these three factors are complex ones, including many individual quantities. For example, one may wonder why the climatic factor, whose influence on the intensity of collapse incidents is well documented, is excluded from the model. However climatic events, such as heavy rainfalls, hurricanes, etc., are immediately expressed in

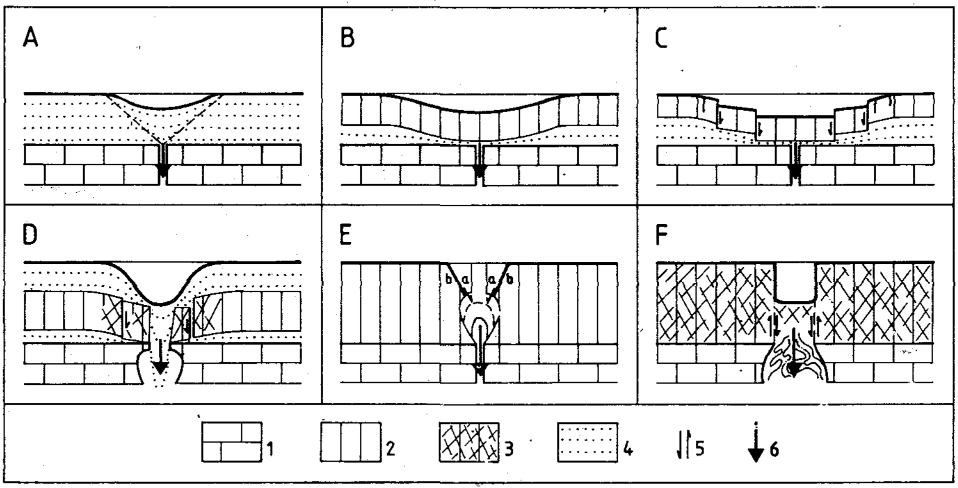


Fig. 2. Mechanisms of ground surface displacments related to drift dolines.
A - sagging or compaction. B - bending of deformable elastic layer, C - bending with tension or shear failure, D - as in C followed by granular (dry or wet) flow, E - tension or shearing failure to subsidence dolines of authors. C to F equals to collapse dolines or sinkholes of authors.
Explanation of signs: 1 - karstified limestone bedrock, 2 - normaly consolidated cohesive soils, 3 - overconsolidated and fissured cohesive soils, 4 - noncohesive soils, 5 - sense of shear, 6 - mass loss by seepage deformations of soils at the bedrock/cover deposits interface.

seasonal or short-term changes of (geo-)hydrologic conditions of the karst geosystem, i.e., in hydraulic head and gradient fluctuations, pore pressure changes, etc., all of which are included in the second factor. Also topography of the bedrock/cover deposits interface may be important in respect to the problem discussed; but the thorough analysis of this factor leads to the conclusion that it influences the probability of arching within the cover deposits and thus the time interval between the initial void formation and the final ground surface subsidence incident only, not the root process itself.

Thus, coupled together, the three factors describe rather completely but in comprehensive manner the geoenvironmental controls of drift dolines formation for the two end-member lithologies of cover deposits in mantled carbonate karst terranes and the processes of energy and mass transfer within them.

Hence, the three factors (=subenvironments) coupled together form the end act as a model for drift dolines formation searched for. This model is - for the two end-member lithologies cited - presented in Fig. 1.

DISCUSSION AND FINAL REMARKS

The model presented may be used in two different ways:

i) If little and only generalized or preliminary data concerning the three main elements (factors) of the mantled karst geoenviroinment are known, the model may help to select the main problems and establish the framework for advanced studies.

ii) If there are sufficient quantitative details known, concerning the three main elements cited, the model may be used for prediction of the likely mechanisms of seepage deformations of soils which will develop at the bedrock/cover soils interface and their likely further development within the soil column and the likely mechanism of ground surface displacement (subsidence s.l.).

However, prediction involves not only types, but place, time, intensity and range of ground surface dislocations too. Our ability to predict place and time of localized subsidence s.l., especially of collapse incidences in covered karst terranes is very minute. This gap in our ability to predict karst subsidences s.l. can be narrowed by accumulating a great amount of information on man-induced drift dolines formation (Yuan 1987, Chen & Xiang 1991, Newton 1984). Somewhat higher is our ability to predict the intensity and range of karst subsidences s.l. But in fact, the first step in any prediction should be the prediction of mechanisms involved in the formation of drift dolines and of modes of ground surfaces deformation. And this ability is offered by the model presented.

Inspection of Fig. 1A & B indicates that there are three main types of seepage deformation of soils involved in drift doline formation: progressive contact suffosion, (subterranean) contact erosion and contact hydraulic penetration, preceeded or accompanied by two other ones: fluidization and liquefaction. In more complex real geological settings, i.e. layered sequences of noncohesive and cohesive cover deposits, superposition of these processes in the vertical profile will occur, depending on site lithologies and geohydrologic conditions. But, unaffacted by the types of seepage deformation of soils involved, only two modes of ground surfaces deformations occur: continous and relatively slow subsidences s.s. and discontinous rapid ground surface failures, i.e. collapses. Thus it will rarely be possible to determine the root cause of drift doline formation from the modes of ground surfaces deformations alone. This reinforces the conclusion of Cramer (1941) (see also Ford & Williams 1989) that the types of ground surface deformation observed do not refer to the true origin of drift dolines. Nevertheless it is possible to clarify and/or detail the mechanisms of soil failures involved in the processes of ground surface deformation, which are much more closely connected with the mechanisms of mass loss at the bedrock/cover deposits interface (Tolmatchev & Reuter 1990). Some of these mechanisms recognized in authors regional and site investigations are presented in Fig. 2.

Thus also now much is known about the real initial mechanisms or processes of drift dolines formations and the real final mechanisms and modes of their occurrence on the ground surface, much more data should be collected and treated before a true genetic classification of these natural phenomena will be achieved.

REFERENCES

Busch, K. F. & L. Luckner, 1974: Geohydraulik.- 2. Aufl., F. Enke, Stuttgart

Chen, J. & S. Xiang, 1991: Sinkhole Collapse Resulting from Pumping of Karst Groundwater: A Problem and its Solutions. In: A. I. Johnson (Ed.), Land Subsidence (Proc. 4th Int. Symposium on Land Subsidence, May 1991), 313-322, IAHS Publ. no. 200

Cramer, H., 1941: Die Systematik der Karstdolinen. Neues Jb. Miner., Geol., Paläont. 85, 293-382

Ford, D. & P. W. Williams, 1989: Karst Geomorphology and Hydrology. Unwin Hyman, pp. 601, London

Jennings, J. N., 1971: Karst: an introduction to systematic geomorphology. M.I.T. Press, pp. 252, Cambridge (Mass.)

Liszkowski, J., 1974: Geological models of development of seepage soilde formations in Poland. Proc. 2nd Congr. IAEG, Vol. 2, Sect. 5, 1-12, Sao Paulo

Liszkowski, J., 1975: Erdfälle und Bodensenkungen der Karstgebiete Polens: ihre Verbreitung und Genese. Proc. Intern. Symp. IAEG: Sinkholes and subsidence: engineering-geological problems related to soluble rocks, Sect. 1, 1-7, Hannover

Liszkowski, J., 1979: Mechanisms of formation and typology of drift dolines in covered karst terranes from Poland (in Polish, Engl. sum.). Biul. Geol. UW, 23, 155-168, Warszawa

Newton, J. G., 1984: Sinkholes resulting from ground-water withdrawals in carbonate terranean overview. In: T. L. Holzer (Ed.) Man-Induced Land Subsidence (Geol. Soc. America, Reviews in Engineering Geology, Vol.6), 195-202, Boulder (Co)

Sweeting M. M., 1973: Karst Landforms. Columbia University Press, pp. 362, New York

Tolmatchev, V. V. & F. Reuter, 1990: Ingenieurgeologie des Karstes (Russian edition). Niedra, pp. 150, Moscow

Witt, K. H., 1986: Filtrationsverhalten und Bemessung von Erdstoff-Filtern. Veröffentl. d. Inst. Bodenmech. u. Felsmech. d. Univ. Fridericiana, H.104, pp. 142, Karlsruhe

Yuan, D., 1987: Keynote address: Environmental and engineering problems of karst geology in China. In: B. F. Beck & W. L. Wilson (Eds.), Karst hydrogeology: Engineering and Environmental Applications (Proc. 2nd Multidisciplinary Conf. on Sinkholes and the Environmental Impacts of Karst, Orlando, February 1987), Balkema, 1-11, Rotterdam - Boston

Ziems, J. 1967: Zur Klassifizierung der mechanischen Erdstoffverformungen durch Wirkung des Sickerwassers. Wasserwirtschaft Wassertechnik, 17(2), 50-55, Berlin

MEHANIZMI IN KINEMATIKA NASTAJANJA VRTAČ V MORENSKEM GRADIVU

Povzetek

V krasoslovni literaturi so običajno trije tipi vrtač: korozijske, udorne in sufozijske. Mehanizmi nastajanja prvih dveh tipov so dobro znani, medtem ko je za tretjega to poznavanje veliko slabše. Pri nastajanju vrtač v morenskem gradivu sodelujejo različni mehanizmi, ne samo sufozija, kot še vedno običajno navajamo. Glavni dejavniki so: litologija ter fizikalne in geomehanske lastnosti prekrivnih sedimentov, geohidrološke razmere ter način močenja stika med kamnino in nanosom ter stopnja zakraselosti matične kamnine. Vsi trije dejavniki skupaj sestavljajo model (sistem), ki opisuje procese prenosa energije in mase v pokritem krasu in omogoča predvidevanje mehanizmov, ki povzročajo spremembe na površju zaradi spiranja na stiku matične kamnine in nanosa. V zvezi z nastajanjem vrtač sta le dva načina sprememb na površju: počasno, a stalno posedanje in hitri, posamični udori.

Prispevek definira posamezne procese in mehanizme deformacij površja zaradi spiranja prsti, kar je osnovni proces nastajanja takih sufozijskih vrtač, kot tudi mehanizme posedanja oziroma udiranja površja, kar je končni in na zunaj vidni odraz sufozijskih vrtač.

INFLUENCE OF VERTICAL CRUSTAL MOVEMENTS ON KARST HYDRAULICS AND THE KARSTIFICATION PROCESS

VPLIV VERTIKALNIH GIBANJ ZEMELJSKE SKORJE NA HIDRAVLIKO IN PROCESE ZAKRASEVANJA

EWA LISZKOWSKA & JERZY LISZKOWSKI

Izvleček UDK 556.34

Ewa Liszkowska & Jerzy Liszkowski: Vpliv vertikalnih gibanj zemeljske skorje na hidravliko in procese zakrasevanja

Različna gibanja zemeljske skorje so poleg klime, reliefa, litologije in strukture najpomembnejši dejavnik v kraškem okolju. Ta gibanja neposredno vplivajo na prepustnost kraških vodonosnikov in na celotno kraško hidravliko. Deloma vplivajo tudi na disperzijo in advekcijo tokov solutantov in s tem na intenzivnost raztapljanja, to je zakrasevanja. Prispevek obravnava te povezave in omogoča tudi določeno kvantificiranje. Poudarja, da vertikalna gibanja skorje vplivajo na hidrogeologijo kraških vodonosnikov v časovnem razponu od 10^1 do 20^2 let.

Ključne besede: geologija, tektonika, hidravlika, hidrologija krasa

Abstract UDC 556.34

Ewa Liszkowska & Jerzy Liszkowski: Influence of vertical crustal movements on karst hydraulics and the karstification process

Differential vertical crustal movements are, besides, climate, relief, lithology, and structure, the most important formation factor of the karst environment. They are the effect of changes of the stress-strain state of rock masses and result in changes of elevation and slope of the Earth's surface. Thus they affect directly the permeability of the karstic aquifers and the geometric, kinematic and dynamic properties of the flow field, i.e. the whole karst hydraulics. Vertical crustal movements (VCM) control partly the dispersion and advection fluxes of solutes and thus the rate of dissolution, i.e. the rate of karstification. The paper discuss the basic theoretical background of these interrelationships which allows the quantification of some of the above conclusions. It is stressed that VCM control the hydrogeology of karstic aquifers for time intervals down to tens and hundreds of years.

Key words: geology, tectonics, hydraulics, karst hydrology

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INTRODUCTION

In Poland, as in many other European countries, carbonate aquifers, many of them strongly karstified, are important sources for municipal, industrial, agricultural and domestic water supply. However, in recent decades a steady and significant decline of head in water table as well as confined karst aquifers has been observed. A preliminary study of causes of this forced "negative retention" indicated that neither decreasing recharge as the result of (frequently assumed only) reduced precipitation, nor the increase of hydraulic conductivity as the result of dissolution explains this effect. Indeed, recent VCM are probably the principal factor responsible for this effect (Liszkowska & Liszkowski 1992).

The main objective of this paper is to testify this as-yet working hypothesis only. Our purpose here is to present the basic physical relations between VCM and the physical, hydrodynamic and dispersion field parameters of karst aquifers. The paper could be read as a contribution to theoretical karstology.

BASIC PHYSICAL RELATION BETWEEN VCM AND KARST AQUIFER CHARACTERISTICS

The relation between VCM and karst aquifer characteristics is very complex. Because of this complexity we limit our consideration to the characteristics most relevant in respect to the problem solved. As relevant characteristics of karst aquifers we consider the structural characteristics of the rock mass, as these control the permeability of the aquifer, and the rates of dispersion and advection of dissolved matter as these affect directly the karstification process. Moreover, only the simplest models and analytical and semi-analytical solutions are used in this paper because, due to the low number of parameters, they are more easily understood and suitable for preliminary evaluations in one- or two-dimensional analysis of problems. That these simplifications are not oversimplifications one may check by reading the publications cited in this text.

First, remember that the most significant characteristic of natural rock masses is their secondary porosity. Such porosity is causd by tectonic stresses and includes openings along bedding planes, fissures and joints, cleavage planes, and faults. In carbonate rocks these structural planes are commonly enlarged by solution. These structural planes control, among other things, the permeability of rock masses, defined by the hydraulic conductivity K and therefore the specific discharge V and average linear velocity U of water through fissures.

For laminar flow conditions the specific discharge V of a fissure of infinite lenght and with plane - parallel sides is given by the well known "cubic law" equation (Lomize 1951):

$$V_f = -(Cb^3)\ J, \qquad (1)$$

and for a set of parallel fissures of mean spacing $\bar{S}_f$:

$$V_f = -(Cb^2n_f)\ J \equiv (Cb^3/\bar{S}_f)\ J, \qquad (2)$$

where b is the aperture of fisures, C is a constant including viscosity and density of water, and roughness of fissure sides, n_f is the fissure porosity, and J is the pressure or hydraulic gradient.

In analogy to Darcy's law for porous media, the quantities in brackets of equations (1) and (2) are expressions of the hydraulic conductivity of fissured media. Hence:

$$K = Cb^3, \qquad (3a)$$

or

$$K = Cb^2n_f \equiv Cb^3/\bar{S}_f. \qquad (3b)$$

Using Forchheimer's relation $U_f = V_f/n^f$ in (2), we get:

$$U_f = Cb^2J. \qquad (4)$$

Note that the presence of a third power in equations (1), (2), (3a) and (3b) makes hydraulic conductivity and specific discharge very sensitive to the distribution of fissure apertures. In fact, from experimental results it seems likely that flow rate through a natural fracture is proportional to b to a fourth power (sic!) (Schrauf & Evans 1986).

The most relevant pecularity of karst aquifers is defined by the solubility of the rock matrix. The dissolution of the rock matrix leads to changes of the flow geometry from fissure to pipe flow. The dissolution, i.e. karstification process, may be expressed by a special case of the general dispersion/advection equation (Scheidegger 1970, Bear 1969). Asumming that the rock matrix is essentially nonporous and impermeable and the solute distribution across the fracture aperture is constant, the dissolution process (karstification) of limestones for the case of two-dimensional flow may be expressed as the sum of three fluxes: the diffusion flux I_D, the dispersion flux I_S and the (negative) advection flux I_A. Thus the dissolution rate $\delta C/\delta t$ or total solute flux I_T may be expressed by the following (very simplyfied) equation:

$$I_T = I_D + I_S - I_A. \qquad (5)$$

The diffusion flux is unrelated to any structural characteristics of the karstifying rock mass. However, the disperssion flux, which is proportional to the coefficient of dispersion D_L, is directly related to structural characteristics of the rock mass:

$$I_S \propto D_L, \qquad (6)$$

where the quantity D_L is defined by (Bear 1969):

$$D_L \equiv \alpha_L \bar{U}_X. \qquad (7)$$

The symbol α_L denotes the dispersivity. For fissured media Neretnieks (1983) indicated that the dispersivity is very sensitive to the fissure apertures disribution f(b). Thus by (4), (6) may be written in the form:

$$I_S \propto f(b)\ b^2. \qquad (8)$$

Also the advection flux I_A, which is proportional to the average flow velocity $\bar{U}_X$, leads by (4) to

$$I_A \propto b^2. \qquad (9)$$

Introducing (8) and (9) equation (5) may be written

$$I_T \propto b^2\ f(b). \qquad (10)$$

Now we need to find some functional relations between VCM and the above defined structural and mass transport characteristics of karst aquifers. If these are found, the hypothesis would be accepted as (at least theoretically) valid.

VCM are the external expression of changes of the stress field in the crust (lithosphere). They are rigid translational strains of large rock masses since the changes of stresses within the crust are much below the yield stress δ_0 of the rocks. Assuming that the strains are infinitesimal and homogenous it follows from the general theory of strain (Jaeger 1969) that, using polar coordinates with the pole at the Earth's center, VCM may be identified with the elongation or contraction in radial direction e_R = !ΔH!/R, where ΔH are changes of elevation and R is the Earth's radius. These are coupled with tangential (transverse) strains e_Q which for discontinous media may be identified with relative changes of fissure apertures !Δb!/L, where L is a characteristic lenght. The components of strain could satisfy the compatibility condition, which means that they are not independent. The simplest general assumption is that they are proportional, i.e.

$$!e_Q! \ \alpha \ !e_R!. \qquad (11)$$

As we are interested in finite strains the relation (11) is almost useless for our purpose. Thus we need to find a similar relation for finite homogeneous strain. To do this we may use the elementary Euler-Bernouilli theory of the deflection of beams. From this we find that also for finite strain the tangential displacements are proportional to the vertical ones and (11) becomes for a beam dissected by discontinuities and flaws:

$$\Delta b \ \alpha \ \Delta H. \qquad (12)$$

Now remember that from (1) and (3a) it follows that:

$$\Delta K \ \alpha \ (\Delta b)^3. \qquad (13)$$

and $\Delta V \ \alpha \ (\Delta b)^3$. (14)

and from (8), (9) and (10) that:

$$\Delta I_T \ \alpha \ (\Delta b)^2 f(\Delta b). \qquad (15)$$

Using (12) in (13), (14) and (15) leads to the proportionalities:

$$\Delta K \ \alpha \ \Delta H^3 \qquad (16)$$

$$\Delta V \ \alpha \ \Delta H^2 \qquad (17)$$

$$\Delta I_T \ \alpha \ \Delta H^2 f(\Delta H) \qquad (18)$$

The proportionalities (16), (17) and (18) are the semiquantitative expressions of the functional relations between VCM and structural, kinematic and mass transport characteristics of karst aquifers sought for.

SUMMARY AND CONCLUSIONS

We have indicated that there are functional relations between VCM and some relevant characteristics of karst aquifers: their structural, hydrodynamic and mass transport parameters. These parameters define the hydraulic conductivity of the rock mass, the specific discharge and average linear velocity of water and, indirectly, the head and hydraulic gradients and thus the whole karst water flow field. Moreover, we have also documented that VCM over changes of structural characteristics define the dispersion of solutes, the advective flux of solutes and hence the rate of dissolution, i. e., the rate of karstification, too. Therefore we may conclude without exaggeration that VCM affect the whole karst development.

This conclusion seems to be not very original and there is general agreement that tectonism is one of the controlling factors in the development of karstic aquifers. There is enough evidence from field observations that this conclusion is true. However, evidence from field observations refers to long-term, involving millions and tens of million years, vertical crustal movements, i. e., true tectonic or Neotectonic ones. For such long-term vertical crustal movements the changes of position (elevation) may be of the order of $10^2 + 10^3$ m and it is not surprising that they have a major influence on hydraulic potential distribution and values, flow velocities of water in karst aquifers etc. as well as on karst topography and the geometry of the subterranean karst conduit or phreatic cave networks (cf. Ford & Williams 1989). But we wish to stress that VCM affect karst hydraulic systems and the karstification process for time intervals down to tens and hundreds of years, even if the changes of elevation are of the order of $10^{-2} + 10^{-1}$ m only. We think that this conclusion, although at yet based only on very few data is new and if proven will be great significance, both theoretical and practical. Work on the experimental verification of this hypothesis is in progress.

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REFERENCES

Bear, J., 1969: Hydrodynamic dispersion.- In: de Wiest R. J. M. (ed.), Flow through porous media, chap. 4, p. 109, Academic, New York.

Ford, D. & Williams, P., 1989: Karst geomorphology and hydrology.- Unwin Hyman, London, 601 p.

Jaeger, J. C., 1969: Elasticity, fracture and flow: with engineering and geological applications.- Methuen & Co., London, 3rd ed., 268 p.

Liszkowska, E. & Liszkowski, J., 1992: On the causes of forced negative groundwater retention in carbonate aquifers.- In: Hydrogeological problems of south-west Poland, p. 79-85 (in Polish, Engl. res.), Wrocław.

Lomize, G. M., 1951: Filtratsiia v treshchinovatykh porodakh.- (See page flow throuhg jointed rock) (in Russian). Gosenergoizdat, Moscow.

Neretnieks, I., 1983: A note on fracture flow dispersion mechanisms in the ground. Water Resour. Res., 19(2) : 364-370.

Scheidegger, A. E., 1970: Theoretical Geomorphology.- Springer, Berlin, 435 p.

Schrauf, T. W. & Evans, D. D., 1986: Laboratory studies of gas glow through a single natural fissure.- Water Resour. Res., 22(7) : 1038-1050.

Snow, D. T., 1970: The frequency and apertures of fractures in rock.- Int. J. Rock Mech. Min. Sci., 7 : 23.

VPLIV VERTIKALNIH GIBANJ ZEMELJSKE SKORJE NA HIDRAVLIKO IN PROCESE ZAKRASEVANJA

Povzetek

Različna gibanja zemeljske skorje so poleg klime, reliefa, litologije in strukture najpomembnejši dejavnik v kraškem okolju. So posledica sprememb pritiskov v kamninski gmoti ter sprememb v višinah in naklonih zemeljskega površja. Ta gibanja neposredno vplivajo na prepustnost kraških vodonosnikov in na geometrijo, kinematiko in dinamiko lastnosti celotne kraške hidravlike. Deloma vplivajo tudi na disperzijo in advekcijo tokov solutantov in s tem na intenzivnost raztapljanja, to je zakrasevanja.

Prispevek obravnava temelje teoretičnih osnov teh povezav in s tem omogoča tudi določeno kvantificiranje omenjenih izsledkov. Poudarja, da vertikalna gibanja zemeljske skorje vplivajo na hidrogeologijo kraških vodonosnikov v časovnem razponu od 10^1 do približno 20^2 let.

PEDOGEOGRAPHIC CHARACTERISTICS OF THE RAKOVŠKO-UNŠKO POLJE

PEDOGEOGRAFSKE ZNAČILNOSTI RAKOVŠKO-UNŠKEGA POLJA

FRANC LOVRENČAK

Izvleček UDK 551.44(497.12)

Franc Lovrenčak: Pedogeografske značilnosti Rakovško-Unškega polja

Predstavljene so nekatere značilnosti prsti z Rakovško-Unškega polja na Notranjskem, severozahodno od Cerkniškega polja. Poudarjene so povezave med morfologijo, osnovnim materialom in značilnostjo prsti. Najpomembnejše je vprašanje izvora rdečkastega glinastega horizonta v profilu, zlasti tistega na dnu kraškega polja. Ta plast je ali netopen ostanek preperele matične kamnine ali pa je nastala pri sedimentaciji drobnih delcev na dnu polja. Rezultati terenskih meritev in laboratorijskih analiz vzorcev prsti so prispevek k iskanju odgovora na to vprašanje.

Ključne besede: pedogeografija, prst na krasu, Slovenija, Rakovško-Unško polje

Abstract UDC 551.44(497.12)

Franc Lovrenčak: Pedogeographic characteristics of the Rakovško-Unško polje

Some characteristics of soils of the Rakovško-Unško polje in Notranjsko, northwest of the Cerkniško polje, are discussed. The searching for correlations is stressed, between landforms, parent material, and soil characteristics. The primary stress is given to the question of origin of the reddish clay horizon in soil profile, the one from the bottom of the karst polje in particular. It is either a horizon of insoluble residue by parent material weathering, or it was generated by depositing fine particles on the bottom of the polje. The results of fieldwork measurements and lab analyses of soil samples are meant to be a contribution to searching for the answer to this question.

Key words: pedogeography, soil on karst, Slovenija, Rakovško-Unško polje

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INTRODUCTION

Just as the landforms and water on the karst are closely related to carbonate rocks, so are the soils. Therefore, the soil is quite a distinctive and characteristic factor of karst landscape, too. In spite of this fact, karstologists and researchers in other branches pay less attention to soils than, for example to karstic surface and underground forms or water characteristics. In order to become acquainted with the karst as universally as possible, it will be necessary to include investigations on karst soils, too, in further researches of karst.

To become better acquainted with characteristics of karst soils, we have started to investigate them on the Rakovško-Unško polje, between the Cerkniško and Planinsko poljes. We were particularly interested in the relation between landforms and the characteristics of soils on them. The occurrence of the reddish clay horizon in the lower part of deep soil profiles is also interesting. Has this clay, being the residue of parent material weathering, been left over on the site of its origin, or was it transported from some other site? The results of fieldwork measurements and lab analyses of soil samples are meant to be a contribution to searching for answer to this question.

METHODS

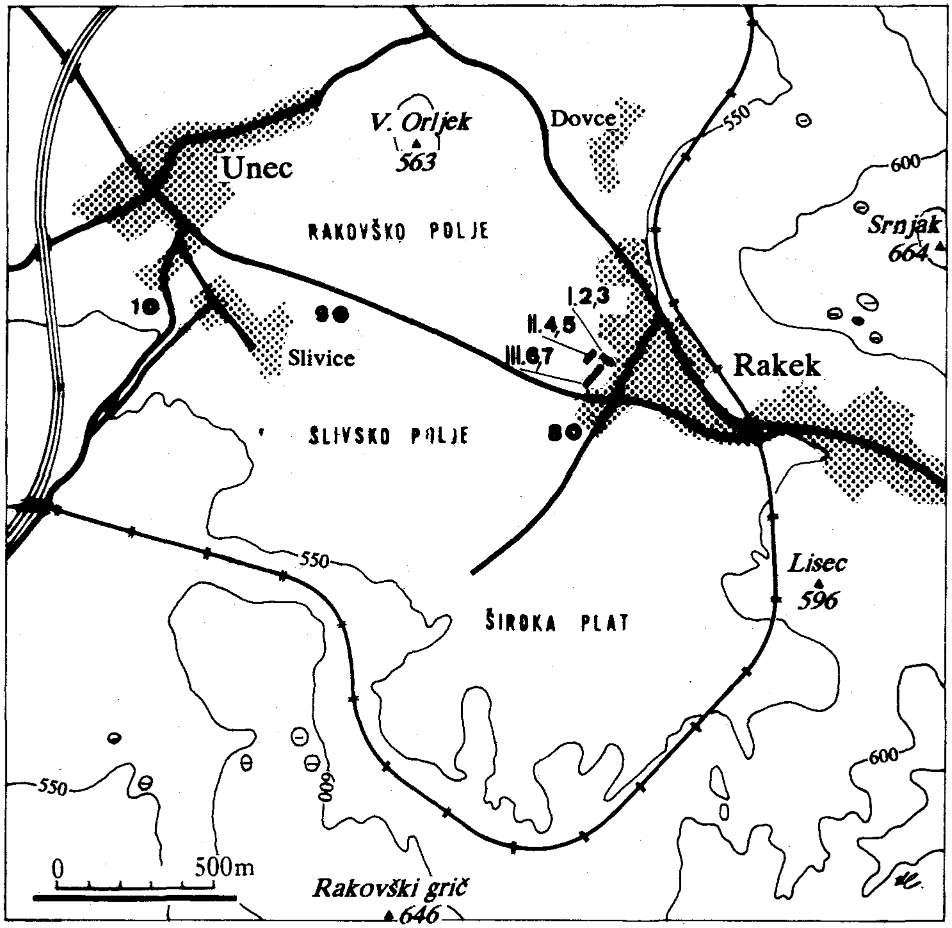
Nine soil profiles were chosen for a detailed presentation, five of which were taken from the border parts of the polje on the northeast and southwest sides, and the other four were taken on the bottom of the polje on its eastern part. (Fig. 1).

Colours of soils were determined according to the Standard Soil Color Chart (1965). Mechanical analysis of soils: samples were prepared with 0.4n $Na_2P_2O_3$ x 10 H_2O; fractions were determined by means of the pipette method, and texture classes according to the international triangular diagram. Soil reaction was measured with the digital pH meter (in KCl). The share of free $CaCO_3$ was determined by means of volumetric method with the Scheibler calcimeter. The share of organic matter was determined by the Walkley-Black method.

SOIL FORMING FACTORS

The Rakovško-Unško polje (the RUP) lies in the Notranjsko valley, northwest of Cerkniško polje. According to Gams (1974) and Habič (1981) it is a karst polje. The polje includes, besides its flat bottom, also the nearby border parts which gently slope towards the bottom. The entire polje lies in the upper Triassic dolomite which has been tectonically broken. The dolomite bedrock on the bottom is covered with a layer of Quaternary sediments, which are most frequently 3-5 m thick. The deepest well drilled in them was 9.45 m deep, and the shallowest one 1.04 m deep (Čadež, 1954). According to

Fig. 1 THE POSITION OF SOIL PROFILES IN THE RAKOVŠKO-UNŠKO POLJE



Čadež (1954), the dolomite bedrock is covered with a layer of dolomite rubble, with pieces no bigger than 8 cm in diameter. In the upward direction this rubble is mixed with loam which is of brownish-red or reddishbrown colour on the bottom and becomes of yellowish-brown and brown colour higher up.

According to Gams (1972) the RUP belongs to the Notranjsko-Kočevsko climate region. Mediterranean climate influence does not reach this part because of the barrier formed by the Dinaric high plateaus. Climatic characteristics are presented by meteorologic data from nearby Planina. The average temperature in January is -1.1 degree C, and in July 18.2 degrees C; the average annual temperature is 9 degrees C. Average precipitations per individual month exceed 100 mm, with the maximum in October and minimum in March; the average annual precipitation quantity amounts to 1821 mm (Pučnik, 1980).

There are no permanent streams on the RUP. Water begins to spring after more abundant precipitations, from several springs on the southeastern side of the polje and drains along the artificial ditch to ponors in Bratni dol below Orlek on the northwest side of the polje. While drilling through the sediments on the bottom of the polje, we discovered ground water (January 1951) in the wells, mainly 5 to 205 cm below the surface. In the three wells east from the road to Slivice, water reached up to the brims of the wells (Čadež, 1954). Yet, no traces of excessive humidity in soils were discovered on the bottom of the polje.

Climate conditions are favourable for wood which originally covered the border parts, and most probably the bottom of the polje, too. Nowadays, there are fields with cultivated plants and grass vegetation on the bottom. On the northeast and north borders of the polje, there are meadows with *Arhenatheretalia elatioris*, on the northwest border, there are mesophile grasslands with *Brometalia erecti*. The southwest border of the polje is covered with *Genista triangularis-Pinetum* (Puncer et al., 1976).

SOIL CHARACTERISTICS

As regards parent material and landforms, soils on the borders of the polje differ from soils on its bottom. Shallow soils and deep soils in fissures interchange, mosaic-like, in the border parts, while deep soils prevail on the bottom.

The dolomite bedrock in the borders of the polje, which slope towards its bottom, is corroded and more or less deep fissures filled with deep soils occur there. In between these fissures, bedrock lies shallow under the surface and shallow soils occur there. The profile of these shallow soils consists of Ah horizon which is 20-25 cm deep (Table 1, Profile 1). It lies directly on the parent material or passes over through the transitional AC horizon into the C horizon. The Ah horizon is of dark brown colour and abounds in roots. Its texture is sandy clay or loam. It contains over 10% of organic matter and over 14% of free $CaCO_3$; its reaction is almost neutral (pH 6.86).

Due to their shallowness, such soils are almost not cultivated at all, and most of them are overgrown with grass vegetation.

On the northeast side of the polje, just below Rakek, where the border gently slopes downwards to the bottom of the polje, different soils were formed. In the upper part of the slope, deep dark brown soils (Profile 2) interchange with deep soils in fissures (Profile 3). In the lower, almost level part of the slope, shallow soils (Profile 4) interchange with deep soils in fissures (Profile 5). As to profile morphology, the soils of the upper part

Table 1: Some characteristics of the soils in the Rakovško-Unško polje

Prof.no.	Place	Horizon	Depth cm	Sand %	Silt %	Clay %	Texture	pH (KCl)	$CaCO_3$ %	Org.mat. %
1	Slivice	A_h	0-20	59	14	27	PG	6,86	14,51	13,4
		C	20-							
2	Rakek	A_{h1}	0-18	33,7	45,2	21,1	MGI	7,12	2,23	7,92
		A_{h2}	18-45	33,1	25,2	31,7	G	7,31	2,98	5,48
		C	45-							
3	Rakek	A_{h1}	0-20	30	48,3	20,7	MGI	7,04	0	9,14
		A_{h2}	20-87	30,4	45,3	21,3	MGI	7,33	4,15	3,05
		(B)rz	87-147	22,5	17,8	59,7	G	7,15	1,36	1,22
4	Rakek	A_h	0-30	60,8	10,8	28,4	PG	7,06	1,42	5,03
		C	30-							
5	Rakek	A_h	0-30	35,7	34,7	29,6	IG	6,96	6,86	6,36
		(B)rz	30-180	22,5	21,6	55,9	G	6,88	1,93	0,34
		C	180-							
6	Rakek	A_h	0-30	29,6	58,6	11,8	MI	6,93	0	6,03
		B_{t1}?	30-70	28,1	42,7	19,2	IG	6,96	2,97	2,85
		B_{t2}?	70-	19,3	49,1	31,6	IG	6,64	0,98	1,34
7	Rakek	A_h	0-30	29,7	45,5	24,8	MGI	6,91	0,68	5,86
		B_{t1}?	30-100	20,4	44,8	34,8	IG	6,90	1,16	2,85
		B_{t2}?	100-	10,8	41,2	48	G	6,68	0	1,34
8	Rakek	A_h	0-15	30,7	42,4	26,9	IG	7,02		4,76
		B_{t1}?	15-45	21	39,4	39,6	IG	6,87		2,99
		B_{t2}?	45-	1,1	22,2	76,7	G	6,68		1,06
9	Slivice	A_h	0-20	32,7	47,7	19,6	MGI	7,62	35,3	6,26
		B_{t1}?	20-70	28,8	35,2	36	IG	7,79	0	
		B_{t2}?	70-	16,2	29,1	54,7	G	7,33		

PG - sandy clay, MGI - silty clay loam, G - clay, IG - clay loam, MI - silt loam

Fig. 2 PROFILE THROUGH THE SOIL ON THE EDGE OF THE RAKOVŠKO-UNŠKO POLJE

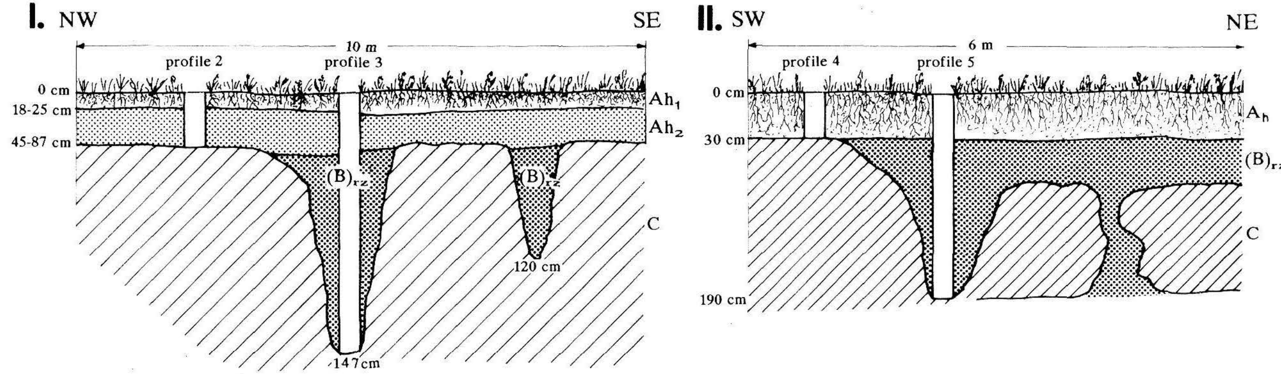
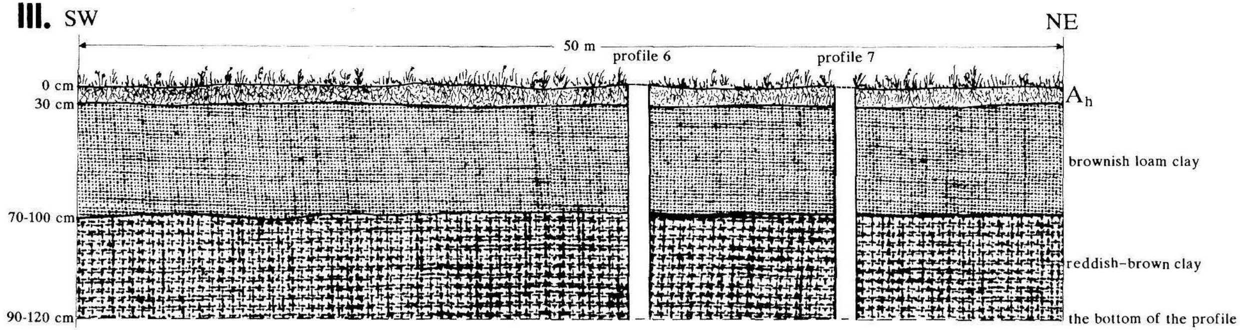


Fig. 3 PROFILE THROUGH THE SOIL ON THE BOTTOM ON THE RAKOVŠKO-UNŠKO POLJE



differ rather greatly from the soils of the lower part.

Profile 2 consists of the humose Ah horizon which is 45 cm deep and lies on the dolomite parent material. The upper part of the horizon, which could be defined as Ah1 subhorizon, is of dark brown colour, of crumb structure, and abounds in roots; it reaches down to the depth of 18 cm. (Fig. 2, I). Its texture is silty clay loam with 21.1% of clay and contains 7.92% of organic matter. The lower part which could be defined as Ah2 subhorizon, is of lighter colour than the upper part; it lies at a depth between 18 and 45 cm, its texture is clay loam with 31.7% of clay and contains 5.48% of organic matter. The entire Ah horizon contains about 2% of free $CaCO_3$, and its reaction is neutral. As to these two characteristics, almost no difference occurs between the two subhorizons. Small stones are present in the whole of the horizon.

About three meters east of the above mentioned profile, very deep soil was formed in the 147 cm deep fissure in dolomite (Table 1, Profile 3). (Fig.2, I). Profile morphology of the upper part is similar to that of the neighbouring profile (Profile 2). The Ah horizon reaches down to 87 cm, Here as well, it is divided into the upper Ah1 subhorizon which reaches down to the depth of 20 cm, its texture is silty clay loam with 20.7% of clay and 9.14% of organic matter. The lower Ah2 subhorizon lies at a depth between 20 and 87 cm, its texture, too, is silty clay loam with 21.3% of clay and 3.05% of organic matter. As to the reaction and share of free $CaCO_3$, only slight differences occur between the two subhorizons.

Under the Ah horizon, reddish clay lies which reaches down to the bottom of the fissure. The horizon of this clay could be defined as (B)rz, since this is the transformed insoluble residue of dolomite weathering. As to the texture of this horizon, it is clay with about 60% of clay; it contains only little organic matter and no free $CaCO_3$; its reaction is neutral.

Similar profile morphology is found with soil lying east and west of the two profiles described above. The clay horizon in one of the fissures which is 3 m deep and 2 m wide, contains 57.7% of clay, thus resembling greatly, so in this characteristic as well as in others, the (B)rz horizon in the profile 3. Peds in it are angular blocky and they have dark coats.

The shallower soil at the foot of the slope which passes over to the bottom of the polje (Table 1, Profile 4) consists of 30 cm deep Ah horizon that lies on the dolomite parent material. (Fig. 2,II). This horizon is of dark reddish colour (5 YR 3/2), abundant in roots, of crumb structure, sandy clay texture with 28.4% of clay - similar to the shallow soil on the higher southwest border of the polje. There is about 5% of organic matter in this horizon and a little more than one per cent of free $CaCO_3$; its reaction is neutral.

An interesting phenomenon has been discovered in this profile: about a 20 cm thick layer of yellowish clay (65.1% of clay) occurs at a depth of about 80 cm under the dolomite, and further down, below it, dolomite parent material is found again. This clay layer is about 1 m long and lies already out of soil forming process; it does not contain organic matter and almost no $CaCO_3$, and its reaction is neutral (pH 6.91).

Two meters from the profile 4, on the slope away from the bottom of the polje, there lies deep soil in a 180 cm deep fissure (Table 1, Profile 5). (Fig. 2, II). The profile consists of a 30 cm thick Ah horizon, in the same way as in the profile 4. The texture is clay loam with 29.6% of clay and 5.36% of organic matter; its reaction is neutral and there is about 1% of free calcium carbonate. Below it, the reddish orange (10 YR 5/6) horizon lies, with a large share of clay (53.7%) almost without organic matter and free $CaCO_3$; its reaction is neutral. This horizon can be defined as (B)rz. Peds are angular blocky.

The slope with interchanging shallow soils and deep soils in fissures slants down to the bottom of the polje. The dolomite bedrock on the bottom lies, for the greater part, more than 1 m below the surface. Thus, deep soils prevail on the bottom of the polje. Besides the depth, profile morphology is also characteristic of these soils. The profile mainly consists of three horizons. Typical characteristics of these soils are seen in profile 7 (Table 1, Profile 7). (Fig. 3, III).

The profile consists of the light Ah horizon which abounds in roots, it is of dark reddish brown colour, 30 cm deep, and has silty loam texture with 24.8% of clay; it contains about 5% of organic matter and very little free $CaCO_3$; its reaction is neutral.

Below it, there lies a black brown horizon which reaches down to 100 cm; it is of clay texture with an even larger share of clay than the upper horizon (34.8%), smaller share of organic matter (2.85%), and about 1% of free $CaCO_3$; its reaction is neutral. Individual peds also occur in it. This horizon lies on a reddish brown horizon of clay texture with the largest share of clay (48%) in the entire profile. It still contains a little bit of organic matter (1.34%), but no free $CaCO_3$; pH 6.68.

Below the humose A horizon of the soils, and also in other parts of the bottom of the polje, there is a clay loam horizon which mainly lies on the reddish clay horizon. The latter everywhere contains a large share of clay (48-76%).

A comparison between the characteristics of the soils on the borders of the polje and those on its bottom shows that they were formed and developed in different soil forming processes. The differences are evident in their thickness and profile morphology. Shallow soils occur on the border parts with the A-C or A-AC-C profiles, and can be ranked among rendzinas which were formed on the dolomite parent material where weathered dolomite had mixed with organic matter which resulted in the humose horizon. Rendzina interchanges with deep soil in fissures, that can be ranked among chromic cambisols with the A-(B)rz-C profile. Stritar (1990) calls them 'fissure-filling chromic cambisols'. A more detailed definition has to be postponed until thorough pedologic investigations, being performed by pedologists within the scope of elaborating a pedologic map on the scale of 1:50000, have been finished for this area, which has not been the case so far.

Soils which can be found on the north border of the polje below Rakek settlement differ from rendzinas and chromic cambisols, especially in profile morphology. They consist of a rather deep humose horizon which is divided into two parts by several characteristics. This thick upper horizon can lie directly on dolomite. Under a fissure, there lies a reddish insoluble clay residue of dolomite weathering. To a certain extent (as to texture) the lower part of the A horizon resembles the second horizon in the soils on the bottom of the polje. Yet, it is difficult to define it more distinctly without detailed pedologic investigations. Possibly, it could be the result of human activities, i.e. the growing of cultivated plants here, in the vicinity of the settlement. It could also be formed in a natural process of transporting and depositing tiny soil particles on the slope.

Soils on the bottom of the polje differ from those in the border parts by their greater depth and the profile which is mainly composed of three horizons. (Fig. 2, III). There are no distinctive and deep fissures on the bottom of the polje. Investigations of soils (Lovrenčak, 1989) and deposits on the bottom of the RUP (Čadež, 1954) have shown that the tectonically broken dolomite bedrock is covered with a more or less thick layer of reddish clay. It occurs at different depths. At the border parts of the bottom of the polje on the southeast and north sides, as well as in one part of the south side, it is 20-90 cm deep. In the central part of the bottom, on the west side, on both sides of the road between Unec and Rakek, it lies at the depth of 100-120 cm. Deeper down, reddish clay occurs in the east part of the bottom, i.e. on the site where clay was dug for the former brick factory (280 cm deep). It is even 400 cm deep near the clay pit. The deepest (500 cm) is the reddish clay near Slivice (Čadež, 1954).

The reddish clay horizon in the lower part of the profile has also been discovered in soils on dolomite and limestone elsewhere in Slovenia. Gregorič (1969) states that the (B) horizon of reddish brown soils (shallow to medium deep) on Triassic dolomite contains 25.2-60.2% of clay, and the B horizon of leached reddish brown soils contains from 37.4% to 43.9% of clay. Sušin (1968) also discovered similar proportions of clay in terra rossa on limestone in the lower part of the profile, e.g. in the B horizon of ilovka (medium leached terra rossa) there is 51.6-80% of clay. Stepančič (1975) states that luvo chromic cambisols on reddish brown clay on dolomite at Stehovec in Dolenjsko, north of Žalna, contain 67.3% of clay in the B1t horizon and 91.7% of clay in B2t horizon. Both horizons are of reddish brown colour. If compared to the proportion of clay in the horizon at the bottom of the RUP where it amounts to 48-77.6%, this percentage resembles the one in ilovka on limestone and the one in the soil on dolomite at Stehovec. In this connection a question occurs about the origin of this clay, as well as the question of how to define systematically the soils on the bottom of the polje.

Reddish clay particles are a transformed insoluble residue of dolomite weathering. They can be autochthonous or allochthonous particles in soil. Gregorič (1969) came to the conclusion that deep leached soils are partly autochthonous and partly allochthonous. They were formed on the wide bottom of the Šmarska dolina valley near Grosuplje and on the levelled ridges which slope gently southwards. Precipitation water transported clay particles from higher areas.

Considering the fact that the RUP is also the bottom of a karst depression, it is supposed that clay particles here could also have been transported from border parts where clay horizons occur in fissures. The conclusion (Lovrenčak, 1989) that the reddish clay (B)rz horizon is autochthonous can only remain a hypothesis. The idea of allochthonous origin of clay is also supported by the conclusion by Čadež (1954); she states that this clay belongs to a group of separate deposits covering the dolomite parent material.

The answer to the question about systematic ranking of soils on the bottom of the RUP can also be just a hypothesis for now. As to their physical and chemical characteristics, they could be ranked among chromic cambisols. While investigating chromic cambisols on dolomite in Dolenjsko, Stepančič (1975) discovered three soil system units:

- luvo chromic cambisols on reddish brown clay;
- acro chromic luvisols with complex profile;
- acro chromic luvisols on silty loam.

It is typical of all units that the profile consists of two strata: the stratum of reddish brown clay lying immediately on dolomite and the stratum of yellowish brown silty clay loam of various depths covering the reddish brown clay.

If soils from the bottom of the RUP are compared with these units it becomes evident that the former also consist of two strata; the lower one of reddish clay and the upper one of brown clay loam. The texture of the lower part resembles the reddish horizon of the soils on dolomite in Dolenjsko (Table 2).

Table 2: Shares of clay and silt in lower soil horizons

	Clay	Silt
On dolomite in Dolenjsko	50-90%	maximum 30%
On the bottom of the RUP	48-77.6%	22.2-29.1%*

* *There is 41.2% of silt in Profile 7 and 49.1% of silt in Profile 6.*

The upper horizon differs in its texture from the lower. Therefore, we can only partly conclude that also the RUP soils have a bi-stratum profile. Even if physical and chemical characteristics of the soils from the bottom of the RUP are compared with the first type of soil on Stehovec, certain similarities can be observed (e.g. the reaction, the proportion of clay in A horizon). In view of these similarities, soils on the bottom of the RUP can be defined as chromic cambisols. A more detailed systematic ranking can supposedly be defined as leached chromic cambisols which developed on the relict layer of red clay.

CONCLUSION

In the RUP, which is divided into two parts regarding the landforms, i.e. the border part and the bottom of the polje, differences in soils are evident between the two parts. In border parts, two soil types interchange in the soil cover, i.e. rendzina and chromic cambisol which repeatedly occurs in fissures in the dolomite bedrock. On gentle slopes, both types of soils are deeper, and fields also occur there, but for the most part they are overgrown with meadows. On steeper slopes only grass vegetation grows.

On the northern border of the polje, below Rakek, a deeper A horizon occurs in the soil; it is present in both soil types. As an assumption, it is explained as the result of human activities, i.e. land cultivation. The reddish clay (B)rz horizon in chromic cambisols could be autochthonous; it was formed through dolomite weathering.

Deep chromic cambisols are stretched over the bottom of the polje. They are supposed to rank among leached chromic cambisols which might have a bi-stratum profile; such a profile is the result of ancient pedogenesis. There are certain indications that the lower horizon of red clay could be the deposit of fine particles transported from border parts of the polje onto its bottom. The thesis that fine particles were transported from the slopes and deposited on the bottom of the polje is also supported by its rather flat and level bottom. A better defined answer to the question about autochthonous or allochthonous origin of this clay and reddish horizon, as well as of clay loam horizon above, should be given by further investigations of these soils.

Because of the flat bottom and the depth of these soils, they are cultivated on almost the entire bottom. It is the location of the major fields of farmers from Rakek and Unec, who grow corn, wheat, potato, turnip, and fodder plants.

REFERENCES

Čadež N., 1954, Geologija ozemlja med Planinskim in Cerkniškim poljem. Ročne vrtine v nevezanem nanosu Unškega polja. V elaboratu: Vodnogospodarske osnove porečja Ljubljanice. Prirodne osnove. Geologija. Ljubljana.

Gams I., 1972, Prispevek h klimatogeografski delitvi Slovenije. Geografski obzornik 19-1. Ljubljana.

Gams I., 1974, Kras. Ljubljana.

Gregorič V., 1969, Nastanek tal na triadnih dolomitih. Geologija 12. Ljubljana.

Habič P., 1981, Geografska podoba Cerkniške doline in njene okolice. Notranjski listi II, Cerknica.

Lovrenčak F., 1989, Pedogeografske razmere na krasu (na dveh primerih). Pedogeographical characteristics of the karst. Dela 6. Ljubljana.

Pučnik J., 1980, Velika knjiga o vremenu. Ljubljana.

Puncer I., Zupančič M., Wraber M., Petkovšek V., 1967, Vegetacijska karta Postojna 1:100 000. Vegetation- Messtischblatt Postojna L 33-77. Ljubljana

Stepančič D., 1975, Pokarbonatna tla na dolenjskem dolomitnem področju.

Stepančič D., Ažnik M., 1977, Rendzina v Sloveniji. Rendzina soils in Slovenia. Zbornik Bitf univerze v Ljubljani. Kmetijstvo, 28. Ljubljana.

Stritar A., 1991. Landscapes, Landscape systems: Soil use and conservation in Slovenia, Ljubljana

Sušin J., 1968, Terra rossa v Slovenskem primorju. Zbornik Biotehniške fakultete, 15-A, Ljubljana

Standard Soil Color Chart. Tokyo 1965.

PEDOGEOGRAFSKE ZNAČILNOSTI RAKOVSKO-UNŠKEGA POLJA

Povzetek

Rakovško-Unško polje lahko reliefno delimo na dva dela: robni del in dno polja. Na vsakem od teh delov se kažejo razlike v lastnostih prsti. Na robnih delih se v odeji prsti prepletata dva tipa prsti: rendzina in rjava pokarbonatna prst, ki se često nahaja v žepih v dolomitni matični osnovi. Tako prepletanje obeh tipov prsti je opazno tudi na kraškem površju, vzhodno od Rakeka, v podolju proti Cerknici. Na položnejšem površju sta oba tipa prsti globlja in so na njih njive, večinoma pa ju porasčajo travniki. Na strmejših pobočjih ju porašča le travniška vegetacija.

Na severnem robu polja pod Rakekom se v prsti pojavlja globlji A horizont, ki se nahaja v obeh tipičnih prsteh. Domnevno ga razlagamo z delovanejm človeka, kot posledica obdelovanja. Rdečkast glinast (B)rz horizont

v rjavih pokarbonatnih prsteh naj bi bil avtohton, nastal s preperevanjem dolomita.

Na dnu polja se razprostirajo globoke rjave pokarbonatne prsti. Domnevno jih uvrščamo med izprane rjave pokarbontane prsti, ki imajo verjetno dvoslojen profil, ki je razultat policikličnega pedogenetskega razvoja starejše pedogeneze. Za spodnji horizont rdeče gline nekateri znaki kažejo, da bi bil lahko nanos drobnih delcev iz robnih delov polja na njegovo dno. Tezo o nanosu drobno zrnatih delcev iz pobočij na dno polja lahko podpremo tudi z reliefno oblikovanostjo. Dokaj plosko in ravno dno polja kaže na to, da je nastalo s sedimentacijo.

Primerjava prsti na dnu Rakovsko-Unškega polja s prstmi na dolomitu na Dolenjskem pokaže, da je spodnji horizont prsti na dnu polja po teksturi podoben rdečkastemu horizontu v prsteh na Dolenjskem. To kaže na sorodno pedogenezo.

	glina	melj
Na dolomitu Dolenjske(Stepančič, 1975)	50-90%	največ 30%
Na dnu Rakovsko-Unškega polja	48-77,6%	22,2-29,1%*

* v 7. profilu je 41,2% in v 6. profilu 49,1% melja

Bolj jasen odgovor na vprašanja o avtohtonosti ali alohtonosti glinastega in rdečkastega horizonta ter tudi ilovnato glinastega horizonta nad njim naj bi dala nadaljna proučevanja teh prsti.

Zaradi ravnega dna in globine teh prsti so skoraj na celotnem dnu obdelane. Tu so poglavitne njivske površine kmetovalcev iz Rakeka in Unca, ki pridelujejo koruzo, krompir, repo in krmne rastline.

PALEOORNITHOLOGICAL REMAINS FROM SOME OF THE CAVES IN SLOVENIA

PALEOORNITOLOŠKI OSTANKI IZ NEKATERIH JAM V SLOVENIJI

VESNA MALEZ

Izvleček UDK 568.4:551.442(497.12)

Vesna Malez: Paleoornitološki ostanki iz nekaterih jam v Sloveniji

Članek podaja rezultate novih paleoornitoloških raziskav iz petih slovenskih jam (Babja jama, Ciganska jama, Jama pod Herkovimi pečmi, Lukenjska jama, Župánov spodmol). Določenih je bilo 8 družin, 13 rodov in 14 vrst (med temi jih je 5 pokazateljev hladnejše klime). Lovski plen pripada družinam *Anatidae, Tetraonidae* in *Otididae.*

Ključne besede: paleontologija, *Aves,* paleolitik, Slovenija

Abstract UDC 568.4:551.442(497.12)

Vesna Malez: Paleoornithological remains from some of the caves in Slovenia

Results of paleoornithological investigations from five caves of Slovenia (Babja jama, Ciganska jama, Jama pod Herkovimi pečmi, Lukenjska jama, Župánov spodmol) are given in the paper. 8 families, 13 genera and 14 species were determined. Five of them are indicators of colder climate. The hunting birds belong to families *Anatidae, Tetraonidae* and *Otididae.*

Key words: paleonthology, cave fauna, *Aves,* palaeolithic, Slovenia

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Slovenia is rich in cave localities in which the Pleistocene and Holocene deposits have been researched. Abundant osteological material has been collected and numerous animal assemblages have been determined, as well as several avifaunal species. Up to now some of the avifaunal material has been taxonomically determined from the Paleolithic localities: Betalov spodmol near Postojna (Rakovec, 1959) - 6 species; Potočka zijalka on Olševa (Brodar & Brodar, 1983) - 1 species; Roška špilja near Divača (Škocjan) - 10 species; and Divje babe I in the Idrijca valley - 8 species. From the Neolithic locality Ajdovska jama near Nemška vas (Krško area) - 5 bird species have been determined (Malez, in press).

Previous determinations of the Pleistocene ornithological material show that 21 bird species inhabited the mentioned caves. Now, five more sites join the Paleolithic localities with their avifaunal osteological material and new bird species (Table I.).

In Babja jama near Dob, in the neighbourhood of Domžale, beside numerous animal bones (Pohar, 1985) some avifaunal material has been collected. Skeletal bird remains belong to the whooper swan (Cygnus cygnus), willow grouse *(Lagopus lagopus)* and blackbird *(Turdus merula)*.

From the Ciganska jama near Željne (Kočevje) two species of the same genus have been determined, which belong to the family Tetraonidae, and they are willow grouse and ptarmigan *(Lagopus lagopus* and *Lagopus mutus)* (Pohar, 1992).

All ornithological remains from the Jama pod Herkovimi pečmi near Radlje ob Dravi (Pohar, 1981) belong to the family Tetraonidae, and they are willow grouse *(Lagopus lagopus)*, ptarmigan *(Lagopus mutus)*, capercailzie *(Tetrao urogallus)* and black grouse *(Lyrurus tetrix)*.

Six bird bones from the Lukenjska jama near Novo mesto (Pohar, 1983) belong to different families: Anatidae - mallard *(Anas platyrhynchos)*, Accipitridae - golden eagle *(Aquila chrysaetos)*, Falconidae - hobby *(Falco subbuteo)*, Tetraonidae - willow grouse *(Lagopus lagopus)*, Laniidae - great grey shrike *(Lanius excubitor)* and Corvidae - raven *(Corvus corax)*.

Somewhat more abundant bird skeletal remins (12 bones) were excavated from the C and D layers of the Paleolithic locality Županov spodmol near Sajevče (Postojna) (Brodar & Osole, 1979). The ornithological remains are represented by five species: ptarmigan *(Lagopus mutus)*, black grouse *(Lyrurus tetrix)*, common partridge *(Perdix perdix)*, great bustard *(Otis tarda)* and red-

FAMILIES, GENERA, SPECIES	LOCALITY				
	BABJA JAMA	CIGANSKA JAMA	JAMA POD HERKOVIMI PEČMI	LUKENJSKA JAMA	ŽUPANOV SPODMOL
ANATIDAE					
CYGNUS CYGNUS	■				
ANAS PLATYRHYNCHOS				■	
ACCIPITRIDAE					
AQUILA CHYSAETOS				■	
FALCONIDAE					
FALCO SUBBUTEO				■	
TETRAONIDAE					
LAGOPUS LAGOPUS	■	■	■	■	
LAGOPUS MUTUS		■	■		■
TETRAO UROGALLUS			■		
LYRURUS TETRIX			■		■
PERDIX PERDIX					■
OTIDIDAE					
OTIS TARDA					■
TURDIDAE					
TURDUS MERULA	■				
LANIIDIDAE					
LANIUS EXCUBITOR				■	
CORVIDAE					
PYRRHOCORAX PYRRHOCORAX					■
CORVUS CORAX				■	

Table 1.

FAMILIES, GENERA, SPECIES	BIOTOPES					RECENT CLIMATIC ZONES					PREY OF HUNTERS
	WATER MEDIUM	OPEN AREAS	REGION OF WOOD	ROCKY AREAS	MIXED BIOTOPE	TUNDRA	BOREAL ZONE	HIGH MONTAIN/ ALPINE ZONE	STEPPE	MODERATE ZONE	
ANATIDAE											
CYGNUS CYGNUS	■						●				▲
ANAS PLATYRHYNCHOS	■					●					▲
ACCIPITRIDAE											
AQILA CHRYSAETOS				■						●	
FALCONIDAE											
FALCO SUBBUTEO			■							●	
TETRAONIDAE											
LAGOPUS LAGOPUS		■				●	●				▲
LAGOPUS MUTUS				■				●			▲
TETRAO UROGALLUS			■							●	▲
LYRURUS TETRIX			■							●	▲
PERDIX PERDIX		■								●	▲
OTIDIDAE											
OTIS TARDA		■							●		▲
TURDIDAE											
TURDUS MERULA					■					●	
LANIIDAE											
LANIUS EXCBITOR					■					●	
CORVIDAE											
PYRRHOCORAX PYRRHOCORAX				■				●			
CORVUS CORAX				■						●	

Table 2.

billed chough *(Pyrrhocorax pyrrhocorax)*, and they belong to three families - Tetraonidae, Otididae and Corvidae.

Some bird species show the existence of the different ecological niches in the Paleolithic. The majority of the caves are surrounded by different biotopes (water medium-environment - rivers, ponds, swamps; opern areas - grassy slopes, lowlands and glades; forests - decidious trees and coniferous; rocky areas) (Table II.). Thus, the nearness of the water biotope suggest two bird species: whooper swan *(Cygnus cygnus)* and mallard *(Anas platyrhynchos)*. The open environment (meadows, glades, etc.) were inhabited by willow grouse *(Lagopus lagopus)*, common partridge *(Perdix perdix)* and great bustard *(Otis tarda)*. The characteristic forest biotope suggest three bird species: capercailzie *(Tetrao urogallus)*, black grouse *(Lyrurus tetrix)* and hobby *(Falco subbuteo)*. Four birds show the existence of the rocky areas in the neighbourhood of the cave, and they are: golden eagle *(Aquila chrysaetos)*, ptarmigan *(Lagopus mutus)*, red-billed chough *(Pyrrhocorax pyrrhocorax)* and raven *(Corvus corax)*. The birds which are not strictly connected to a particular biotope or often inhabite the border zones between two biotopes (forest - meadow, rocks - forest) are: blackbird *(Turdus merual)* and great grey shrike *(Lanius excubitor)*.

Single bird species are significant climate indicators, which show the climate changes during the sedimentation of the Paleolithic depostis (Table II.). Thus, some birds are representatives of the cold climatic areas - tundra, and boreal climate, and high-alpine climate. Although rare, these cold-climate representatives are very significant, and they are: whooper swan *(Cygnus*

Cygnus cygnus (Linné)	- Whooper swan - žutokljuni labud
Anas platyrhynchos (Linné)	- Mallard - divlja patka
Aquila chrysaetos (Linné)	- Golden eagle - suri orao
Falco subbuteo (Linné)	- Hobby - soko grlaš
Lagopus lagopus (Linné)	- Willow grouse - močvarna snježna jarebica
Lagopus mutus (Montin)	- Ptarmigan - alpska snježna jarebica
Tetrao urogallus (Linné)	- Capercailzie - veliki tetrijeb
Lyrurus tetrix (Linné)	- Black grouse - mali tetrijeb
Perdix perdix (Linné)	- Common partridge - trčka
Otis tarda (Linné)	- Great bustard - veliki potrk
Turdus merula (Linné)	- Blackbird - crni kos
Lanius excubitor (Linné)	- Great grey shrike - veliki svračak
Pyrrhocorax pyrrhocorax (Linné)	- Red-billed chough
Corvus corax (Linné)	- Raven - gavran

Table 3. Descriptions of species, authors, English and Croate names of birds.

cygnus), mallard *(Anas platyrhynchos)*, willow grouse *(Lagopus lagopus)*, ptarmigan *(Lagopus mutus)* and red-billed chough *(Pyrrhocorax pyrrhocorax)*. The only representative of the steppe climate zone is great bustard *(Otis tarda)*. The most numerous bird species (8) suggest the temperate climate: golden eagle *(Aquila chrysaetos)*, hobby *(Falco subbuteo)*, capercailzie *(Tetrao urogallus)*, black grouse *(Lyrurus tetrix)*, common partridge *(Perdix perdix)*, blackbird *(Turdus merula)*, great grey shrike *(Lanius excubitor)* and raven *(Corvus corax)*.

Particular bird species had great importance in the Paleolithic inhabitant diet (Table II.). This could be seen from the relative number of the skeletal remains of the so-called hunting birds, which are represented by eight species: whooper swan *(Cygnus cygnus)*, mallard *(Anas platyrhynchos)*, willow grouse *(Lagopus lagopus)*, ptarmigan *(Lagopus mutus)*, capercailzie *(Tetrao urogallus)*, black grouse *(Lyrurus tetrix)*, common partridge *(Perdix perdix)* and great bustard *(Otis tarda)*.

At the end it can be concluded that the determination of the bird skeletal remains from five Slovenian Paleolithic localities gives the following results:

- 8 families, with 13 genera and 14 species have been determined;
- all ecosystems are represented with almost equal numbers of the bird species;
- the important indicators of the colder climatic conditions are represented with 5 species;
- the hunting birds belong to three families: *Anatidae, Tetraonidae* and *Otididae.*

BIBLIOGRAPHY

Brodar, S. & Brodar, M., 1983: Potočka zijalka visokoalpska postaja aurignacienskih lovcev.- Dela SAZU, 24/13, 1-213, Ljubljana.

Brodar, M. & Osole, F., 1979: Nalazišta paleolitskog i mezolitskog doba u Sloveniji.- Praistorija, I, 135-157, Sarajevo.

Malez, V., (in press): Fosilni avifaunski ostaci iz nekih spilja Slovenije.- 19 Mednarodna razstava mineralov in fosilov, 1991, Velenje.

Pohar, V., 1981: Pleistocenska favna iz Jame pod Herkovimi pečmi.- Geologija, 24/2, 241-284, Ljubljana.

Pohar, V., 1983: Poznoglacialna favna iz Lukenjske jame.- Geologija, 26, 71-107, Ljubljana.

Pohar, V., 1985: Kvartarni sesalci iz Babje jame pri Dobu.- Razprave IV. razreda SAZU, XXVI, Zbornik Ivana Rakovca, 97-130, Ljubljana.

Pohar, V., 1992: Mlajšewürmska favna iz Ciganske jame pri Željnah (Kočevje, južnovzhodna Slovenija).- Razprave IV. razreda SAZU, XXXIII, 147-187, Ljubljana.

Rakovec, I., 1959: Kvartarna sesalska favna iz Betalovega spodmola pri Postojni.- Razprave IV. razreda SAZU, V, 289-348, Ljubljana.

PALEOORNITOLOŠKI OSTANKI IZ NEKATERIH JAM V SLOVENIJI

Povzetek

V članku so prikazani rezultati novih paleoornitoloških raziskav iz petih slovenskih jam - paleolitskih postaj: Babje jame, Ciganske jame, Jame pod Herkovimi pečmi, Lukenjske jame in Županovega spodmola. Do sedaj so bili iz Slovenije znani ptičji ostanki iz 4 paleolitskih postaj, in sicer vsega skupaj 21 vrst. Z novimi raziskavami je bilo določenih 8 družin, 13 rodov in 14 vrst. Med njimi jih je 5 pokazateljev hladnejše klime, enakomerno pa so zastopani predstavniki vseh ekosistemov. Lovski plen pripada družinam *Anatidae, Tetraonidae* in *Otididae.*

CAVES AS MASS-GRAVEYARDS IN SLOVENIA

MNOŽIČNA GROBIŠČA V JAMAH V SLOVENIJI

ANDREJ MIHEVC

Izvleček UDK 551.442:940.540.56(497.12)

Andrej Mihevc.: Množična grobišča v jamah v Sloveniji

Gverilsko vojskovanje ter revolucija je na kraškem delu Slovenije v času od 1941 do 1945 spremenila v masovna grobišča za vojaške in politične nasprotnike večje število brezen. Po podatkih iz katastra jam so bili človeški ostanki opaženi v 71 jamah, dejansko število jam uporabljanih v ta namen pa verjetno presega število 100. Točno število oseb, ki so bili vržene v jame ni znano, verjetno pa preko 10 000. Večina žrtev likvidacij je bila vržena v okrog 10 brezen.
Uporaba brezen za masovna grobišča, predvsem pa še kasnejša zakrivanja sledov so v veliki meri spremenili fiziognomijo številnih vhodnih delov teh jam. Nekatera brezna so bila povsem zasuta ali razstreljena in so tako postala nedostopna.

Ključne besede: raba jam, brezno, človeški ostanki, masovno grobišče, likvidacija, 1945, zasipanje jam, dinarski kras, Slovenija

Abstract UDC 551.442:940.540.56(497.12)

Andrej Mihevc: Caves as Mass-graveyards in Slovenia

From 1941 to 1945 the guerrilla fighting and revolution changed a considerable number of shafts in the karst areas of Slovenia to mass-graveyards for military and political opponents.
According to data from the Cave Register the human remains were registered in 71 caves, but the real number probably exceeds 100 caves. The exact number of people thrown into the shafts is not known, it may be more than 10.000 persons. Most of the terror victims were thrown into about 10 shafts.
The use of caves for such a purpose and in particular later camouflaging of the traces considerably changed the physiognomy of numerous entrance parts of the shafts. Some of them were completely filled up or even blown up and thus became inaccessible.

Key words: cave use, pothole, human remains, mass graveyard, liquidation, 1945, cave filling, Dinaric karst, Slovenia

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INTRODUCTION

One of the consequences of the political changes in Slovenia is also the possibility to discuss since now forbidden subjects. One of such taboos in past 50 years was the use of shafts for mass-graveyards for military and political opponents that were liquidated without trial. The phenomenon is documented by rich memoirs of mostly emigrant literature, but there are no official sources or data. The phenomenon is burdened by political content and by question of responsibility and this makes studies difficult.

From speleological point of view we are mostly interested in number of caves used for this purpose, number of victims in them and how the traces of massacres were disguised.

The data presented in this paper are uncomplete and thus this report may be preliminary only. I was mostly based on the Cave Register and my own observations.

HISTORICAL BACKGROUND

To understand the phenomenon we must shortly introduce the events in Slovenia during 1941 to 1945. The actual Slovene territory belonged to the Monarchy of Yugoslavia and its western part to Italy. In spring 1941 it was occupied by Germany and Italy and on these areas the resistence against the aggressors started. At first heterogeneous political movements have taken part. The Communist Party prevailed, it started with revolution and at the end gained the victory.

In the first years of the war the caves were chosen to conceal the liquidation of war prisoners and civil opponents. However, the use culminated at the end of the war, between May and August 1945 when several ten thousands of refugees (Tolstoy 1986) were returned from the British occupation zone to Yugoslavia. A part of these people was liquidated and thrown into the caves of karst Kočevski Rog (Ižanec 1965; Kovač 1968).

Similar events may be traced in other parts of former Yugoslavia, on the Dinaric karst of Croatia, Bosnia and Hercegovina and in Montenegro (Božičević 1991; Žanko & Šolić 1990).

DATA ON CAVES-GRAVEYARDS

The first written information about throwing the people into the caves appeared already during the war. The book In the Sign of the Liberation Front, printed in Ljubljana in 1943 mentions several caves supposed to contain dead human bodies; the cave Krimska Jama (Cad. no. 293) where several dead bodies were seen during the visit is described also.

In the literature of the political emigrants numerous caves are cited. Ižanec (1965, 1970, 1971) mentions 17 shafts into which the people were thrown. In some of them, for example in Repičnikova Jama (Cad. no.3071), in Krimska Jama (Cad. no. 293), and in Koševniško Brezno (Cad. no. 589) the bones may be seen still today. Some shafts, for example Kozlovka and Brezarjevo Brezno are filled up by rubbish, the others cannot be identified due to either inaccurate location or name.

Several caves are named by Karapandzich (180), for example Kaserova Jama (Cad. no. 4264) and a cave near Skadanščina. In the first one the bones confirmed his statements, the second cave was not identified.

The exact number of people that died in the caves is not known. Various authors give different numbers; the book Vetrinjska tragedija (page 79) gives number 14.000 victims for the caves on Kočevski Rog. For other karst areas and caves in Slovenia there are not even approximative estimations.

In last few years this phenomenon was a frequent subject of writing in newspapers and periodical magazines.

THE DATA FROM THE CAVE REGISTER

In reviewing the Cave Register that contains 6280 caves we found the mention of recent human bones in the records of 71 caves. The number of caves containing bones is probably much greater, as I have seen myself the bones in 6 caves that are registered, the bones are known, but there is no mention of them in the records. Each year new caves with bones are discovered.

At several caves there is in the Cave Register a suspicion mentioned that the cave is a "burial-ground" but the bones are not visible in them. In such cases the data may be wrong, maybe the bones are covered by deposits or even removed. Such caves we considered as the graveyards only when the source was reliable enough, or when we have several different sources, or when there are traces at the caves indicating unusual activites that have taken place.

Such case is for example Brezarjevo Brezno (Cad. no. 415). The record about the visit mentions rubbish in the cave and traces of blasting at the entrance. Kovač (1968, 70) quotes that 1000 people were thrown into this cave, the entrance was later blown up and covered by concrete plate. Because of pollution of the nearby karst spring the dead bodies were shortly afterwards drawn out and transported elsewhere.

Similar cases are Šemonovo Brezno (Cad. no. 192) and Dvojno Brezno (Cad. no. 5668); regarding the first cave one may conclude, comparing the before and after-war records that on the bottom of the shaft some 10 m^3 of allochthonous gravel are accumulated. The bottom of the second shaft is covered by gravel due to blasting at the shaft's entrance.

In most cases the bones are found in shafts, but there are three examples that the bones are found in horizontal caves. In such a case the people were obviously hidden in the caves and died there. In one case the described human remains, according to the uniform remains, belong to an Italian soldier from the First World War.

The number of skeletons seen in the caves is usually not precisely defined in the records, usually there is written under "Remark" very generally "human bones". In some cases only one may conclude on the base of preserved characteristical parts of the skeletons which is the minimal number of persons that were thrown into the cave. Sometimes, when the number is small enough the number of victims can be absolutely precise. In 15 cases it is cited that in the cave there are many bones, in a sense, that there were many persons thrown in. Many uncovered bones are still visible in the cave Zalesnika (Cad. no. 3386) on Trnovski Gozd.

Not only human remains but also parts of clothes or shoes are found in the caves and they provide partial identification. In several cases the persons were German soldiers. The identification is easier because of quality and discernible cloth of German military uniform. In two caves the identification numbers of German soldiers were found, in Kaserova Jama the military plate 2/BAU. 11 B 563 and in Jama na Koševcu (Cad. no. 332) two plates labelled 1.J ERS BH 45 5278 0 and 1.Scstz.Ers.Komp Inf.ERS. Bfl.192 355 A.

Frequent are the reports about recent accumulations of various material over the bones, about rubbish in such caves and about traces of blasting at the entrances.

There are 7 reports about blasting at the entrance part of the caves in the Cave Register. The blasting had dual purpose. The first one was to kill the survived people in the cave and the second one to camouflage the traces. At 9 caves there are beside the bones the remains of unexploded ammunition. At some, at Koševniško Brezno for example, only one part of the entrance was blown up; at Jama pod Krenom (Cad. no. 6158) and at Jama pod Macesnovo Gorico (Cad. no. 6157) the entrances to the caves are completely destroyed and the cave is closed.

More frequent are remarks of buried human remains. In some cases the process is natural, steep debris cones settled, or, sometimes, the covering was deliberate. The cave Jama v Rugarskih klancih (Cad. no. 6161) which is now only 2 m deep was surely filled up as at the wall of the shaft and at the border of the fill the bones and remainders of clothes are still seen.

In 13 caves the bones are partialy covered by rubbish. It is hard to distinguish whether in these cases the covering of the remains was intentional or is it just the "usual" pollution, typical of caves of easy access near the roads and villages. Such examples are Socerbska Jama za Vrhom (Cad. no. 1005) and Jama ob Poti near Jama pod Krenom. Both caves are located far from the sources of dumping.

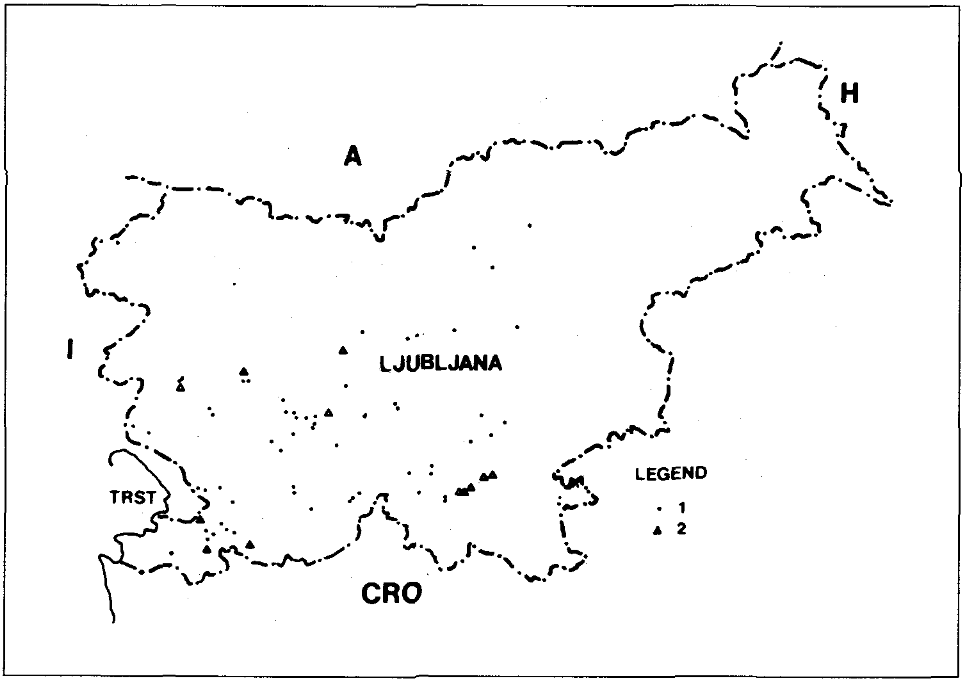

Fig. 1. Location of caves where human remains were found. According to Cave Register of Slovenia
Legend: 1. shafts, containing human remains 2. shafts, mass-graveyards

SOME EXAMPLES OF SHAFTS

As this phenomenon is rather common and there is the possibility that in future the bones will be found in other caves or new cases of such cave-use may appear I quote some typical examples of the ossuaries in the caves.

Brezno v Mrzlih Dolih (Cad. no. 6460) lies in a large beech forest, about 3 km distant from the nearest village Račica. The cave is known to the natives only but they do not know that the bones are in it.

During our visit we found shoes below 40 m deep entrance shaft. After examination we found among the leaves and rocks at the contact of break-down cone and the wall of the entrance chamber two skeletons. Nearby were some remainders of clothes and two rucksacks, with basic necessities of life: spoon, messtin, shaving and sewing outfits and rubber for mending the soles. Different clothes, shoes and rubber soles indicate that the two men were not soldiers of a regular army and not natives either.

Brezno na Koševcu (Cad. no. 332) lies in the middle of a forest some 2 km from Logatec. The entrance is 1,5 m^2 large. The record from before war, from 1934 does not mention any particularity. After the war the rumours appeared that several people were thrown into this cave. The first visitors found out that the bottom of the entrance shaft was covered by skeletons. They notified the police.

Later nobody found the entrance to this cave; it was established that the entrance was covered by timbers and disguised. When the timber rotted, the cover fall into the cave. Our visit evidenced that the sekeletons on the bottom were covered by several cubic metres of allochthonous rocks and rubble, but the skeletons were still visible at the border. Some parts of clothes and remains of civilian shoes, and two identification plates of German soldiers were found.

According to bones at least 8 people were thrown into this cave. Using the identification of soldiers and the time of their disappearance we may find out when the cave was used.

Jama pod Macesnovo Gorico (Cad. no. 6157) lies in the middle of a forest, about 10 km from Kočevje. The shape and the depth of the shaft is not known as the entrance part was blown up and this changed the shaft into depression, 10 m in depth with vertical walls on some places. On them the traces of blasting are still visible. The bottom is entirely covered by under-mined material, more than 10 m^3 in volume.

The location and the shape of the cave probably corresponds to the cave that is quoted in the memoirs of one of the three men that survived and saved himself out of this cave (Ižanec 1971, 191). The wittness cites that the victims were transported by six lorries, each containing 50 people. He himself was wounded and thrown into the cave on June 2, 1945 and escaped from there on June 5, 1945. Shooting and throwing the people lasted for two days and a half. In this time the border of the entrance to the cave was blown up five times. When the blasting started the survivers hid themselves in a lateral passage. During the blasting a tree fall into the cave and by it the witness later escaped. Today the cave is completely filled up and thus the passage where the surviver was hidden is inaccessible; we may infer that the cave was undermined still later. If the quotations are accurate, and the lorries made only three drives per day to this cave, 2250 people ended there.

The witness quotes that the victims in front of the cave must cast away all the objects they had and later take off the clothes. I wanted to check these informations beacuse I was certain that all the objects were not collected; in the nearby doline we excavated a test trench of one square metre. In 15 cm thick superficial layer we found numerous objects that confirm the witness's statement. We found parts of clothes, buttons, belt-buckles, parts of shoes and personal objects as are spoons, pocket-knives, pieces of pocket-mirrors and combs. Also we found pieces of rosaries, occupation, Italian, German and also Serbian, Croatian and Albanian coins evidencing that people of other nations died in the cave also.

The cave was known to the people and they used to visit it in secret. Since 1989 the cave is indicated by road signs and protected by fence.

CONCLUSION

The data from the Cave Register, quotations in literature and other evidences indicate that the use of caves for mass-graveyards was very diffused in the time from 1941 to 1945.

According to data in the Cave Register the human remains were found in 71 caves. The number of victims cannot be ascertained. According to the Cave Register there are 15 caves reported that a lot of people were thrown into.

After estimations in memoir literature there would be more than 10.000 people thrown into the caves but we do not have any official data. The precise number will never be found out as in the caves there are citizens of other nations and countries, for example Serbs, Croats, Albanians and Italians.

Although this phenomenon is spread all over the Slovene karst there are some common properties. On the base of number of victims and in particular in respect to interventions and traces how the "burial" was executed, the caves - mass-graveyards, may be divided into two types.

The caves where there are bones of some persons only, who were thrown dressed into a cave, probably became tombs during the guerilla fighting and revolution or, after the war, due to personal revenge. In these caves nobody disguised the traces later and the bones are found on the surface or they are covered by natural processes. These caves are usually less known and are located in remote woodlands.

The second type of the caves are places of mass execution. The remains of great number of people are usually found. The executions were organized and lasted longer time this is why they could not be kept secret. The disgusing of traces followed, blasting of entrances or filling up the shafts, somewhere even ten years after the war.

Some caves that are known as mass-graveyards became in last time the places visited by relatives of people that disappeared during the war.

REFERENCES

Anonimus, 1943 (XXI): V znamenju Osvobodilne fronte, 1-181, Ljubljana
Arhiv inštituta za raziskovanje krasa, Postojna

Božičevič, S., 1991: Jame (kao)grobnice, 1-79, Zagreb
Ižanec, F., 1965: Odprti grobovi, 1-119 Buenos Aires
Ižanec, F., 1970: Odprti grobovi II , 1-169 Buenos Aires
Ižanec, F., 1970: Odprti grobovi III, 1-263 Buenos Aires
Ižanec, F., 1971: Odprti grobovi III, 1-319 Buenos Aires
Karapandzich, B., 1980: The Bloodiest Yugoslav Spring 1945 - Tito's Katyns and Gulags. A Hearthstone Book, Carlton Press Inc. New York
Kovač, T., 1968: V Rogu ležimo pobiti. 1-95, Buenos Aires
Tolstoj, N., 1986: Celovška zarota. 1-63, Celovec
Zveza slovenskih protikomunističnih borcev 1960: Vetrinjska tragedija 1-160, Cleveland
Žajdela, I., 1990: Kočevski Rog. 1-136, Maribor
Žanko, Ž., N. Šolič, 1990: Jazovka. 1-143, Zagreb

MNOŽIČNA GROBIŠČA V JAMAH V SLOVENIJI

Povzetek

Iz podatkov katastra jam, navedb v literaturi ter drugih pričevanj je moč ugotoviti, da je bil pojav uporabe jam za masovna grobišča v času od 1941 - 1945 zelo razširjen.

Po podatkih katastra jam Slovenije so bili človeški ostanki najdeni v 71 jamah. Števila žrtev se v jamah ne da ugotoviti. Po podatkih katastra je pri 15 jamah navedeno, da je bilo vanje vrženo veliko ljudi.

Po ocenah memoarske literature naj bi bilo v jamah nad 10 000 ljudi, uradnih podatkov pa ni. Točnega števila ne bo moč ugotoviti, saj so v jamah tudi pripadniki drugih narodov in držav, na primer Srbi, Hrvati in Albanci in Italijani.

Kljub razprostranjenosti po praktično celem slovenskem krasu, je moč ugotoviti nekaj skupnih značilnosti tega pojava. Na osnovi števila žrtev, predvsem pa po drugih posegih in sledovih lahko po načinu "pokopa" ločimo jame grobišča na dva tipa.

Jame z ostanki kosti le nekaj oseb, ki so bile v jamo običajno vržene oblečene so postale grobnice verjetno v času gverilskega vojskovanja in revolucije ali povojnih osebnih obračunavanj. V teh jamah kasneje sledov ni nihče več zakrival, zato najdemo kosti na površju ali pa jih prekrivajo naravni procesi. Te jame so običajno manj znane in leže v odmaknjenih gozdnatih predelih.

Drugi tip jam pa so jame masovna morišča. V njih je so običajno ostanki večjega števila ljudi. Poboji pri njih so bili organizirani ter so trajali dlje časa zato jih ni bilo moč obdržati povsem v tajnosti. Sledilo je zakrivanje sledov, miniranje vhodov ali zasipavanje brezen, ponekod še več deset let po vojni.

Nekatere jame, ki so poznane kot masovna grobišča pa so postale v zadnjem času točke, ki jih obiskujejo svojci v vojnem času izginulih ljudi.

DIRECTIONS OF GROUNDWATER FLOW AND POSSIBILITIES OF THEIR CONTAMINATION IN ONE PART OF DOBRA AND KUPA RIVER BASIN.

SMERI PODZEMELJSKIH TOKOV IN MOŽNOSTI NJIHOVEGA ONESNAŽENJA V DELU POREČIJ DOBRE IN KOLPE

DARKO MIHLJEVIĆ

Izvleček UDK 556.38(497.13)

Darko Mihljević: Smeri podzemeljskih tokov in možnosti njihovega onesnaženja v delu poručij Dobre in Kolpe

S pomočjo injiciranja natrijevega fluoresceina v požiralnik s požiralnostjo okoli 50 l/s pri vasi Luke, 3 km južno od Vrbovskega, je avtor želel ugotoviti smer podzemeljskega toka ne le proti izvirom Gojačke Dobre in drugim bližnjim izvirom, ampak tudi proti enako oddaljenim izvirom ob Kolpi. Na podlagi dokazanih in verjetnih podzemeljskih vodnih zvez je moč predvidevati onesnaževanje izvirov, ki so že oziroma ki so potencialni vodni viri.

Ključne besede: hidrologija krasa, podzemeljska vodna zveza, sledenje vode, Hrvaška, Dobra, Kolpa.

Abstract UDC 556.38(497.13)

Darko Mihljević: Directions of groundwater flow and and possibilities of their contamination in one part of Dobra and Kupa river basin

Having put natrium fluorescein into a swallow hole with capacity over 50 l/sec., near the village Luke, 3 kilometers south of Vrbovsko, we would like to determine the direction of underground flow, not only towards the springs of Gojačka Dobra, and other nearby springs, but also towards the equally distant springs near the Kupa river. On the basis of proved and probable underground flow connections we assume a possibility of springs contamination, which have been used or which could be captured for water source menagment.

Key words: karst hydrology, underground water connection, water tracing, Croatia, Dobra river, Kupa river.

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INTRODUCTION

The area of research, in its more specific sense has been limited by the river Kupa, in the north, by the river Dobra of Ogulin towards south-west and south and by the Dobra of Gojak and its tributaries, the brook Bistrac, to the east (Fig.1). As for the relief, it consists of the four morphographic entities: mountain region in the south-west (3 mountain ranges: Klek (1182 m),Smolnik (1219 m) and Crna Kosa (1004 m), of the more or less Dinaric orientation); the river Dobra valley of Ogulin; the central hilly region; and the extensive karst plain in the north-east.

Natrium fluorescein (50 kg) was put into a permanent swallow-hole of Luka with a capacity of 50-100 l/sec, situated about 3 km towards south-east from Vrbovsko, right by the left Dobra shore of Ogulin.

We organized observation spots for the possible outflow of fluorescein at the springs within the immediate Kupa river basin (the spring Jezerce,by the village Ponikve, 210 m above sea-level), at the springs along the Kupa (the captured spring Umolac near Severin, 170 m above sea-level, the spring Prikrajnik, 165 m above sea-level and the Jezerine, 170 m above sea-level in the village Fratrovci, and the spring Potok in Pribanjci),also at the Dobra springs of Gojak (the main spring of the Upper Dobra within the hydro-power plant "Gojak", 190 m above sea-level, the spring Bistrac, 3 km towards north-west from Tounj, 220 m above sea-level and the spring Ribnjak by the village Trosmarija, 210 m above sea-level) (Fig.1).

GEOLOGIC AND HYDROLOGIC RELATIONS

The area under study consists in its major part of Jurassic and Cretaceous carbonate deposits. Only towards the north-west from Vrbovsko we may find clastic and dolomite Triassic deposits in a reverse contact with the clastics of the youngest Paleozoic members. The younger Paleozoic and Triassic deposits, could be considered, due to their lithologic composition and tectonic position, as impervious (Bahun 1968). The Dobra flow of Ogulin is hydrologically very stable in this section, since there are almost no water losses by sinking. From the Paleozoic-Triassic complex of deposits near Vrbovsko, towards the south-east, the Dobra of Ogulin enters into the Dogger limestones and dolomites; however, since they form an anticline limb with a core of impervious Lias

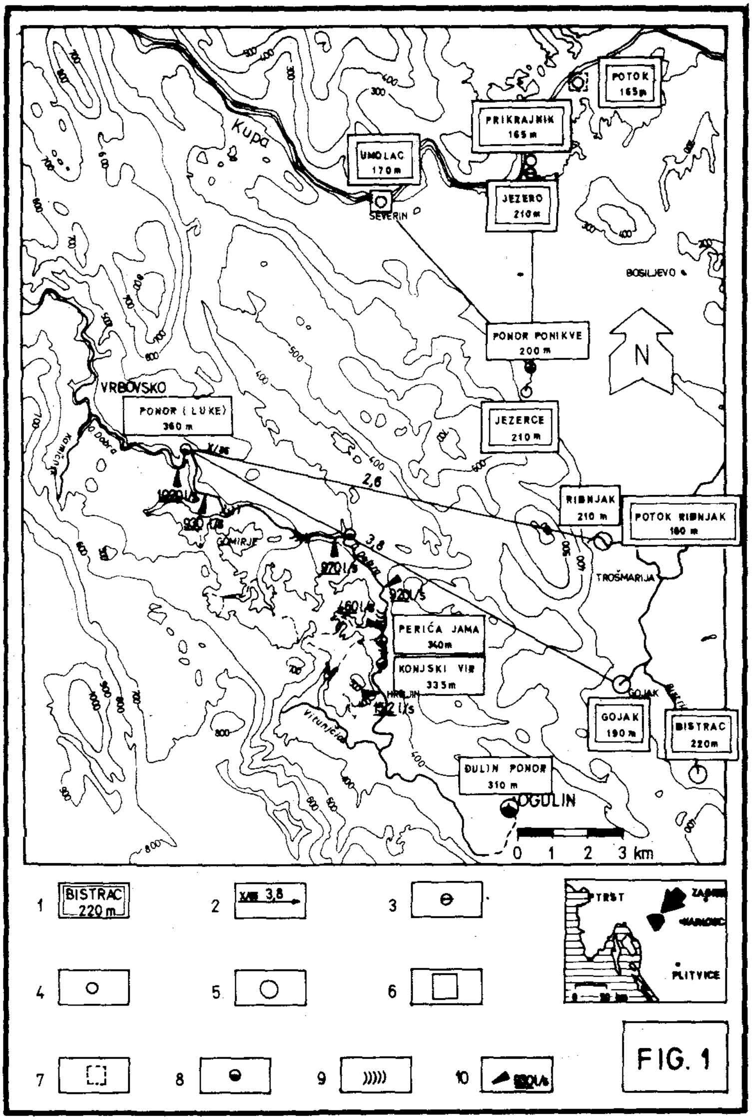

FIGURE 1. Situation map of the area under research

1. Observation place of fluorescein outflow (name and height) 2. Prooved underground water connection with an apparent velocity of underground waterflow and with date of fluorescein drop 3. Occasional spring, medium capacity 1-10 l/s 4. Permanent spring, medium capacity 1-100 l/s 5. Permanent spring, medium capacity 100-1000 l/s 6. Capture for public water supply 7. Simple spring capture 8. Swallow hole 9. Sinking zone 10. Hydrometric profile

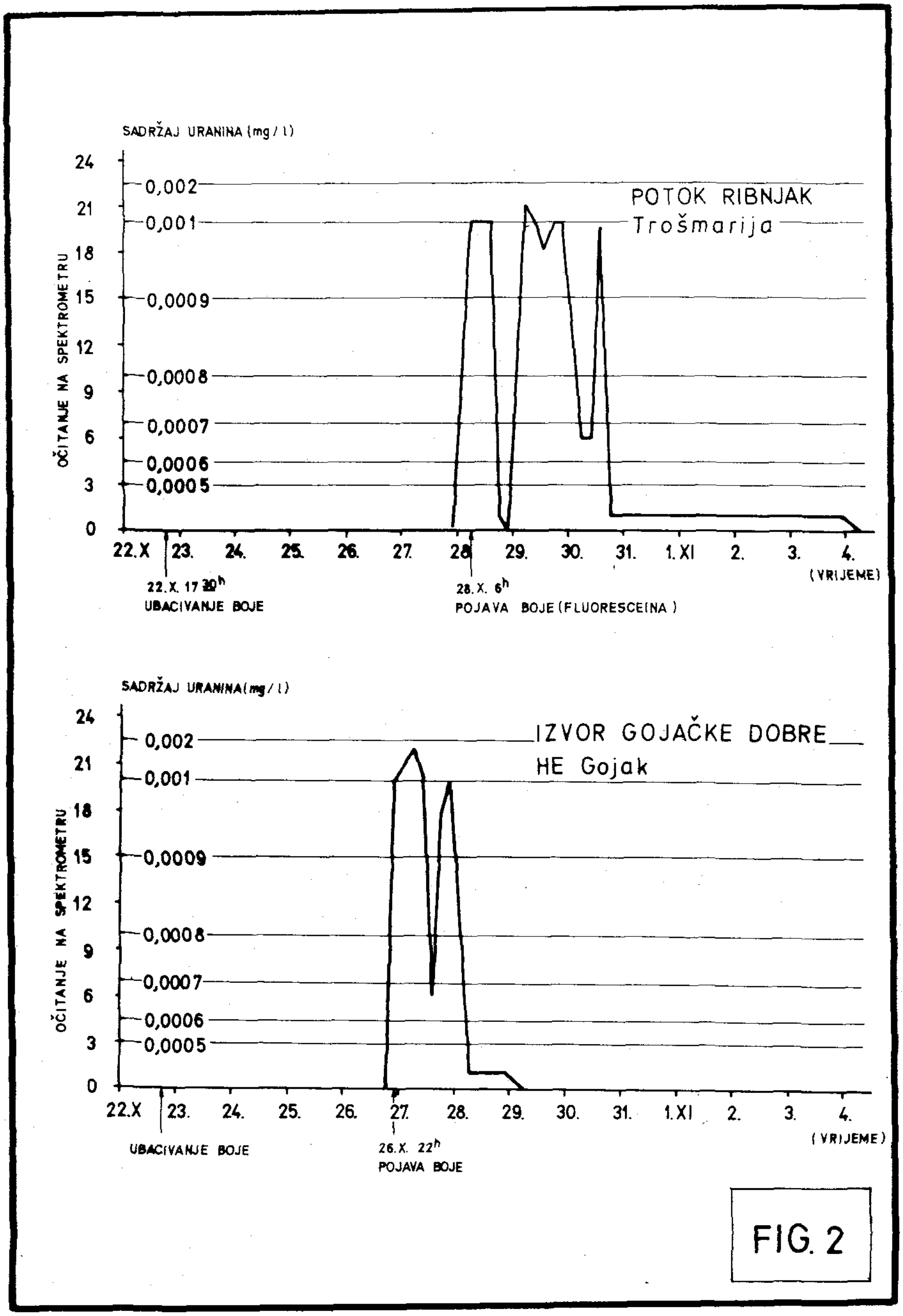

FIGURE 2. Diagram of natrium fluorescein outflow

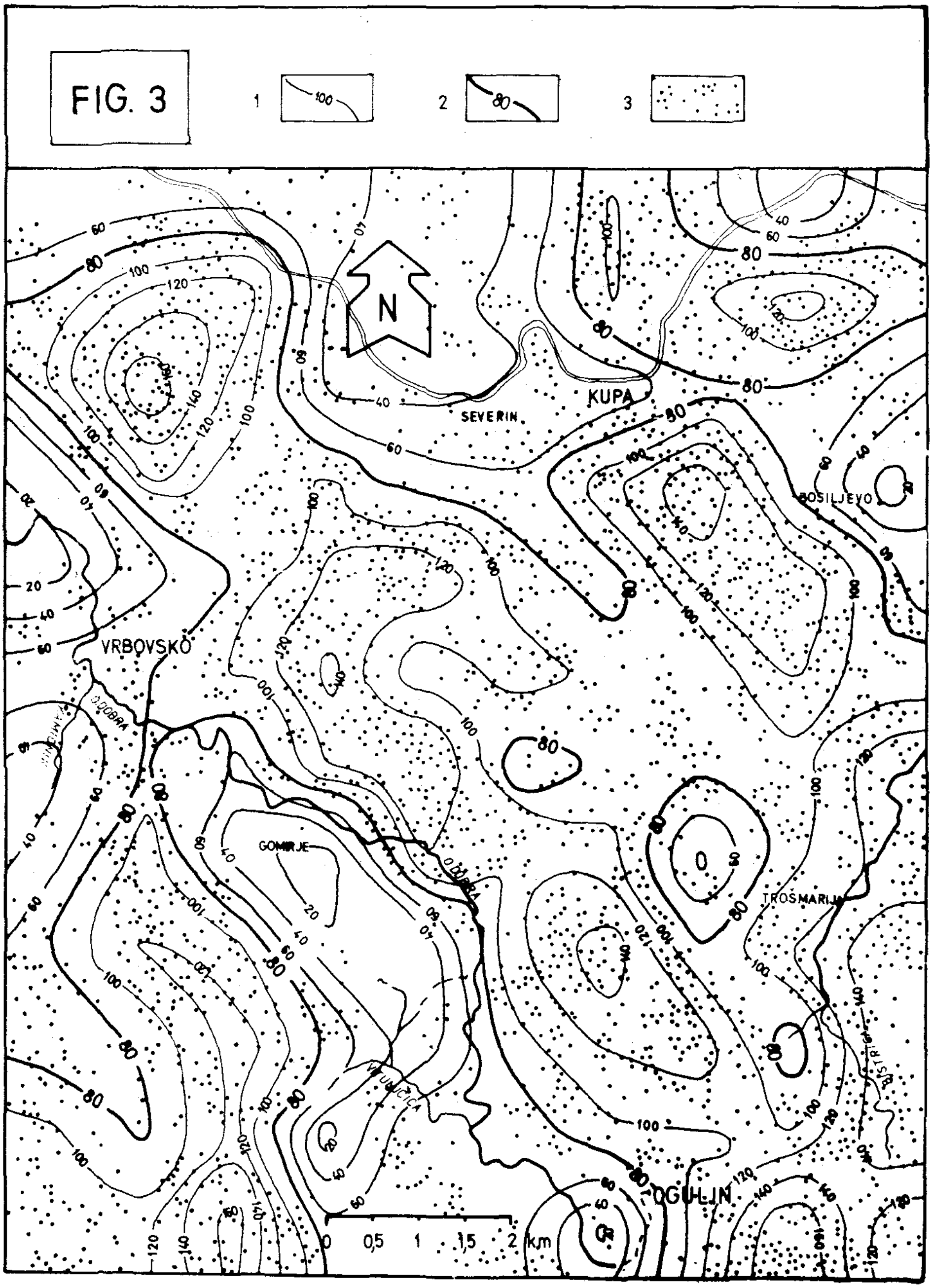

FIGURE 3. Dolina density as an indicator of permeability grade
1. Isolines of dolinas density 2. Average density 3. Spatial distribution of dolinas

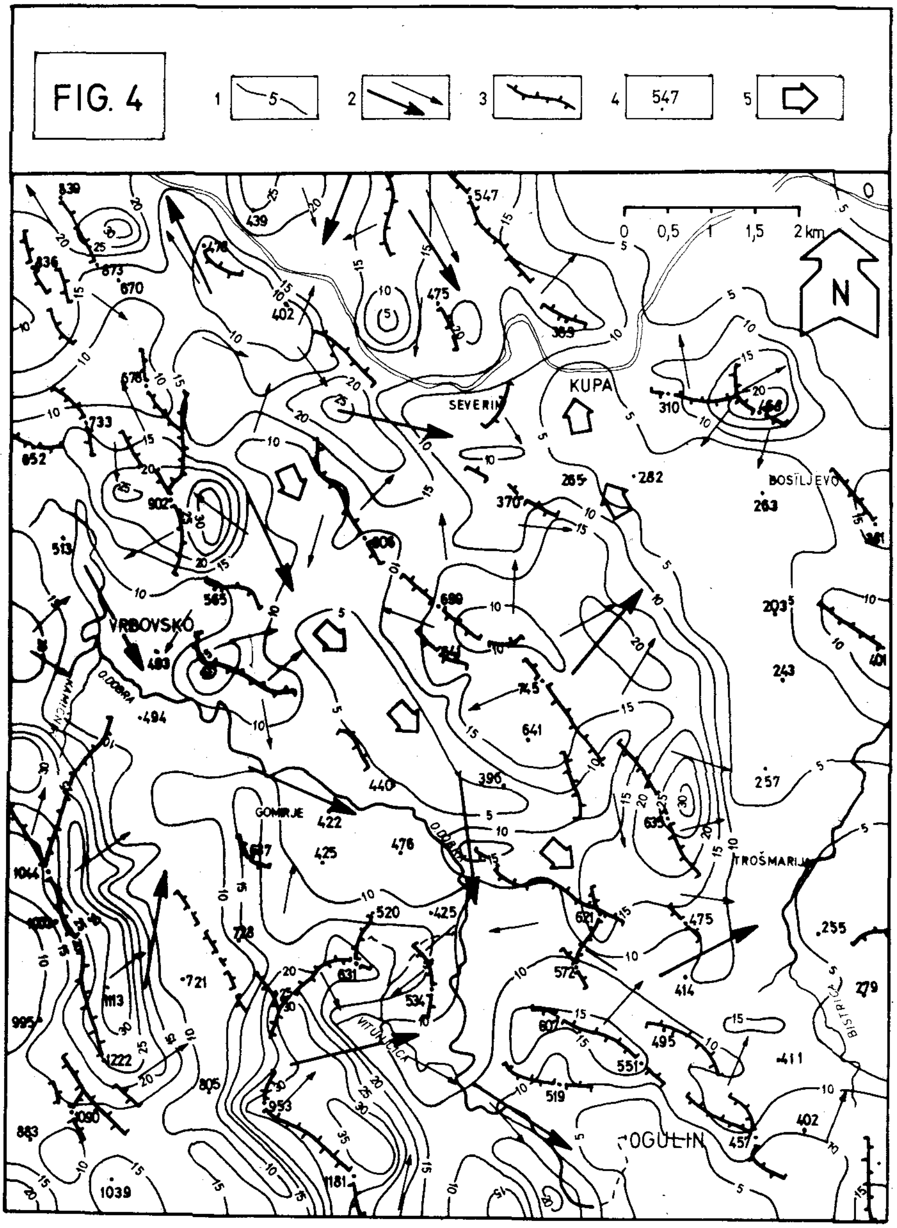

FIGURE 4. Directions of superficial and the underground water outflow
1. Average inclination of slopes 2. Directions of superficial outflow 3. Local topografic watershed 4. Peaks with marked altitude 5. Direction of the underground outflow

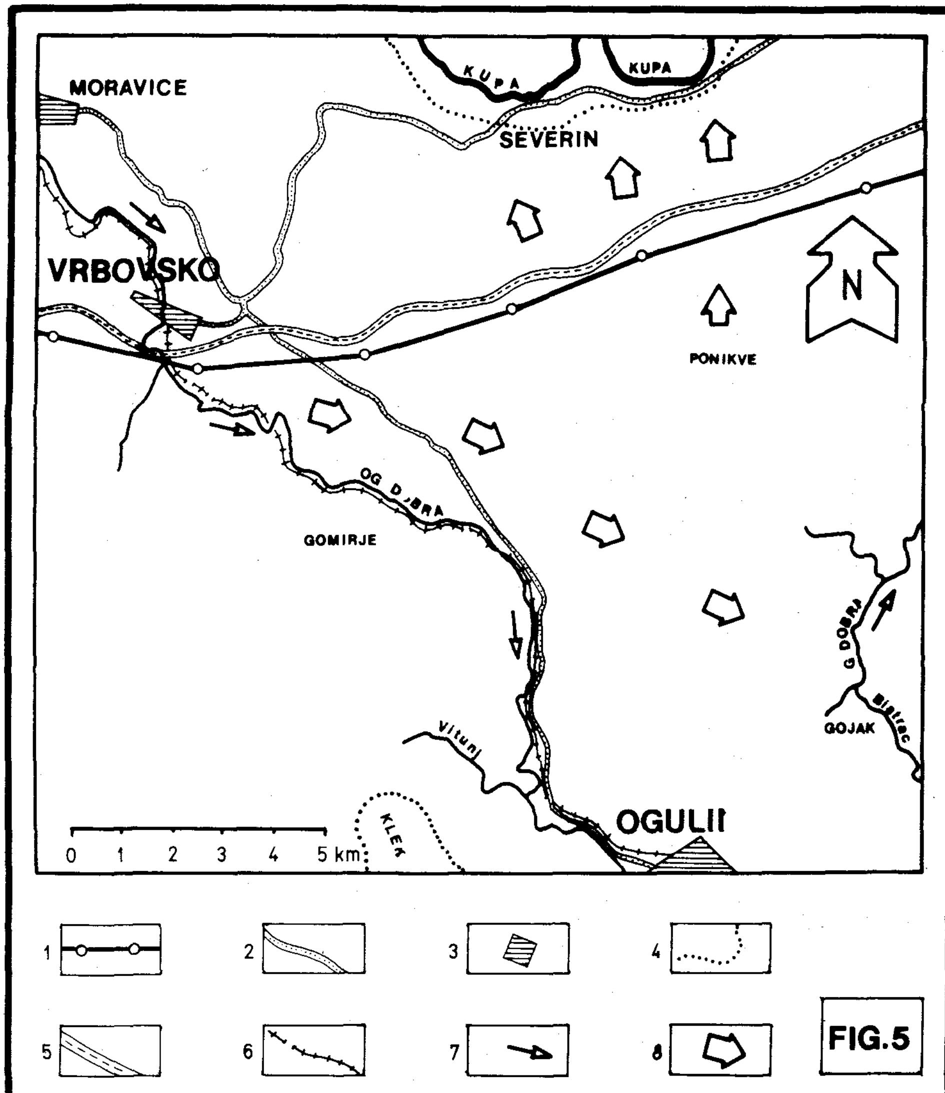

FIGURE 5. Map of possible contaminations in the Dobra and Kupa catchment area 1. Pipe-line route 2. Main and local communications 3. Industrial plants 4. Areas under protection 5. Future highway route 6. Railway 7. Contaminents with a possibility of superficialy outflow 8. Contaminents with a possibility of underground out flow

dolomites, in this section, again, Dobra would not loose any considerable quantities of water by sinking. The first bigger swallow-hole has been registered by the village Luka, where we had dropped fluorescein, at the reverse contact of the Lias dolomites and the Low Cretaceous limestones. The swallow-hole has developed due to the already-mentioned reverse contact of the pervious Low Cretaceous limestones and a transcurrent fault crossing the quoted contact. Its capacity has been estimated at about 50-100 l/sec and also later confirmed by hydrometric measurements. The measurements were carried out during the hydrologic minimum (after a long-lasting summer aridity and before abundant autumn rains).In the section where the Dobra of Ogulin does not lose much water, the average flow was 970 l/sec.

An increase in flow values between the hydrometric profiles 3 and 4 (Fig. 1) resulted from the inflow of right tributaries into the Dobra and from the Dobra flow through the still impervious or at least partially impervious Lias dolomites. However, entering into a zone of Cretaceous limestones, water sinks more and more through the active, periodically active, morphologically very distinct or dispersed swallow-holes (swallow-hole zones), situated in or by the river bed of the Ogulin Dobra. A zone of the most intensive water sinking is at the extreme south-west limb of the Cretaceous syncline, cut by a whole range of parallel faults in direction of its axis and lowered along the regional fault Vrbovsko-Ogulin. The mentioned geologic and hydrologic situation affects the striking of subterranean waters towards the nearby profuse springs of the Gojak Dobra, to the north-east.

According to the hydrogeologic classification by Herak, Bahun and Magdalenic (1966) and by Bahun (1967), the area of research represents a contact zone between the pervious regions in the south-west,with possible retentions of subterranean water, and the region with definitely slowed down subterraenean waters, coming up as the abundant springs of the permanent surface flows.

THE RESULTS OF INVESTIGATION OF UNDERGROUND FLOWS

With reference to the seven springs under observation, fluorescein appeared in only two springs: at the spring of the Gojak Dobra and at the Ribnjak. The result is completely reliable since the observations at the springs lasted long enough (24 days); sampling has been carried out 3-5 times a day and the fluorescein content or absence in the samples were determined by the state-of-art laboratory instrument (Fluorescent spectrometer "PERKIN-ELMER") (Šarin, Mihljević, Singer 1987).

At first, fluorescein appeared at the spring of the Gojak Dobra (within the water power plant Gojak), 100 hours after putting in. It was flowing out for 56 hours. A maximum concentration was 1.5x10-3 mg/l. There was also another, slightly lower maximum,about 16 hours later (Fig. 2).

At the spring Ribnjak, fluorescein appeared 132 hours after being put in.

It was flowing out for about 160 hours, which is three times longer than the flowing out at the spring of the Gojak Dobra. Here, too, we had two maximums, but the second one was bigger, namely 1.3x10-3 mg/l. The fluorescein concentration maximums were similarly shifted apart, at both springs. The apparent velocity of the subterranean flow, between the swallow-hole with the fluorescein and the Gojak Dobra spring is 3.8 cm/sec, and to the Ribnjak spring 2.6 cm/sec. The occurence of two maximums might be explained by the existence of the subterranean water pulse, caused by the first profuse rains that fell immediately before and after the injection of fluorescein, on 22. October 1986 (the first considerable precipitation were registered on 20. October (20.5 mm) on 23.October (73.9 mm) and from 26. to 27. October (100.5 mm).

DISCUSSION

Absence of fluorescein at the spring Jezero near Ponikve could be explained in two ways. Firstly, that the subterranean water level, caused by the hydrologic minimum (drained subterranean), has due to the long-lasting summer and autumn aridity(1), temporarily made impossible a subterranean connection, which is quite common under the "normal" hydrologic conditions, during fairly high or high subterranean water levels. Secondly, that the assumed connection does not exist, irrespective of the actual subterranean water-level.

In order to determine more closely the outflow of surface waters, we analysed the relief properties and constructed a map of the surface and a (presumed) subterranean water flow (Fig. 3). We described the regions where, due to the lithologic composition, a tectonic disarrangement grade and rock fissures, a pronounced surface outflow occurs,actually, a stronger infiltration of precipitation into the subterranean.

A mountain region, to the south-west from the Ogulin Dobra valley This consists of two elongated ranges of ridges; the south-west range includes: Crna kosa (1044 m), Smolnik (1222 m) and Tisovac (1039 m) and the north east: Klek (1181 m), Kobeljak (953 m), Trovrh (885 m) and Gomirska kosa

(1) A period from 24th July to 20th September could be considered as especially arid, since in that period only 176.6 mm precipitation has fallen, which makes some 11% of the average annual precipitation at the station Ogulin (Source: RHMZ (The Republic Weather Service Institution), Daily precipitation in mm at the meteorological station of Ogulin for the year 1986)

(2) Fluorescein was dropped on 22nd September 1986 at 17:30 o clock. Two days before, 24.4 mm of precipitation fell whereas up to the day of the first registered outflow of fluorescein, some 78.6 mm fell.

(728 m). Their slopes are rather steep (over 25 grades) but are covered with forests, with a predominant linear outflow in rills and gulleys, towards the two topographically lower catchment areas; to the first one, the karst valley of Kujina and Jasenova draga with intensive infiltration of precipitation into the subterrain, either because of the prevailing limestones or because of the gentle inclination of the valley bottom, whereof we have an indirect evidence in the terrain morphology, characterized by the larger sink holes density; and to the second one, the valley of the Ogulin Dobra, where due to the prevailing dolomites and an anticline position of layers,there is a pronounced surface outflow in gulleys and temporary flows. At the north-east overthrust contact defining the north-east boundary of this morphostructural zone with mostly impervious dolomite deposits of the next entity, there is a whole range of big and small springs, marking the beginning of the "upper impounding area"(Bahun 1968).

Valley of the Ogulin Dobra

Due to the relatively small slope inclinations and impervious deposits in anticline position, there is mostly a superficial water circulation. At the south-west edge of the zone, there is a rise in the subterranean water level, partially accumulated in the former entity, and they occur on the surface as the profuse springs (Vitunj, Kamicnik) or smaller temporary springs, creating short permanent or periodic currents, flowing into the Ogulin Dobra.

The central hilly region of Severin and Gojak

Due to its syncline structure and limestones, this is most probably the area of major accumulation of subterranean waters, coming to the surface at the contact zone between this area and the anticline dolomites and limestones, to the north-east. Since the dolomites in an anticline position force the subterranean waters to rise, they come up to the surface in a line of abundant springs (Kukaca, Tounjščica, Bistrac, the spring of the Gojak Dobra, Ribnjak). Sinking of the syncline structure axis towards south-east could be one of the reason for non-occurrence of fluorescein at the spring Jezero. Sinking of folds intensifies a subterranean outflow towards structure sink, namely towards southeast or towards the springs where fluorescein appeared. Running of subterranean waters (in direction SW-NE) between the swallow zone of the Ogulin Dobra and the northeast springs, is getting weaker and weaker towards northwest, which is also proved by reduction of profuse springs on the line, in this direction (the extreme northwest spring on the line is the spring Jezero of a much smaller capacity).

Another fact which makes questionable a subterranean connection between the swallow hole of the Ogulin Dobra and the spring Jezero is a relatively small coefficient of sinking in the section, in which such assumed connection might be established (Fig. 1). A more sizeable sinking starts only from the village Ljubosina downstream, so running of subterranean waters should be perpendicular to the direction found out by tracing, in order to make a connection with the spring Jezero. This is also supported by the data obtained on the fluorescein outflow diagram (Fig. 2). Fluorescein occurred first at the more remote spring of the Gojak Dobra (14 km air-distance from the swallow hole), and only later at the closer spring Ribnjak by the village Trosmarija (12 km air-distance from the swallow hole). Outflow of fluorescein at the spring Ribnjak lasted much longer than at the spring of the Gojak Dobra, thus indicating that a subterranean connection between the swallow hole and the Gojak Dobra spring was more rapid and more direct in spite of the larger distance, than was the case with the northwest situated spring Ribnjak.

A POSSIBILITY OF CONTAMINATION OF SPRINGS AND UNDERGROUND WATERS

In the karst region, possibilities of contamination result from the well developed subterranean water circulation in impervious carbonate deposits, due to remarkably pronounced connections between the swallow-hole zones and the springs. Construction of facilities and of industrial sites within the spring inflow zones utilized for a water supply system, increase the contamination possibilities greatly. One of the examples of the already registered disruptions of the natural spring regime (which is likely to occur again) is a location of pipeline on the section between the settlements Vrbovsko, on the west and Bosiljevo, to the east.(Fig. 5) By the analysis of hydrologic situation Delić, Lukas (1074), Delić (1986), Šarin, Mihljević, Singer (1987), there are critical spots where oil might possibly enter the subterrain, like the zone Senjsko, with contamination of the spring Ribnjak (this research work found out about the links with the swallow holes by the Ogulin Dobra), and the zone Ponikve, with contamination of numerous springs along the Kupa (whereof the spring Umolac was captured for the water supply system of Severin on Kupa), since a subterranean link of the swallow hole in Ponikve with the springs by the Kupa has been proved (Delić 1986).

Apart from this, here we deal with the especially striking problem of oil entering into the Dobra. The pipeline leakage has been registered so far at the section Vrbovsko-Bosiljevo, by the air outlet station Dobra II, near the swallow zone in Ponikve (Delić 1986), which consequently contaminated the captured spring Umolac (Severin on Kupa) and an oil outflow into the river Dobra, which consequently contaminated the water wells for the settlement Duga Resa.

CONCLUSION

Having put natrium fluorescein in to the permanent swallow hole of capacity over 50 l/s, near the village of Luke, the exsistence of the underground connection between the Ogulin Dobra with the spring of Gojak Dobra and the source Bistrac have been confirmed. An expected connection with the source Ponikve was not realized, and we tried to explain the situation by means of the underground water level at the time when the fluorscein was inserted, namely, we attempted to elaborate the hydrological circumstances due to wich the presumed connection could not have been realised. On the basis of archieved and available results of underground connections marking, and on the basis of spatial distribution of the available, and potential contaminents, the regions of possible undergroundwater contamination have been displayed.

REFERENCES

BAHUN, S. (1968): Regional basis of hydrogeologic relations of the karst region between Slunj and Vrbovsko, Geoloski vjesnik 21, Zagreb (Bulletin Geol., Vol.21, Zagreb)

BOJANIĆ, L., IVICIC, D. (1972): Regional hydrologic research on the Kupa river basin, Arh.161, Zagreb

DELIĆ, D., LUKAS, Z. (1974); A concept of terms by the water resources managment at the construction of pipeline "Omišalj-Gola". The section Ravna Gora - Velika Trepca, Water Resources Managment "Karlovac".

DELIĆ, D. (1986); Problems of utilization and protection of the karst springs for the water supply, with examples from the Kupa river basin, Yugoslav symposium "Protection of springs intended for water suply", Split.

HERAK, M. *(1954); Geologic representation of the swallow hole zones of the* Ogulin Dobra, Arh.161,no.2045, Zagreb

HERAK, M., BAHUN, S., MAGDALENIĆ, A. (1966); Positive and negative effects on the development of karst and karst hydrology in Croatia, Symposium on the water economy in karst, Split

ŠARIN, A., MIHLJEVIĆ, D., SINGER, D. (1987); Marking of subteranean flow of the Ogulin Dobra, by the village Luka, Arh.161, Zagreb.

SMERI PODZEMELJSKIH TOKOV IN MOŽNOSTI NJIHOVEGA ONESNAŽENJA V DELU POREČIJ DOBRE IN KOLPE.

Povzetek

S pomočjo injiciranja natrijevega fluoresceina v požiralnik s požiralnostjo 50 - 100 l/s pri vasi Luke, tri kilometre južno od Vrbovskega, je avtor želel ugotoviti smer podzemeljskega toka ne le proti izvirom Gojačke Dobre (190 m n.m.) in drugim bližnjim izvirom, ampak tudi proti enako oddaljenim izvirom ob Kolpi. Ta kraški svet grade predvsem jurske in kredne kamnine. V izviru Gojačka Dobra se je sledilo pojavilo po 56 urah, ob maksimalni koncentraciji 1,5 x 10^{-3} mg/l (ob navidezni hitrosti 3,8 cm/s). Sledilo se je po 132 urah (navidezna hitrost 2,6 cm/s) pojavilo tudi v izviru Ribnjak. Na podlagi dokazanih in verjetnih podzemeljskih vodnih zvez je moč predvidevati onesnaževanje izvirov, ki so že oziroma ki so potencialni vodni viri. S pomočjo morfostrukturne analize je avtor skušal opisati tudi značilnosti podzemeljskega vodnega toka.

SOME KARST FEATURES OF TECTONIC ORIGIN AS AN INDICATOR OF RECENT TECTONIC ACTIVITY ON THE NORTHEAST PART OF THE ISTRIAN PENINSULA

NEKATERE KRAŠKE OBLIKE TEKTONSKEGA NASTANKA KOT POKAZATELJI RECENTNE TEKTONSKE AKTIVNOSTI V SEVEROVZHODNEM DELU ISTRE

DARKO MIHLJEVIĆ

Izvleček UDK 551.24(497.12/.13)

Darko Mihljević: Nekatere kraške oblike tektonskega nastanka kot pokazatelji recentne tektonske aktivnosti v severovzhodnem delu Istre

Na območju Učke in Ćićarije so bile analizirane anomalije nekaterih reliefnih oblik. Te lahko kažejo na smer in intenzivnost recentne tektonske aktivnosti. Avtor skuša razložiti morfološki razvoj posebnih morfoloških oblik, ki so se razvile kot rezultat recentne tektonske aktivnosti vzdolž smeri glavnih prelomov različnih tipov. Prikazana je temeljna vloga recentne tektonske aktivnosti na razvoj reliefa v velikem in srednjem merilu.

Ključne besede: tektonika, recentna tektonika, morfologija krasa, tektonske morfološke oblike, Hrvaška, Istra

Abstract UDC 551.24(497.12/.13)

Darko Mihljević: Some karst features of tectonic origin as an indicator of recent tectonic activity on the northeast part of the Istrian peninsula

On the area of Učka and Ćićarija the anomaly of some relief forms has been analysed. They could indicate the direction and intensity of the recent tectonic activity. We tried to interprete the morphological evolution of the specific morphological forms which have been developed as a result of recent tectonic activity along the traces of principal faults of different types. We have pointed out the basic role of the recent tectonic activity on the relief formation, in macro and mezo scale.

Key words: tectonics, recent tectonics, karst morphology, tectonic morphological features, Croatia, Istria peninsula

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INTRODUCTION

Within the structural geomorphology, more and more we come across the already asserted morphoneotectonic research, aimed to register and interpret the recent or the present-day tectonic activities of certain region on one side, and its influence upon the today's shape, distribution, density, deviations and finally the evolution of particular macro and mesomorphologic relief forms, on the other side.

Although we may follow the influence of recent or present-day tectonic activities on changes and anomalies in relief forms apart from its affiliation to a certain predominant morphogenetic type (fluvial, derrasion, karst relief etc.) and apart from its affiliation to the basic morphographic categories (plain, lowland, upland relief; hills, mountains) the most suitable, however, for morphoneotectonic research are hilly or mountain karst regions since the effects of structural transformation are preserved for the longest period and are most clearly pronounced in the karst mountain relief.

From the latest studies dealing with effects of active structures on the shaping and changes in relief assembly, on the wider area of the mountain part of Istria and the Kvarner Bay, we may point out the works by Bognar (1992), Benac (1989), Faivre (1992), Mihljević (1992), Mihljević and Prelogović (1992), Prelogović (1989).

HOW ACTIVE STRUCTURES AFFECTED SHAPING OF THE MOUNTAIN PART OF ISTRIA

The term "mountain Istria" implies a mountain area enclosed by the structural entities of Ćićarija and Učka. It is built of carbonate Cretaceous and Paleogene deposits, clastic Paleogene deposits and Eocene flysh. Many reverse relations resulted from the extremely compressive tectogenic regime, stimulated by an exchange of stiff limestones and plastic deposits of marls, flysh). Fig. 1 shows a map of faults, classified into 6 categories according to the fault type and rank.

The first category includes reverse faults, bordering the main overthrusts, with gently laid paraclases, which is reflected in their convex outline.They define the basic orographic structure of Ćićarija and Učka.

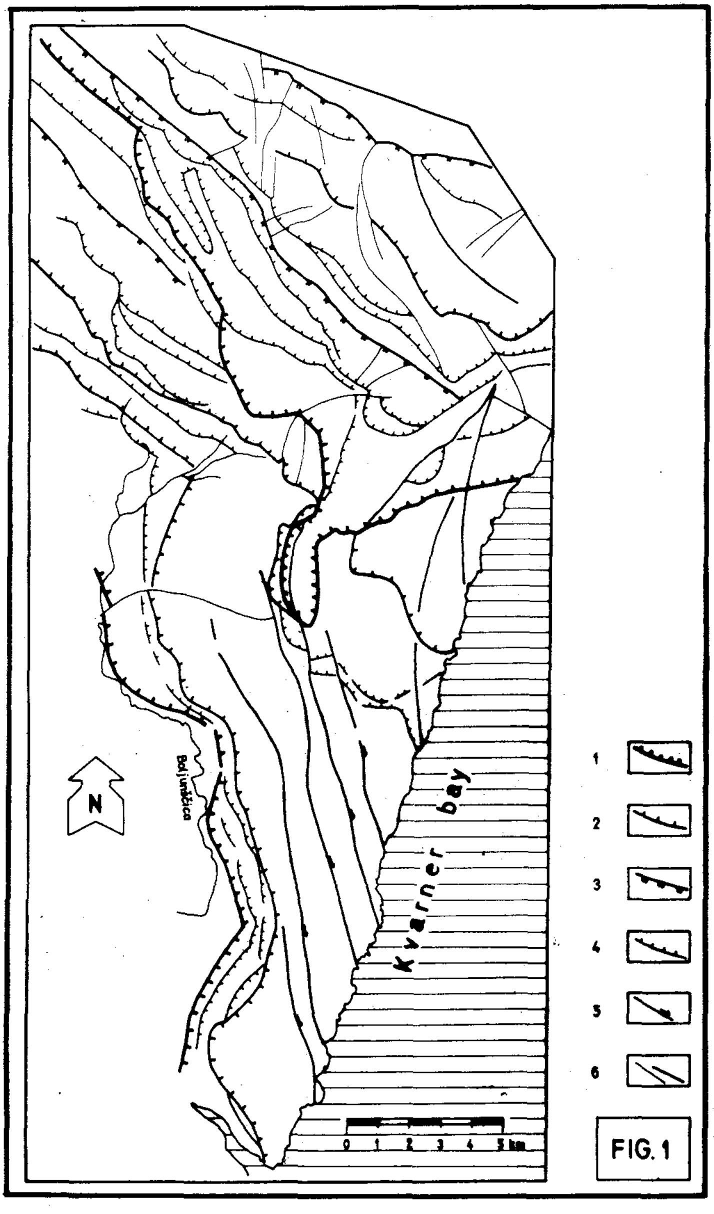

FIGURE 1. Map of faults

1. Main faults bordering the principal thrusts (reverse faults of gently inclined paraclase) 2. Major faults within the structures of Učka and Ćićarija (reverse faults of gently inclined paraclase) 3. Steep reverse faults with northeast vergence (bordering particular structures) 4. Reverse faults with gently inclined paraclases within the structures of Učka and Ćićarija 5. Dextral transcurent faults 6. Unclassified faults

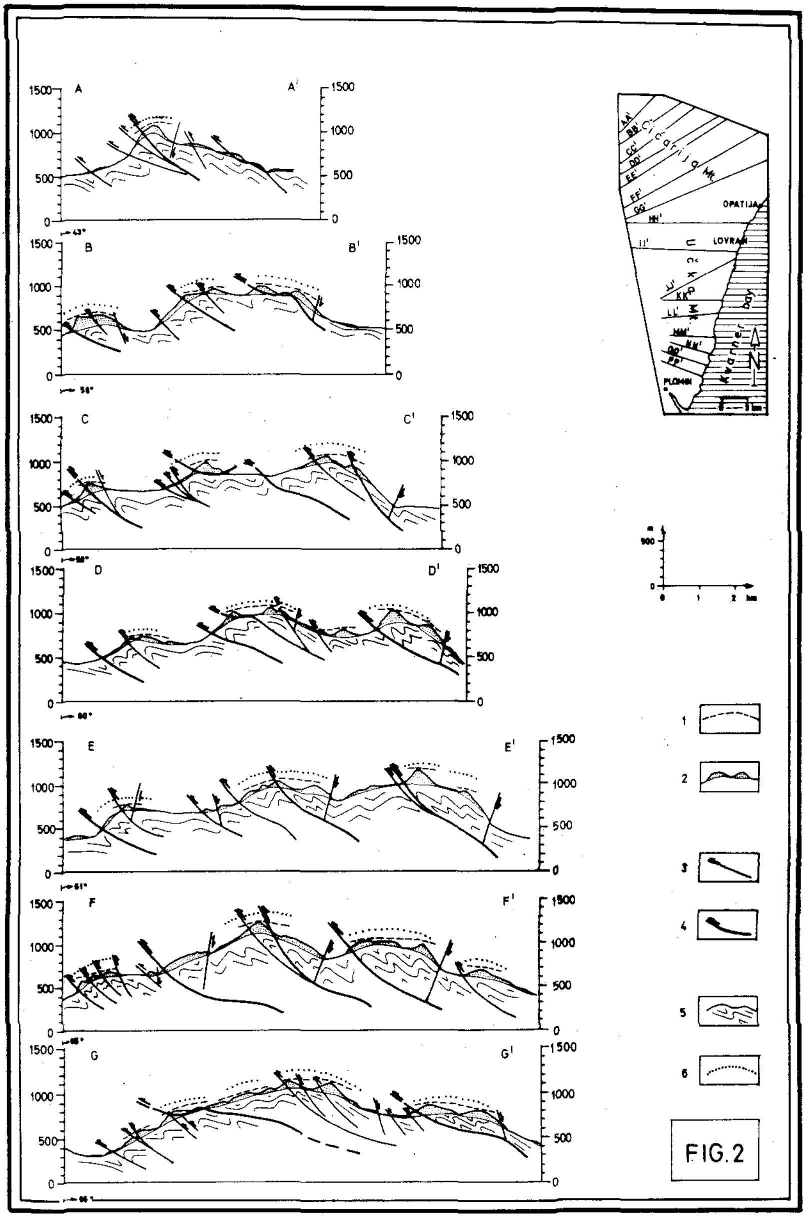

FIGURE 2. Structural-geomorphologic profiles across southeast part of Ćićarija
1. Denudation surfaces 2. Relief partly affected by denudation processes 3. faults with specified limb shift 4. Main reverse faults bordering the principle overthrusts 5. Folded beds beneath the surface 6. Outlines of principle overthrusts

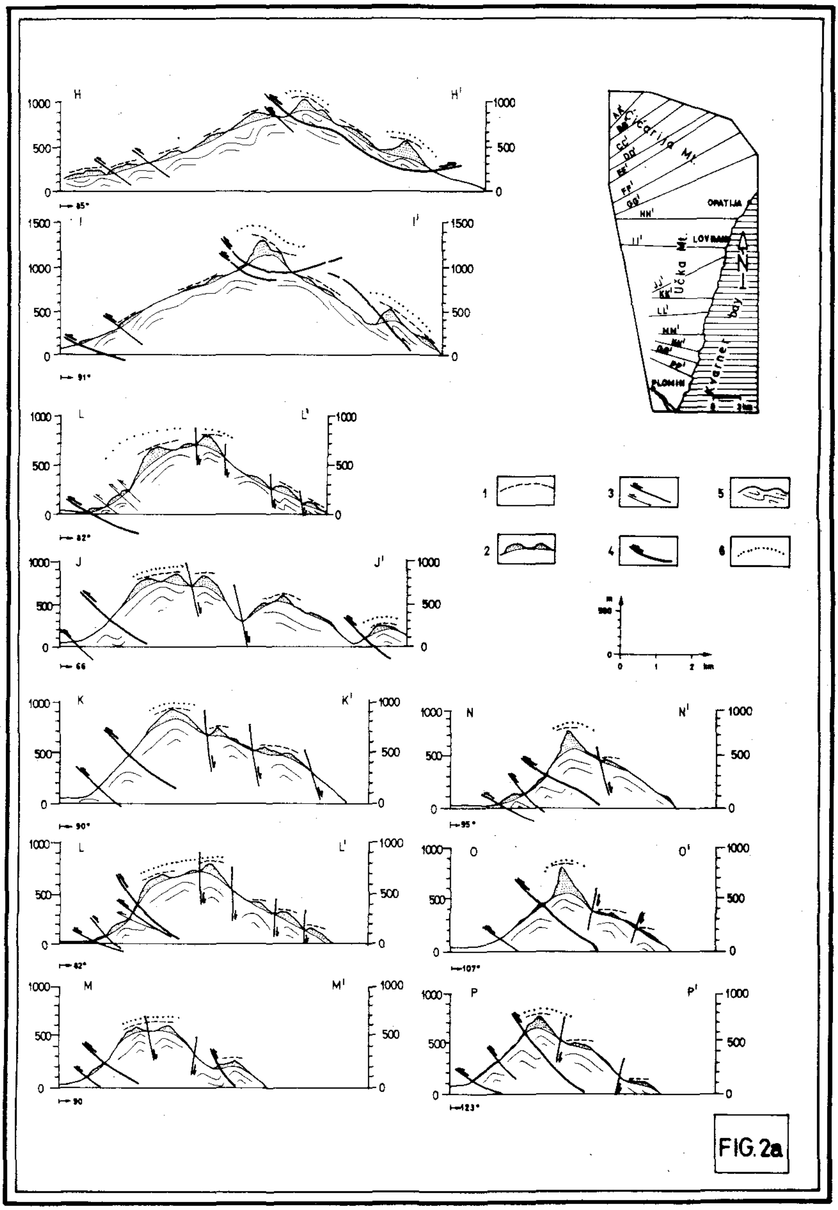

FIG. 2a

FIGURE 2a. Structural-geomorphologic profiles across Učka (See fig. 2. for explanations)

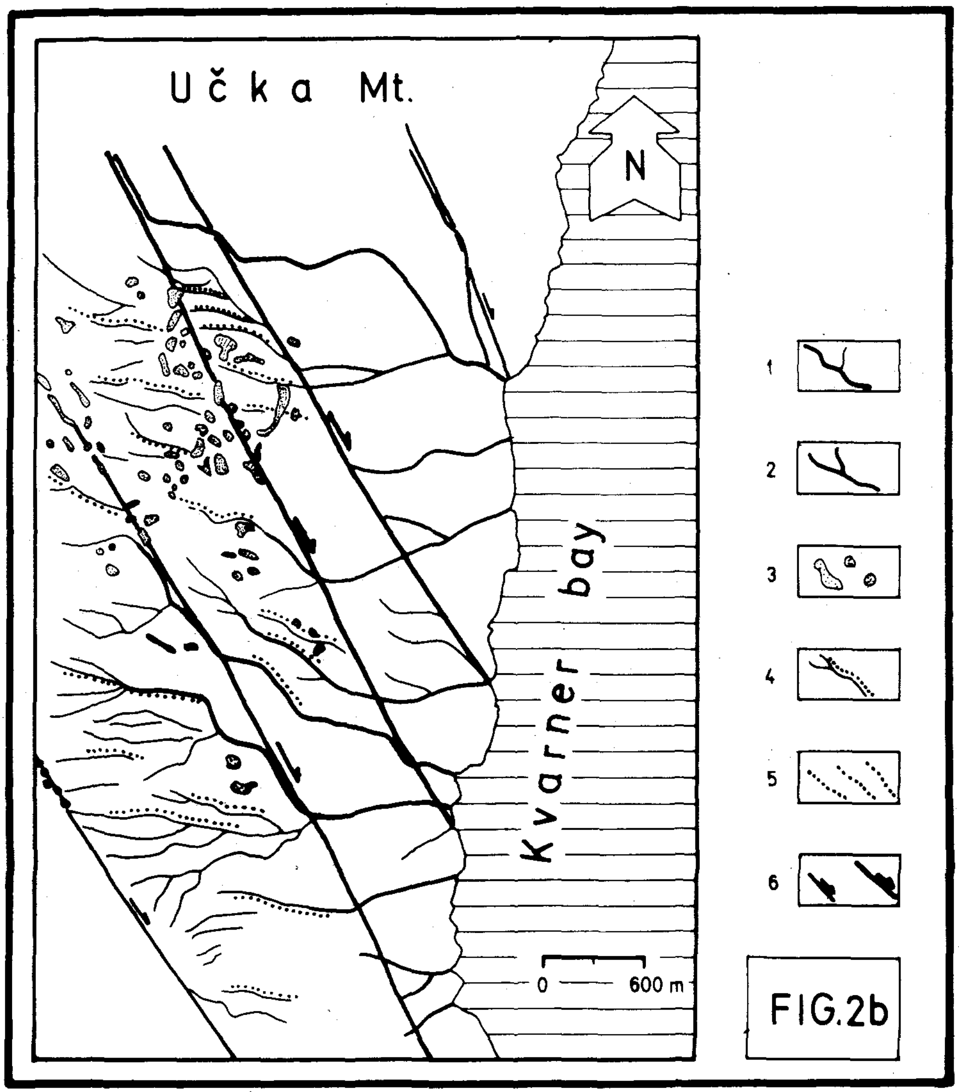

FIGURE 2b. Relief indicators of dextral transcurent faults
1. Major steplike valleys 2. Valleys of lower rank 3. Karst dolinas filled with quaternary deposits (mainly terra rossa) 4. Smaller valleys of the same direction as shear joints 5. Shear joints 6. Dextral transcurent faults

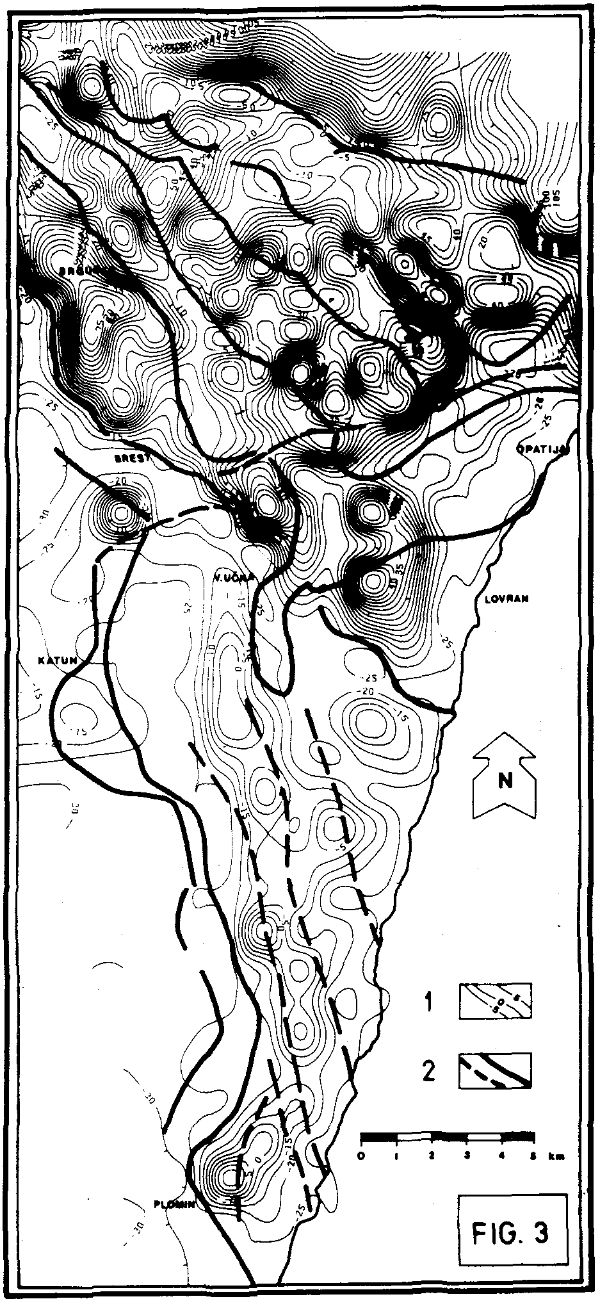

FIGURE 3. Dolinas density map as an indicator of recent active fault traces 1. Isolines of dolinas density (number/sq.km) 2. Principal faults

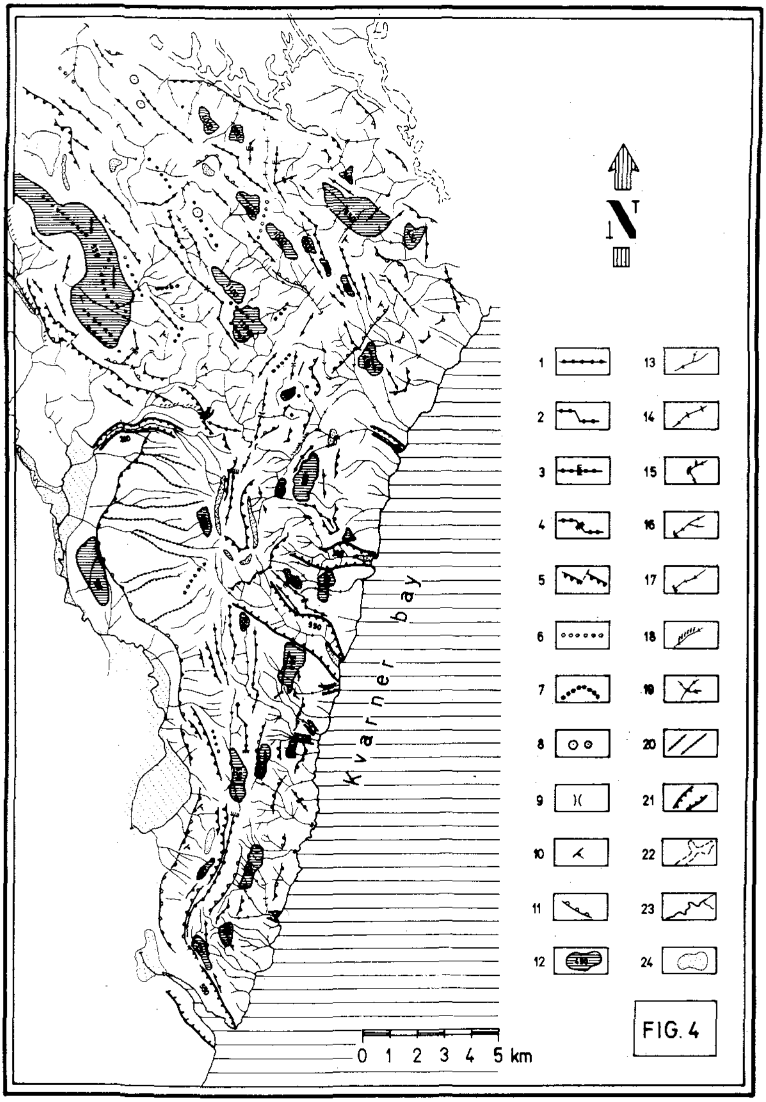

FIGURE 4. Map of the morphotectonic relief elements

1. Linear ridge 2. Planar discontinuity of ridge 3. Altimetric discontinuity of ridge 4. Altimetric and planar discontinuity of ridge 5. Planar discontinuity of escarptment 6. Linear alignment of karst dolinas 7. Arc shaped alignment of karst dolinas 8. Bigger karst dolinas 9. Coll 10. Reverse slope (dip of layers opposit to the slope inclination) 11. Abrupt changes in slope inclination (bulges are directed towards inclination increase) 12. Denudation surfaces with marked average altitude 13. Direction of valley outflow 14. Anomalies in the longitudinal profile of valley talweg 15. Abrupt valley turn 16. Blind valley 17. Hanging valley 18. Valley assimetry 19. Barbed confluence 20. Rectilinear valley 21. Canyons (with marked maximum incision depth) 22. Paleokarst valley 23. River bed 24. Intensive accumulation areas

The second category are reverse faults within the separated principal structures of Učka and Ćićarija. They define the boundaries of the morphostructural entities within principal morphostructures. Their past activity and partly the activity of today has determined the basic step-like orographic outline of Ćićarija, reflected in a succession of ridges, parallel to the orientation of basic structures and their heights increase towards north-east.

The third category of faults are normal or reverse faults with inclination towards north-east and are a result of compartmental fault type.

The fourth type of faults are manifold reverse faults of lower rank, developed in the front part of more significant higher rank faults, reflected in relief in step-like slope deformations and alternate occurrence of lower ridges and more shallow karst valleys.

The fifth category of faults include right transcurrent faults, and we shall discuss their effect on relief later in the text.

Finally, the sixth category are the faults of non-identifiable type and rank, which however, might be explained within the Ćićarija region as diagonal (tear) faults and separation faults (compartmental faults), and their activity is reflected in planar discontinuity or ridge alignment.

The basic tectogenic mechanism of reverse faulting in the region of Ćićarija, is possible to explain in the sense of a Richore concept on tectonic steps or ramps, especially because there is an alternation of competent and incompetent layers. Main faults (the first category) cut the layers in the direction of tectonic transport. At first anticline forms are shaped and then further towards tectonic transport syncline forms.When the internal resistance of masses in transport direction along the main fault plain is overcome, the main fault breaks in the front part of an overthrust.

Fig. 2 shows structural geomorphological profiles. Dotted lines show contours of the main overthrusts. On the profiles AA', CC', FF', GG', we may see a described fault break, as a consequence of compression (folding) of masses whe coming accross a tectonic ramp. A relief reflection of such tectonic style is noticeable on a step-like increase of the ridge height towards north-east,as on a wavy profile outline of the south-west slopes.

Fig. 2a shows structural geomorphological relations within the structural entity of Učka. We noticed manifold reverse relations on the west part of Učka and transcurrent relations on the east slope. In relief, their activity may be noticed by a pronounced assymetry of the west (much steeper) and of the east slopes. Within the zones of manifold reverse faults, we noticed terraces at various levels (profile HH') and shaping of so called tectonic bulges (profile LL'). The east Učka slopes decrease step-like towards the sea, resulting from the activity of the right transcurrent faults, which in an echalone diagonally cut the basic structure of Učka.

Fig. 2c shows a relief manifestation of the quoted activities. If it were not for these activities, the orientation of gulleys and valleys on the east Učka slopes would be vertical to a direction of water shed. However, valleys have a sigmoidal outline and are generally oriented under the angle of 45 degrees, regarding the water shed. When temporary torrents and gulleys on the eastern Učka slopes come across the fault, they change their direction, according to the fault orientation to the moment when a gravity force outdoes the inert flow along the fault. Since we deal here with an echelon of the right transcurrent faults, the quoted relations are many times repeated, resulting in a described outline of karst valleys and gulleys. Besides, a detailed analysis of gulleys showed that the deeper gulleys are cut in the sections in which a direction of their orientation overlaps with a fault route.

Another relief phenomenon bound to the activities of the quoted faults is reflected in a retrograde development of low rank valleys, exactly to the direction of fault route. The next indicator of a recent fault activity is a development of sink holes and karst pocket valleys with terra rossa in a fault direction. Finally, we noticed a development of shorter gulleys and parts of lower rank valleys, according to a direction of shear joints between the two neighbouring faults.

Fig. 3 shows a distribution and a density of sink holes in the region of Učka and Ćićarija. At first sight we may see a considerable difference in density of sink holes between the structures Učka and Ćićarija. An increased density of isolines represents a gradient of change in the number of sink holes. The biggest gradients of change coincide with the routes of active faults. We may also notice changes of gradients perpendicular to orientation of the basic structures which may denote the presence of tear faults. Within the Učka structure, the gradients of density indicate an activity of the right transcurrent faults.

Fig. 4 displays the separated morphotectonic relief elements showing the activity of the youngest faults. In the region of Ćićarija we may see escarpments and an abrupt change in slope inclination in direction of fault routes. We may also notice the aligned sink holes and an asymmetry of valleys parallel to the main structures. Planar discontinuities in the orientation of ridges and escarpments, and of the deeply cut valleys of an arc-outline perpendicular to the orientation of the main faults indicate to a possible activity of tear faults and a compartmental faulting type.

CONCLUSION

Having analyised the faults of different types and dimensions, as well as specific karst relief forms, we separated the faults that had a large impact on the relief on mountain part of Istrian peninsula. Especially remarkable are morphotectonic relief elements, pointing to the recently active faults, reflecting in relief as steplike valley anomalies, and in shaping of smaller valleys, of the same direction as shear joints.

REFERENCES

BENAC, Č. (1989): Morfogeneza vrlo strmih i okomitih obala na području Kvarnera. Pomorski zbornik 28, 593-609, Rijeka.

BENAC, Č., ŠEGOTA, T. (1990): Potopljena ris-virmska abrazijska terasa u podmorju ispred Rijeke. Geološki vjesnik 43, 43-52,Zagreb.

BOGNAR, A. (1992): Some of basic geomorfologic features of Kvarner region. Proceedings of the international symposium "Geomorphology and Sea", 5-13, Zagreb.

FAIVRE, S. (1992): The analysis of the dolinas density on the north Velebit and Senjslo bilo.Proceedings of the international symposium "Geomorphology and Sea", 135-143, Zagreb.

MARINČIĆ, S., MATIČEC, D. (1991): Tektonika i kinematika deformacija na primjeru Istre. Geološki vjesnik 44, 257-264, Zagreb.

MIHLJEVIĆ, D. (1992): Strukturno-geomorfoloske osobine Učke i jugoistočnog dijela Ćićarije. M.Ph. Thesis, Faculty of Sciences, 1-171,Zagreb.

MIHLJEVIĆ, D., PRELOGOVIĆ, E. (1992): Structural-geomorphological characteristics of the mountain ranges Učka and Ćićarija. Proceedings of the international symposium "Geomorphology and Sea" 13-24,Zagreb.

PRELOGOVIĆ, E. (1989): Neotektonski pokreti u području sjevernog Velebita i dijela Like. Geološki Vjesnik 42, 133-147, Zagreb.

NEKATERE KRAŠKE OBLIKE TEKTONSKEGA NASTANKA KOT POKAZATELJI RECENTNE TEKTONSKE AKTIVNOSTI V SEVEROVZHODNEM DELU ISTRE

Povzetek

Na območju "gorske Istre" (Učka in Ćićarija) so bile analizirane anomalije nekaterih reliefnih oblik. Priložena karta kaže prelome, razdeljene v šest kategorij. Podobno so bile analizirane reliefne oblike, nato pa izdvojeni tisti prelomi, ki so bistveno vplivali na razvoj reliefa. Posebej pomembni so tisti morfotektonski reliefni elementi, ki kažejo na smer in intenzivnost recentne tektonske aktivnosti oziroma na današnje aktivne prelome. Ti se kažejo kot stopnjaste anomalije v dolinah in v obliki manjših dolin. V prispevku je torej prikazana temeljna vloga recentne tektonske aktivnosti na razvoj reliefa v velikem in srednjem merilu.

ARTIFICIAL DRAINAGE OF THE POLJES AND KARST DEPRESSIONS IN THE SOUTH-EASTERN FRANCE

UMETNO ODVAJANJE VODE S POLJ IN IZ KRAŠKIH DEPRESIJ JUGOVZHODNE FRANCIJE

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Izvleček UDK 556.116(44)

Jean Nicod: Umetno odvajanje vode s polj in iz kraških depresij jugovzhodne Francije

V preteklosti so bila od rimskih časov dalje opravljena različna melioracijska dela: urejanje ponorov, kopanje osuševalnih jarkov (na polju Cuges v Srednjem veku) in predorov. Z napredkom urbanizacije se veča onesnaženost vode, ki ponika na poljih, kljub gradnji čistilnih naprav. Poseben problem je odvajanje vode iz industrijskih con Aubagne in Gemenos, ki sta na semipolju Coulin. Zaradi urbanizacije oziroma povečanega odtočnega količnika so danes potrebna dodatna dela za odvajanje meteorne vode: ob ponorih kot tudi v coni Gemenos sta potrebni črpalni postaji, ki prečrpavata vodo proti reki Huveaune.

Ključne besede: človek in kras, poplave, hidrologija, kras (odtok), polja, onesnaževanje, Francija (JV), Provansa

Abstract UDC 556.116(44)

Jean Nicod: Artificial drainage of the poljes and karst depressions in the South-eastern France.

In the past, many works have been achieved at various times from the roman period: fitting up of ponors, cutting of drainage network (in the polje of Cuges, in Middle Ages) and tunnels. Now, in some cases, with the progress of urbanization, increase polluted waters absorbed in karst despite building of sewage-works.
A particular problem is that of draining the industrial parks of Aubagne and Gemenos. These parks are located in the half-polje of Coulin. Because of the urbanization, increasing the runoff coefficient, now works have been required for draining off the rain waters: at the main ponors, and also in the industrial park of Gemenos, the harnessing of a pump-station for drain off the waters towards the Huveaune river.

Key words: anthropic impact, floods, hydrology, karst (drainage), poljes, pollution, France (SE), Provence.

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Un certain nombre de dépressions karstiques du Sud-Est de la France ont fait l'objet à diverses époques (romaine, medievale et surtout XVIII -XIX ème siècles) d'important travaux de drainage, pour conquérir des terres basses et fertiles à l'agriculture. Différentes méthodes, classiques dans les pays méditerranéens (aménagement des ponors, forage de tunnels, creusement de drains) ont été adaptées aux conditions locales.

Mais aujourd'hui les problèmes de drainage se posent dans un contexte différent, en raison des transformations de l'habitat (rurbanisation) et des implantations touristiques et industrielles : les problèmes de pollution et d'évacuation des eaux de ruissellement deviennent prépondérants: ce sera l'objet de notre seconde partie.

LES SYSTÈMES DE DRAINAGE TRADITIONNELS DES POLJÉS ET DÉPRESSIONS KARSTIQUES.

La problématique est en renouvellement du fait des travaux récents sur l'évolution proto-historique et historique des milieux humides, effectués par les géomorphologues (VAUDOUR,1986), les palynologues (TRIAT-LAVAL et REILLE,1981) et les archéologues (LEVEAU, 1993), ainsi que par les études pluri-disciplinaires (PROVANSAL et al.,1993).

Situation et typologie des dépressions karstiques drainées.

C'est en Provence que se trouvent les principaux poljés et bassins fermés ou semi-fermés ayant des difficultés d'écoulement naturel (fig.l). Dans cette étude nous envisagerons aussi bien le cas des poljés et semi-poljés dans les roches carbonatées, comme ceux bien connus de Caille,Cuges et Coulin (JULIAN et NICOD, 1989) que celui des ouvalas du karst des plateaux triasiques du département du Var, entre Besse et Flassans, dus à la dissolution des évaporites (MASUREL,1984; NICOD,1987,1991). A titre de comparaison on peut envisager aussi le cas des dépressions pseudo-karstiques de la molasse à l'ouest de l'Etang de Berre (cuvettes nivéo-éoliennes, AMBERT,1973,1991) et celui des sections de vallées barrées par des accumulations de travertins, comme sur le Haut Argens (NICOD,1988). En Languedoc, par contre, les grandes dépressions inondables sont principalement tectoniques (Pujaut) ou hydro-éoliennes (Montady près de Beziers); et dans les grands Causses, seules les deux grandes dolines de Soulages, sur le Causse de Sauveterre ont fait l'objet d'un aménagement méthodique (NICOD, 1990).

Conditions et caractères de la submersion.

Comme la plupart des poljés dinariques, les dépressions étaient temporairement inondées pendant l'hiver, en raison d'un bilan hydrologique excédentaire: les précipitations

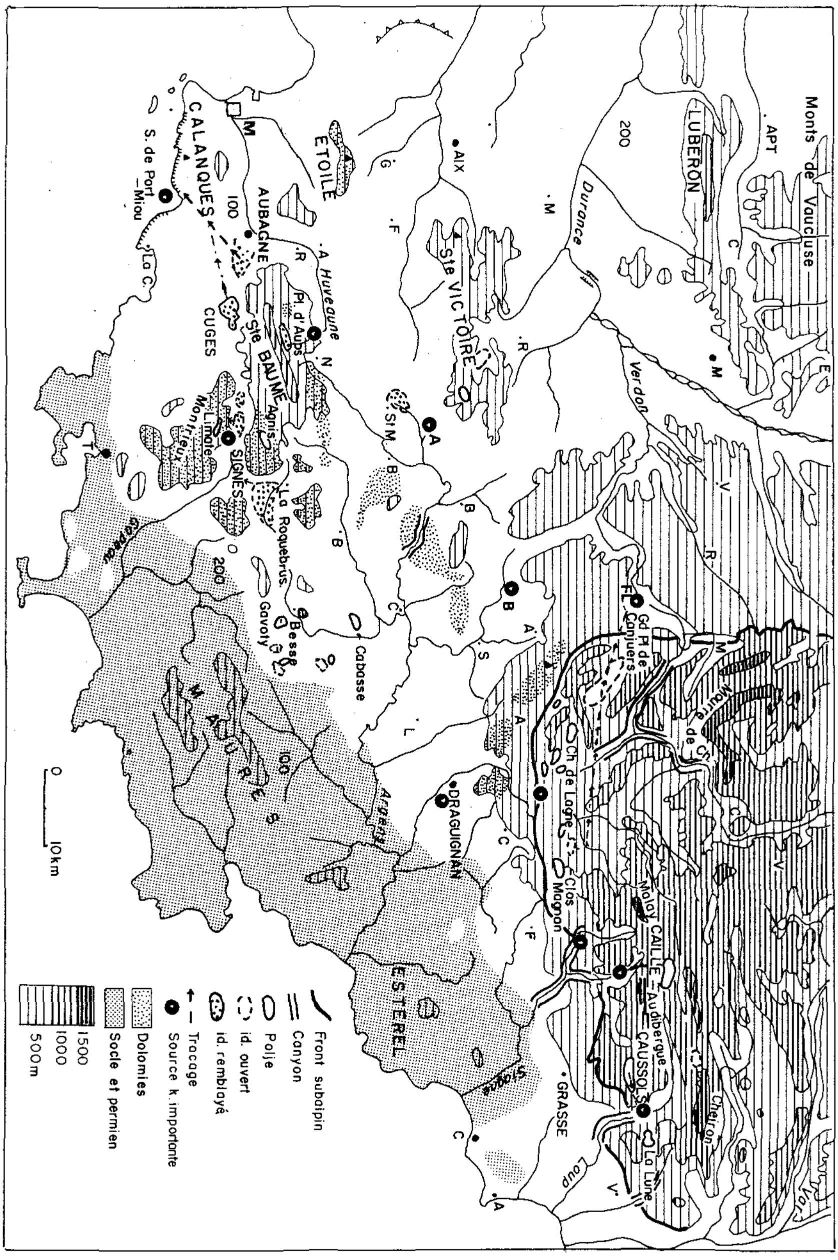

Fig. 1. Carte de localisation des poljés de Provence (in JULIAN et NICOD, 1989)
Map of the poljes of Provence. Keys : subalpine front, canyon, polje, open polje, filled polje, water tracing, main spring, dolomites, basement and Permian.

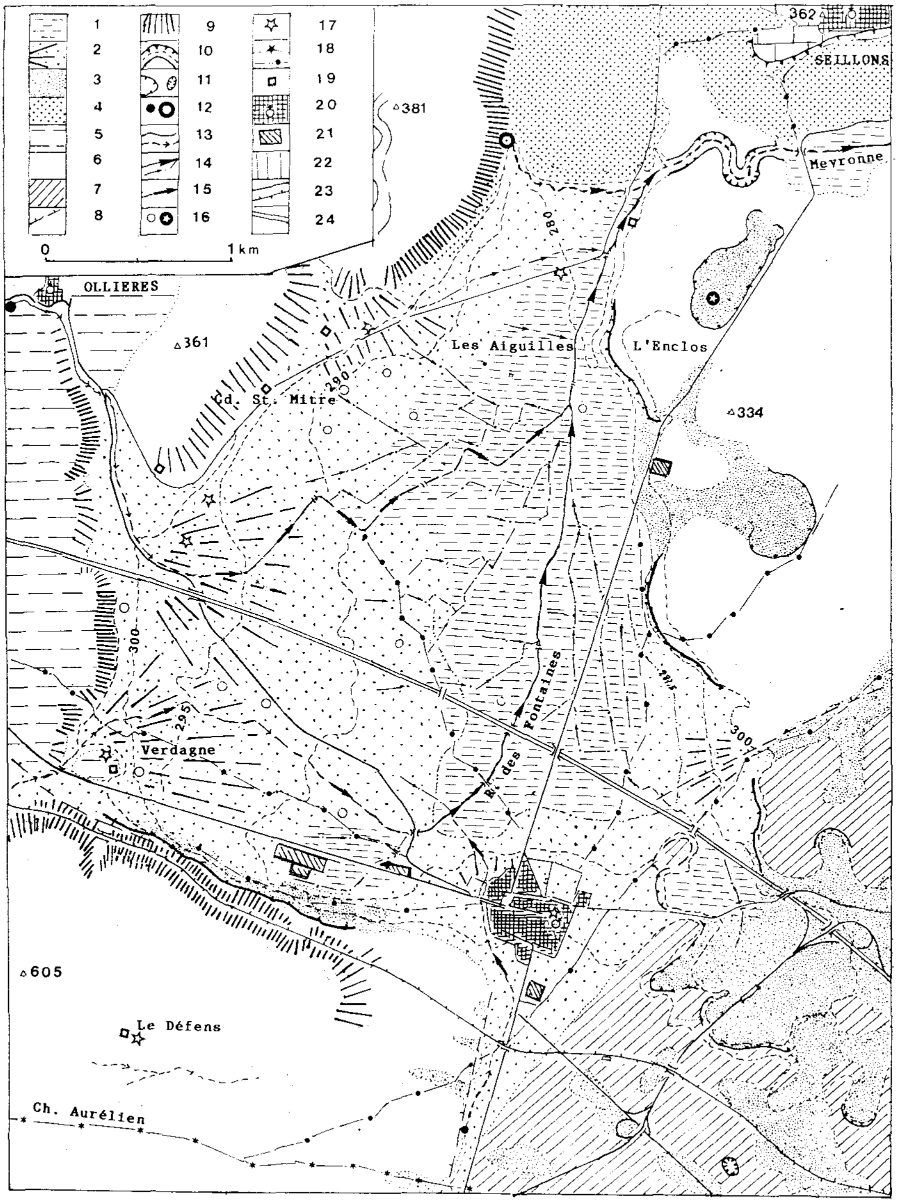

Fig.2. Géomorphologie et occupation du sol dans le bassin de Saint-Maximin (Var)
1 - ancien marais, 2 - cône de déjection, 3 - terra-rossa et colluvions, 4 - argiles et sables vindoniens, 5 - marnes et calcaires du Crétacé sup., 6 - calcaires et dolomies jurassiques, 7 - Trias argilo-gypseux.
8 - faille, 9 - talus, 10 - gorge, 11 - embayement, doline, 12 - source permanente/temporaire, 13 - cours d'eau id., 14 - fossés de drainage, 15 - torrent endigué, 16 - ancien puits/ station d'épuration.
17 - villa romaine, 18 - voie romaine, 19 - ancienne ferme, 20 - agglomération, 21 - zone industrielle, 22 - lotissement, 23 - route/ voie ferrée, 24 - autoroute.

sur leur impluvium (spécialement les apports des cours d'eau affluents comme à Cuges) dépassant les possibilités d'infiltration,en particulier du ponor ou "embuc", ou de l'exutoire subaérien pour les dépressions ouvertes. L'extravasement de l'aquifère karstique ne peut guère être invoqué que pour les ouvalas du Trias, entre Besse et Flassans, en particulier pour le lac de Bonne Cougne, sorte d'estavelle alternativement absorbante ou émissive, ou pour le lac de Besse (NICOD,1991), ainsi que pour quelques dépressions sur le Causse dolomitique du Larzac (SALVAYRE,1964).

Ces bassins à submersion périodique conservaient des marais, et des séquences tourbeuses ont pu y être étudiées.

Mais on doit envisager aussi la possibilité de submersions épisodiques lors d'averses d'intensité exceptionnelle . Ce fut le cas pour de nombreuse dolines et ouvalas du Causse Noir, lors de l'épisode pluvieux du 20-21 septembre 1980 (pluie de 300 mm à Meyrueis, DORIA,1986). Le petit poljé du Coulet, en bordure S. du Larzac a été inondé lors d' un violent orage en 1907 (AMBERT,1991, p.176). On ne doit pas perdre de vue que lors de ces épisodes violents, les branches charriées jouent un rôle efficace dans l'obstruction de ponors (comme des ponts: catastrophe de Vaison-la-Romaine, 22 septembre 1992). Et en milieu karstique, le rôle de la saturation de l'epikarst, permettant le fonctionnement des cours d'eau à écoulement épisodique (les "cadereaux") a été démontré lors de la catastrophe de Nîmes, le 3 octobre 1988 (FABRE 1990). Dans un seul cas, la submersion peut durer plusieurs mois et même plusieurs années, à la suite de pluies importantes et par colmatage argileux du ponor et des fissures: c'est celui du Lac des Rives dans le karst dolomitique du sud du Larzac (SALVAYRE 1964; AMBERT 1982).

Méthodes d'évacuation des eaux et de drainage.

La plus classique en milieu karstique consiste dans l'aménagement des ponors, utilisée dejà dans la Grèce Antique (poljé de Tripolis, etc.). Des barrages en maçonnerie, ou des grilles retiennent les branches et débris, et un curage périodique est effectué. Un réseau de drainage est creusé et aboutit au ponor aménagé (à Cuges, dès 1472-75).

Dans les poljés ouverts le drainage est opéré à partir de l'exutoire subaérien approfondi comme à Saint-Maximin; et les bassins faiblement encaissés sont drainés par une simple tranchée, comme la Trenque, attribuée aux Templiers pour le petit poljé de l'Etang, sur le Cengle, au pied de la Sainte-Victoire.

Dans quelques cas le forage de tunnels s'est avéré nécessaire: pour les dépressions pseudo-karstiques dans la molasse à l'Ouest de l'Etang de Berre, et pour quelques ouvalas du Trias entre Besse et Flassans... Mais ce sont des ouvrages très modestes: rien de comparable à l'aqueduc de l'Empereur Claude, qui assécha partiellement le Fucino!

Epoques d'aménagement.

C'est aux Romains que la tradition attribue les premiers aménagements dans les lieux humides de Provence, comme cela est bien démontré pour les marais d'Arles et d'Orange (discussion in LEVEAU,1993). En ce qui concerne les dépressions fermées de basse altitude, des arguments peuvent être tirés de la densite des *villae* (Aubagne,Cuges), du passage de la *via Aurelia* (Campdumy près de Cabasse) et des centuriations (cadastrations) remarquables à St Maximin et à Cuges, où elles orientent encore le parcellaire actuel (cf. SOYER,1985). Il est possible que l'étang du Pourra, à l'W de l'étang de Berre soit alors drainé par un tunnel (PROVANSAL et al.1993) et certaines dépressions du Cengle déjà par des tranchées (LEVEAU et al . 92). Le cas le plus intéressant est celui du bassin de Saint-Maximin. Ce poljé ouvert, remblayé de plus de 70 m de sédiments détritiques (d'après les sondages effectués lors de la construction de l'autoroute) était une dépression lacustre jusqu'à l'époque romaine, comme le montre bien la carte (fig.2) des témoignages archéologiques, dressée grâce aux coupes exploitées lors de la construction du réseau d'irrigation par la Société du Canal de Provence (CARRAZE,1990). Mais au cours de l'époque romaine, des drainages furent certainement entrepris, puisqu'une *villa* s'installa en pleine zone humide (dans le quartier des Aiguilles) .

La seconde période se situe au cours du Moyen-Age, avec les ordres monastiques en particulier, (le drainage du marais de St Maximin est entrepris par l'abbaye dès le milieu du XI siècle et la "Trenque" de la dépressions de l'Etang, sur le Cengle est attribuée aux Templiers), mais surtout avec le développement des communautés au XVème siecle. C'est ainsi que Charles de Castillon entreprit le drainage des "paluns" d'Aubagne (*infra* ,II 3), que le lac temporaire de Cuges fut éliminé par l'aménagement du ponor du Caranquet (1472-1475), d'où le déperchement du village, et que le creusement du Grand Vallat assécha le bassin du Valavès, près de Rians, évidé dans le Trias argilo-gypseux .

Au cours du XVIII ème siècle, avec les idées des physiocrates et surtout dans les deux premiers tiers du XIX siècle, les drainages furent entrepris systématiquement. C'est le cas sur le Haut Argens, dans la commune de Bras où un barrage de travertin fut scié pour assécher la zone humide du " Pré de la Cadette "(NICOD 1980); de nouveaux aménagements furent réalisés dans le poljé de Cuges (cf. *infra* II 2), et le drainage de la plaine de Saint-Maximin systématiquement repris en 1864 (approfondissement du Ruisseau de Fontaines et aménagement des torrents affluents; NICOD,1967 p.424).Dans ces deux derniers cas l'amélioration du drainage permit l'extension du vignoble de masse, tel qu'il se présentait encore dans les années 60.

LES PROBLÈMES ACTUELS

Les aménagements traditionnels avaient surtout pour but le drainage des marais pour conquérir des terres fertiles à l'agriculture. Mais les problèmes actuels sont ceux de l'introduction massive de pollutions dans le karst et de l'écoulement des crues.

Ces problèmes nouveaux résultent d'une mutation profonde des régions rurales, où les espaces construits se sont multipliés avec la "*rurbanisation* ", le développement des activités industrielles et touristiques. Partout l'adduction d'eau potable est assurée, d'où la nécessité de stations d'épuration et la possibilité d'introduction massive de polluants dans le karst. Par ailleurs l'imperméabilisation des sols (constructions,parkings) entraine la possibilité de débits bien plus élevés pour les petits ruisseaux des poljés (coefficients d'écoulement de crue de 90% et plus admis en zone urbaine) alors qu'en l'état naturel une partie des eaux pluviales pouvait être absorbée par ou à travers les alluvions (cas de Cuges). De ce fait les ponors sont insuffisants à écouler les débits instantanés. C'est le cas classique des inondations récentes dans le poljé et la ville de Cetinje, au Montenegro (BONACCI,1987, p.108 et GAMS et al. 1987, p.200).

Pollution introduite dans le karst par les poljés montagnards: Caille et Plan d'Aups.

Dans les chaines subalpines au N de Grasse, le poljé de Caille évidé dans les terrains tendres d'une structure synclinale chevauchée au N, est de type fluvio-karstique (JULIAN et NICOD 1986)(fig.3). Son fond, situé à 1122 m est constitué par un mince remblaiement limoneux, un petit réseau hydrographique y serpentait (cf.carte d'Etat-Major au 1/80000), et des prairies marécageuses s'y étendaient. Ce bassin montagnard est bien arrosé (1343 mm /an à Andon), et enneigé l'hiver. Les eaux absorbées par le ponor de l'Antre, au pied du mont de l'Ubac, participent à l'alimentation, à travers la chaine de l'Audibergue, des grosses résurgences de la Siagne et de la Pare.

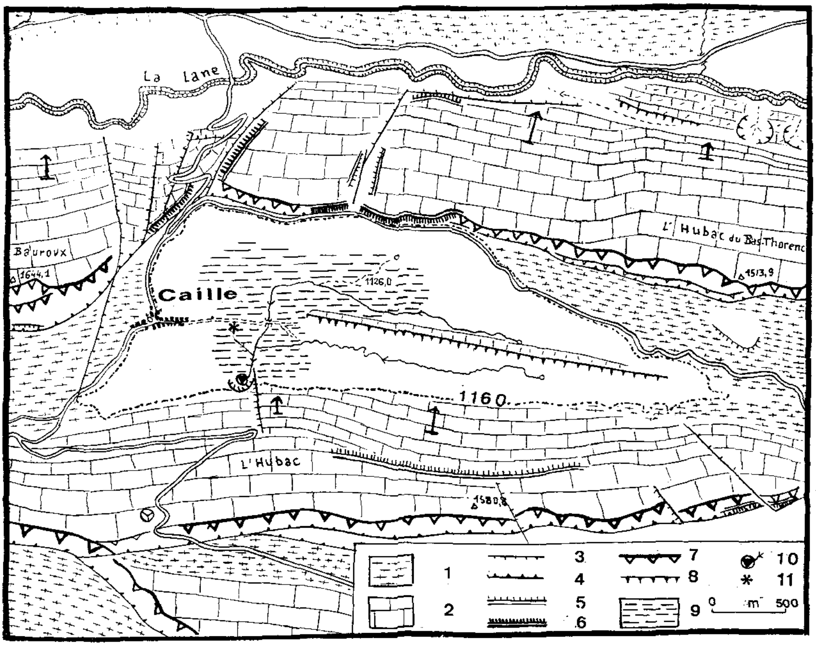

Fig. 3. Le poljé de Caille, d'après JULIAN et NICOD (1975, 1986)
1 - marnes crétacées, 2 - calcaires jurassiques, 3 - faille, 4 - chevauchement, 5 - escarpement de faille, 6 - id; de chevauchement, 7 - crêt majeur, 8 - crêt mineur, 9 - ancien marais, 10 - ponor, 11 - station d'épuration.

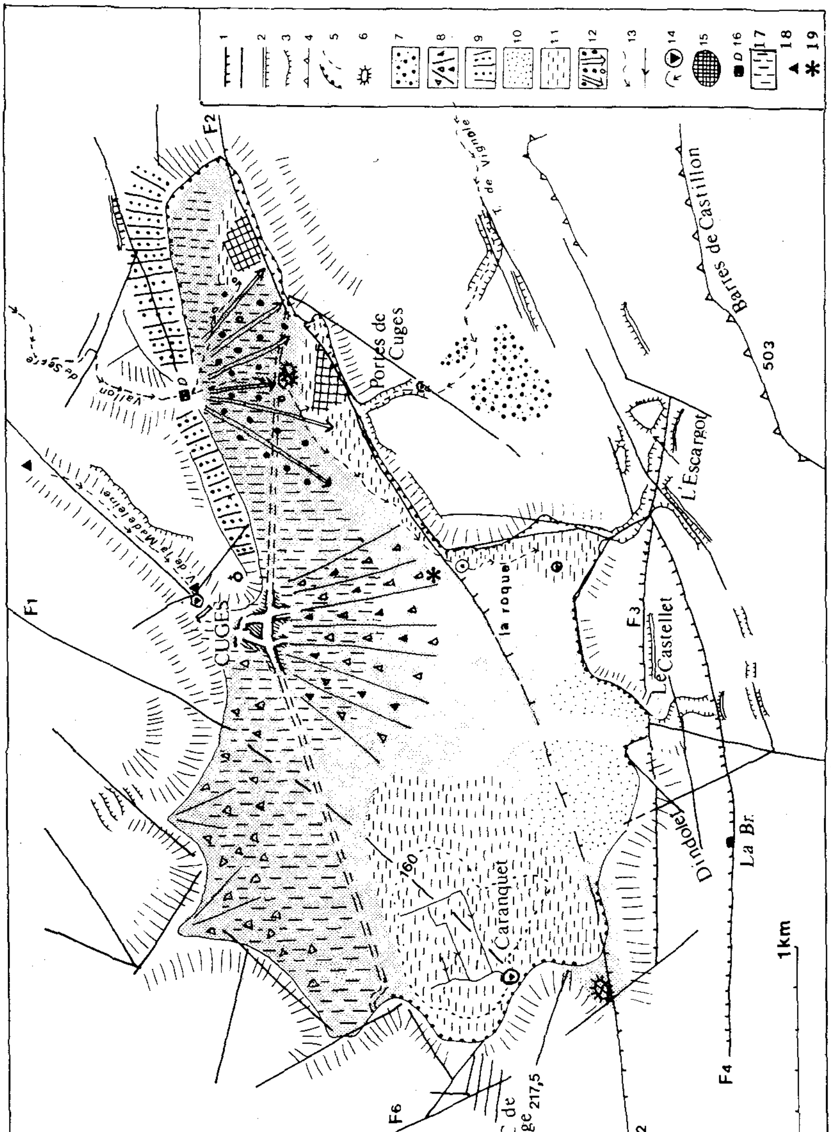

Fig. 4. Carte géomorphologique du poljé de Cuges (d'après NICOD, 1967 et JULIAN, NICOD, 1989) 1 - faille, fracture, 2 - escarpement de faille, 3 - autre, 4 - cuesta, 5 - contour de corrosion, autre, 6 - hum, 7 - alluvions anciennes, 8 - cône et accumulation cryoclastiques (Würm-Tardiglaciaire), 9 - versant réglé avec éboulis, 10 - loess, 11 - limons palustres, 12 - cône historique, 13 - cours d'eau temporaire, canal, 14 - perte, ponor aménagé, 15 - zone d'absorption diffuse, 16 - déversoir alternatif, 17 - extension aire construite, 18 - sondage producteur d'eau, 19 - station d'épuration.

Une photo de R.BLANCHARD (1945,pl.L A) nous présente un bassin agreste, voué à la production fourragère et à l'élevage de vaches laitières exploité par un petit village. Aujourd'hui il s'est agrandi grâce à l'essor de la villégiature et de la station de ski proche de la Moulière,un réseau de drainage a été établi dans les prairies humides, le ponor a été aménagé, et une station d'épuration installée 400 m en amont,ce qui pose problème....

De ce dernier aménagement résulte une partie de la pollution des sources de la Siagne et de la Pare. Les recherches hydrologiques et hydrochimiqes effectuées dans le cadre du rapport P.A.C.A. (NICOD et al. 1989) ont montré que si la pollution est en général tamponnée par la zone noyée de l'Audibergue (homothermie de la source de la Siagne 9 5 a 11 et variation lente des paramètres chimiques) l'épisode pluvieux du 1-7 mars 1985, accélerant la fusion nivale prouve qu'en situation d'aquifère profond saturé, des circulations rapides suivant les failles transverses interviennent: d'où le transfert des polluants en une période ou la station d'épuration fonctionne difficilement. Une autre source de pollution est constituée par l'ensemble résidentiel de La Moulière et les équipements du Parc de la Glacière, sur l'impluvium des mêmes sources et très fréquentés en période de ski.

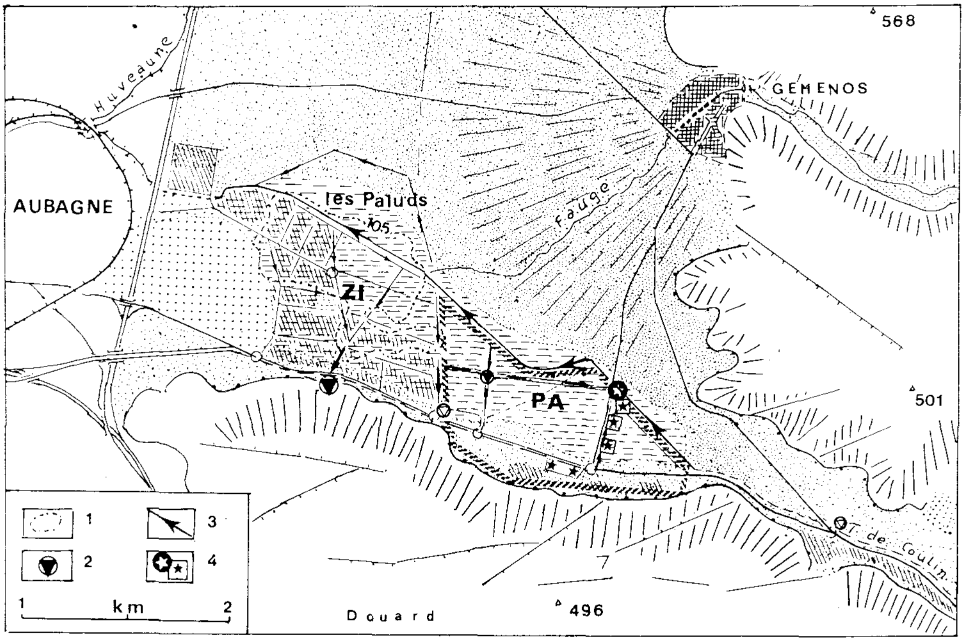

Fig. 5. Carte du drainage artificiel du semi-poljé de Coulin (anciens "Paluns" d'Aubagne) maintenant zones industrielles d'Aubagne et de Gémenos.

1 - isohypse 105m (AUBAGNE n 7,1934), 2 - ponor aménagé, 3 - chenal surélevé, 4 - bassin pluvial + station de pompage. Pour les autres signes, voir légende des fig. 2 et 4.

Dans le massif de la Sainte-Baume, le poljé du Plan d'Aups a pour émergence principale la source de Castelette qui connait une pollution bactérienne importante, en hautes eaux principalement, et avec une forte turbidité (MAZET,1984; MARTIN,1991,p.285.). Cette pollution semble liée à l'intense fréquentation touristique dans le secteur de l'Hôtellerie, et à l'extension du lotissement du Plan d'Aups (problème des fosses septiques). Et plus à l'Est, dans le même massif, les déficiences de fonctionnement de la station d'épuration du Plan de Mazaugues sont sensibles dans les phases de pollution de la source de la Figuière, dans les gorges du Caramy (*ibidem.* , p.293).

Le drainage du poljé de Cuges, nouveaux problèmes.

Rappelons que le bassin fermé de Cuges a tous les caractères d'un poljé tectonique, déterminé par les fractures et zones de broyage, et dont le fond est remblayé par plus de 40 m de matériaux périglaciaires auxquels s'ajoutent ceux des cônes holocènes (NICOD,1967). Son drainage, fortement aménagé, est complexe (fig.4). La partie occidentale,la plus déprimée (158m) et présentant un embayement caractéristique, est drainée par un réseau de fosses par le ponor du Caranquet (aménagement de 1472-1475). Les eaux des deux ruisseaux temporaires provenant de la Sainte-Baume sont absorbées: celui du Vallon de Ste Madeleine par le ponor aménagé en amont du village, et celui du Serre, le plus actif, dans les zones d'épandage et d'infiltration de la Culasse et de la Grande Vigne, et éventuellement aux ponors de La Roque. Ces derniers reçoivent aussi le surplus des eaux du torrent de Vignole, en général absorbées dans le canyon des Portes de Cuges.

Sans qu'aucun traçage ait pu le démontrer formellement, on s'accorde en fonction des dispositions structurales (bande des calcaires urgoniens et système de fractures) à considérer que les écoulements souterrains du poljé rejoignent la puissante source sous-marine de Port-Miou, près de Cassis (3 a 100 m3/s). De plus l'impluvium de cette résurgence s'étend à une partie de la chaîne de la Sainte-Baume, comme le montrent les sondages réalisés (ROUSSET,1988) et le déficit hydrologique du massif (COULIER,1985; Ph. MARTIN,1991).

Les aménagements réalisés au XVème et au XIXème siècles, que nous avons décrits en 1967, étaient ceux d'une commune rurale, alors viticole. Or il s'agit maintenant d'une agglomération de 2360 habitants (en 1990) essentiellement village dortoir; 95 % des actifs (en 1982) sont des migrants pendulaires vers Aubagne et Marseille. Une alimentation suffisante en eau est fournie par trois sondages, dans l'aquifère de la Sainte-Baume (Ste Madeleine et Dausserand) et du fond du poljé (Puyricard). En corrélation une station d'épuration a été installée au quartier de La Roque et le déversement des eaux traitées dans le ponor voisin est assez nauséabond... Le caractère complexe de l'aquifère et les difficultés d'exploitation de la source sous-marine de Port-Miou font que cette pollution est jusqu'à présent négligée.

Mais le problème d'écoulement des eaux pluviales est tout autant en suspens. Les aménagements anciens ne sont guère entretenus, les lits des ruisseaux temporaires encombrés... Cet état est lié au fait que leur fonctionnement est devenu plus intermittent que dans les années 60, où nous pouvions estimer que le seul ruisseau de Serre pouvait apporter dans le poljé 2 à 3 millions de m^3 d'eau en un mois pluvieux souvent en fin d'hiver (NICOD,1967,p.266). Deux causes peuvent être envisagées: des séquences d'hivers moins arrosés, et le prélèvement des sondages dans l'aquifère (80 l/s possibles, soit 2,5 M de m^3 annuels. Par ailleurs, la surface d'infiltration dans le poljé est réduite en raison de l'extension de l'habitat pavillonnaire, des hangars et des parkings: de ce fait il y a un risque en cas de très fort épisode pluvieux (cf. la catastrophe de Nîmes en 1988) de cumul des apports des vallons et du ruissellement en zone urbanisée, aboutissant à l'inondation partielle du poljé et dégâts multiples.

Les aménagements récents du semi-poljé de Coulin, pour les zones industrielles d'Aubagne et de Gémenos.

La partie sud de la plaine d'Aubagne a un caractère de semi-poljé tectonique analogue à celui de Cuges. Sa bordure S est déterminée par un système de fractures, qui hachent les calcaires urgoniens du massif du Douard (BECKER,1983; COULIER, 1985). Le remblaiement périglaciaire et holocène est marqué par une dépression à un peu moins de 105 m (fig.5).

Le drainage s'effectue principalement par des ponors, en direction de la source résurgence sous-marine de Port-Miou (traçage réussi en décembre 1965 à partir du ponor principal, cf. COULIER, 1985, p.296). Les difficultés de drainage ont été accentuées au Moyen-Age par l'activité du cône du Fauge, cours d'eau provenant du vallon de St. Pons, dont l'activité torrentielle est attestée à cette époque par l'incision des barrages de travertins (Ph.MARTIN,1991,p.370) et celle du torrent de Coulin. L'endiguement de ce dernier, et le drainage des marais par un réseau de fossés aboutissant aux ponors (XV ème siècle) avaient fait de cette partie sud de la plaine d'Aubagne une riche terre agricole (irriguée à la fin du XIXème par une dérivation du Canal de Marseille). Toutefois, une première perturbation du drainage a été constatée à partir de 1915, par suite de la construction du hangar à dirigeables, masquant un des ponors (MASSON,1928, p.404).

Les conditions hydrologiques ont été totalement modifiées par l'aménagement des zones industrielles, dans les années 80. Alors que les terres agricoles épongeaient une partie des précipitations,la densification des constructions et la multiplication des voies et des parkings entraînent une forte augmentation du coefficient de ruissellement, jusqu'à des taux supérieurs à 90% . En ce qui concerne la zone industrielle d'Aubagne on s'est contenté d'aménager le ponor principal par excavation des calcaires et installation d'un système de dégrillage; par ailleurs l'écoulement est partiellement assuré vers l'Huveaune, cuvelée et partiellement recouverte dans sa traversée d'Aubagne. Pour le "Parc d'activités " de Gémenos, l'aménagement qui vient d'être achevé a comporté les éléments suivants:

- remblai systématique des terrains bas (au N de la N 8) par prélèvement des cailloutis et limons loessiques du pied du versant du Douard;
- aménagement d'un réseau de canaux bordés d'arbres, dans l'axe des avenues, se croisant au ponor de l'ancien hangar à dirigeables ;
- création d'un bassin de stockage des eaux pluviales, et d'une station de refoulement dans le ruisseau de Coulin, surélevé et endigué, assurant un écoulement complémentaire vers l'Huveaune.

Le fonctionnement de ces aménagements n'a pu être véritablement testé en raison de la sécheresse de ces dernières années. Il n'y a pas eu dans le bassin de l'Huveaune de précipitations torrentielles depuis l'épisode des 16/17 janvier 1978, entraînant une grave inondation surtout à l'aval, dans Marseille. Il faut remonter au 1/10/1892 pour avoir une crue d'ordre centennal (270 m^3/s à Aubagne) mais dans des conditions d'occupation des sols totalement différentes de celles d'aujourd'hui (GABERT et NICOD,1982,p.16).

CONCLUSION

L'exemple des aménagements récents d'Aubagne-Gémenos montre que les Autorités et Services techniques concernés commencent à prendre en compte les risques spécifiques que représentent en matière d'écoulement des eaux pluviales les bassins fermés : la capacité des exutoires parfois déficiente en milieu agricole, doit être considérablement accrue en zone urbanisée.

En ce qui concerne les risques de pollution, il semble qu'ils soient encore assez négligés en Basse-Provence, pour deux raisons au moins:

- complexité des aquifères et effet-tampon important (cf. Ph.MARTIN,1991);
- faible recours aux ressources locales, en raison du transfert des eaux du Verdon, par le système du Canal de Provence.

Mais les besoins augmentant, il sera nécessaire d'apporter dans l'avenir plus grande attention à la protection des ressources locales. Dans ce sens on doit noter que pour la première fois dans le Sud de la France, dans l'étude du tracé d'une autoroute, une attention particulière est apportée à la protection des aquifères, sources et rivières: pour l'A 75 à travers le Larzac et le Causse Rouge (NW de Millau) une enquête est actuellement en cours sur les caractères des dépressions fermées, l'aménagement de bassins de stockage des eaux pluviales,et de leur écoulement (travaux en cours de P.AMBERT, J.L. GUENDON et Ph. MARTIN ...).

REFERENCES

AMBERT P., 1982 - Le Causse de Guilhaumard..., Phénomènes Karstiques III, Mém. et Doc. CNRS, 171-179

AMBERT P., 1991 - L'évolution géomorphologique du Languedoc Central depuis le Néogène; Thèse d'Etat, Aix, 2 vol.

BLANCHARD R., 1945 - Les Préalpes françaises du sud, 2 vol. + cartes h.t.

BONACCI O., 1987 - Karst Hydrology; Springer Series on Physical Environment, Springer V., 184 p.

CARRAZE C. et F., 1990 - Carte archéologique de la plaine de Saint-Maximin; Ann. Soc. Sc. Nat. et Archéologie Toulon et Var, 42 (4), 216-219.

COULIER C., 1985 - Hydrogéologie de la Sainte-Baume occidentale; Th. 3ème cycle, Marseille, 400 p.

DORIA B., 1986 - Le Causse Noir et les canyons bordiers, Thèse 3 ème cycle, Aix, 1 vol. + cartes h.t.

FABRE G., 1990 - La catastrophe hydrologique éclair de Nîmes; Bull. Assoc. Géogr. Fr. 2, 113-122.
GABERT P. et NICOD J., 1982 - Inondation et urbanisation en milieu méditerranéen: l'exemple des crues de l'Arc et de l'Huveaune; Méditerranée, 3-4, 11-24.
GAMS I. (édit.) 1987 - Man's impact in Dinaric karst (Guide-Book), Ljubljana, 205 p.
JULIAN M. et NICOD J., 1986 - La région karstique Audibergue-Mons; Z. Geomorph., Suppl. Bd. 59, 1-25.
JULIAN M. et NICOD J., 1989 - Les karsts des Alpes du Sud et de la Provence; Z. Geomorph., Suppl. Bd. 75, 1-48.
LEVEAU Ph., 1993 - Sociétés antiques et écologie des milieux montagnards et palustres..., in Archéologie et Environnement, Publ. Univ. Provence, 17-44.
LEVEAU Ph., MOCCI F., MULLER A. et STROBEL M., 1992 - L'occupation du sol dans le massif de la Sainte Victoire...,Méditerranée, 1-2, 69-79.
MARTIN Ph., 1991 - Morphologie des géosystèmes karstiques des versants N et O de la Ste Baume; Th. Aix, 412 p.
MASSON P. (édit), 1928 - Les Bouches du Rhône, Encycl. départ., t. VII, l'Agriculture
MASUREL Y., 1984 - La Provence cristalline et ses enveloppes sédimentaires (Thèse), 414 p.
MAZET J., 1984 - Recherches sur l'évolution du karst dans le massif de la Ste Baume; Th. Univ. Aix, 138 p.
NICOD J., 1987 - Recherches morphologiques en Basse provence calcaire (Thèse Aix) 557 p. + XII pl. et 7 cartes h.t.
NICOD J., 1988 - Barrages de travertins, marais et aménagements dans la haute vallée de l'Argens; URA 903 du CNRS, Travaux n XVII, 73-87.
NICOD J. et al., 1989 - Détermination de la vulnérabilité à la pollution et des aires de protection de quelques sources karstiques de Provence-Alpes-Côte d'Azur (*Rapport PACA*, inédit) 55 p. + annexes
NICOD J., 1990 - Quelques problèmes d'aménagement de dépressions karstiques dans le domaine méditerranéen...; 115 *Congrès des Sociétés Savantes, Milieux calcaires et politique hydraulique*, 19-37.
NICOD J., 1991 - Phénomènes karstiques et mouvements récents de terrain dans le Trias du département du Var; *Etudes de Géogr. Physique, Travaux URA 903*, n 20, 5-14.
PROVANSAL M., BERTUCCI C. et PELISSIER M., 1993 - Les milieux palustres de la Provence occidentale, indicateurs de la morphogenèse holocène; *Archéologie et Environnement..., Publ. Univ. Provence*, 249-266.
ROUSSET Cl., 1988 - Apports de nouveaux forages à la connaissance de l'aquifère karstique de Port-Miou; 6 Colloque Hydrogéol., *Ann. Sc. Univ. Besançon, Géol.* 6, tI, 275-280.

SALVAYRE H., 1964 - Les lacs temporaires du Larzac et de son avant-pays; *Spelunca Mém.* n 4, 79-103.

SOYER J., 1973-74 - Les centuriations de Provence; *Rev. Archéol. Narbonnaise,* 6/1973, p.197-232 et 7/1974, p.177-199.

TRIAT-LAVAL H. et REILLE M., 1981 - Analyse pollinique d'une séquence tourbeuse de Provence orientale (Seillons...); *Ecologia mediterranea,* n 7 (2),31-37.

VAUDOUR J., 1986 - Travertins holocènes et pression anthropique; *Méditerranée,* n 1-2, p.168-173.

UMETNO ODVAJANJE VODE S POLJ IN IZ KRAŠKIH DEPRESIJ JUGOVZHODNE FRANCIJE

Povzetek

Vrsta kraških depresij jugovzhodne Francije je bila v določenih obdobjih (rimsko, srednjeveško, predvsem pa v 18. - 19. stol.) prizorišče velikih melioracijskih del, s ciljem osuševanja, da bi nizki in rodovitni svet pridobili za obdelovanje. Različne metode, sicer tradicionalne v sredozemskih deželah (urejanje ponorov, vrtanje predorov, kopanje odvodnih jarkov), so prilagajali krajevnim razmeram. Danes je problem drugačen, zaradi sprememb v načinu poselitve (urbanizacija) ter zaradi turističnih in industrijskih potreb. Najpomembnejše je postalo vprašanje onesnaževanja voda in odvajanja meteorne vode. Voda priteka deloma že onesnažena z više ležečih polj, kljub čistilnim napravam. V drugem primeru pa se je odtok visokih voda, ki jih je prej deloma vpila aluvijalna ravnica, zaradi komunikacij, parkirišč in podobnih vodotesnih površin, močno povečal (odtočni količnik poplavne vode lahko preseže 90 %). Ker so v Provansi lokalni vodni viri le malo izkoriščeni (večino pitne vode dajejo akumulacijska jezera na reki Verdon), se je zanemarjalo vprašanja njihove zaščite. Da pa se tudi to spreminja, najbolje kaže primer gradnje nove avtoceste preko krasa (Larzac, Causse Rouge), kjer so naročili posebno študijo o zaprtih depresijah, zastajanju meteorne vode v podzemlju, njenem odtekanju, ipd.

MINERALOGICAL DATA CONCERNING MOONMILK SPELEOTHEMS IN FEW CAVES FROM NORTHERN NORWAY

MINERALOŠKI PODATKI O KAPNIKIH IZ JAMSKEGA MLEKA V JAMAH SEVERNE NORVEŠKE

BOGDAN P. ONAC

Izvleček UDK 552.55:551.44(481)
551.435.84(481)

Bogdan P. Onac: Mineraloški podatki o kapnikih iz jamskega mleka v jamah severne Norveške

Prispevek predstavlja mineraloške raziskave nekaj vzorcev kapnikov iz jamskega mleka, nabranih v nekaterih jamah severne Norveške in razlago njihovega izvora. Različna morfologija kristalnih oblik je bila določena z vrstičnim elektronskim mikroskopom, difraktogrami x-žarkov pa predstavljajo glavni način analize jamskega mleka.

Ključne besede: speleologija, jamski sedimenti, mineralogija, jamsko mleko, kristalografija, Norveška

Abstract UDC 552.55:551.44(481)
551.435.84(481)

Bogdan P. Onac: Mineralogical data concerning moonmilk speleothems in few caves from northern Norway

The paper presents some mineralogical investigations on some moonmilk speleothems sampled in few caves from north of Norway, as well as some considerations concerning their origin. Different morphological crystal shapes are characterized through scanning electron microscope analysis. The X-ray diffractogramms results are also presented being the main way to analyse the mineralogical composition of the moon- milk.

Key words: speleology, cave sediments, mineralogy, moonmilk, cristalography, Norway

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GENERAL DATA

Very little has been written about the mineralogy of moon-milk from Norwegian caves. As a matter of fact the very first step was done by Horn (1937) who sampled a "soft white mud" from a cave called "Tukthuset". These samples were analysed from micro-biological point of view a few years later by Hoeg (1946).

Sporadically informations on this topic are published in periodicals such as Studies in Speleology (e.g. S. St.Pierre,1967) and Norsk Grotteblad. Two recent papers (Onac, and Farcas, 1992) and (Onac, and Lauritzen, in press) contain a mineralogical approach to the moonmilk deposits of some Norwegian caves.

The present paper aims to offer some mineralogical results on moonmilk speleothems sampled from fifteen different caves, all situated beyond the Arctic Circle, as well as several considerations concerning their origin. Given the anthropogenic "contribution" to environmental change in caves we will avoid specifying the location of those in which important moonmilk speleothems have been observed.

FIELD OBSERVATIONS

As we have mentioned above, all sampled caves are located beyond the Arctic Circle, being developed in methamorphosed calcite and dolomite marbles. These have suffered extensive recrystallizations and tectonic folding during the Caledonian orogenesis (**Lauritzen, 1991**).

Developed under certain circumstances such as the cold climate with precipitations which rise above 1000 mm/yr (snow and rain) and the petrography of the karstifiable areas, the entire karst of northern Norway has several peculiarities. We will dwell just with the endokarst, looking upon those caves which provided moonmilk samples for our study.

Such being the case we can say that most of the caves visited are active vadose streamways, just a few being completly dry (without underground stream). We sampled moonmilk from both categories.

The measured temperatures around the sampled points was between 4.5°C and 8.0°C, relative humidity being 100%.

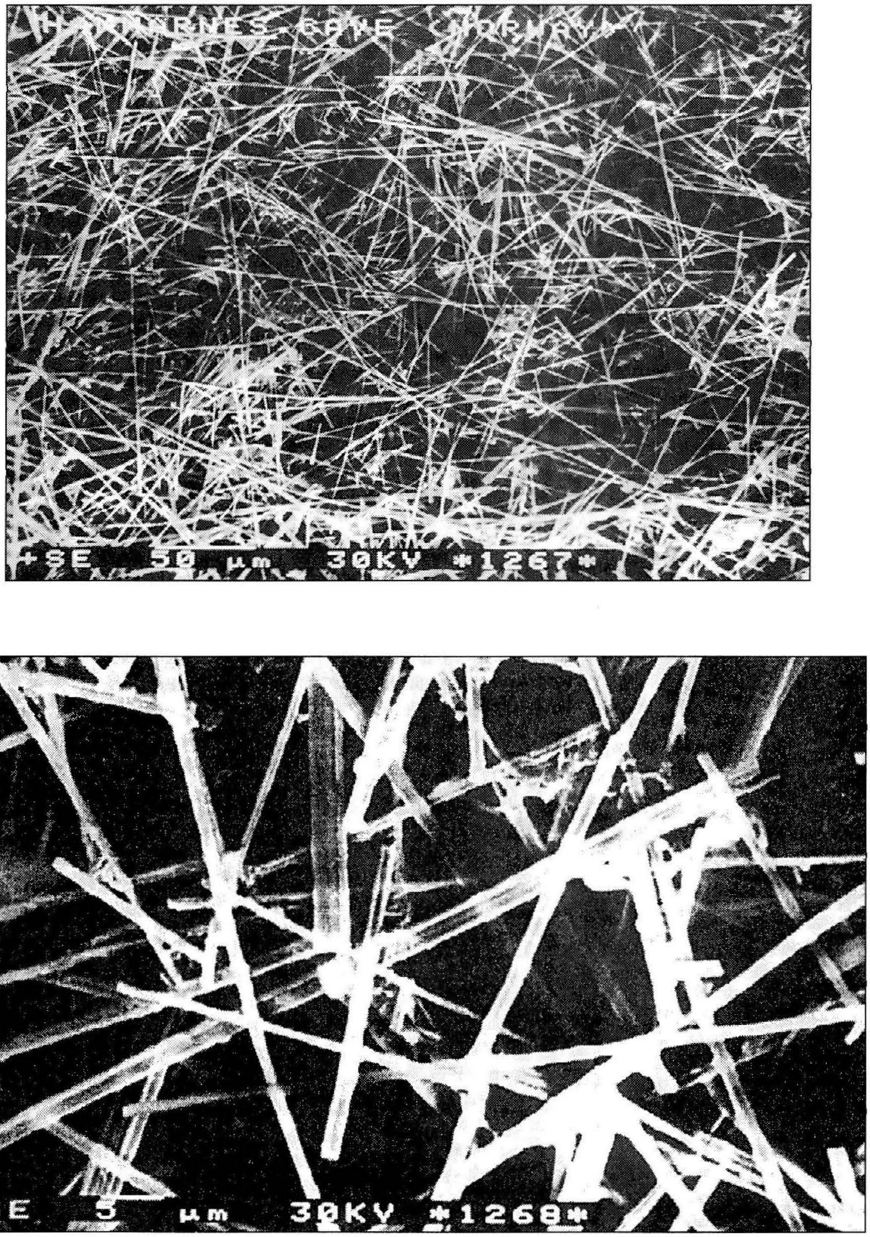

Fig. 1 - Threadshaped calcite crystals (SEM)

ANALYSIS RESULTS

Moonmilk often occurs as a white, sometimes whitish-yellow pasty coating covering cave walls (the thickness varies between a few mm. up to 15-20 cm.) or other speleothems. It can also form as cauliflower-like flowstone, stalactites, draperies, and even small pools. All temperatures we measured inside the sampled mooonmilk were under 5°C. When wet it is soft and plastic, but when dry it is white powdery material.

Water absorbtion capacity was calculated on 5 different samples using the following formula: (Ww-Wd)*(Ww) *100(%). Ww and Wd represent wet respectively dry sample weight. The values we obtained are: sample 1 (S1)=58%, S2=91%, S3=88%, S4=90%, S5=68%.

X-ray Analysis

Using a Phillips X-ray diffractometer, our analysis detected the presence of the calcite in more than 70% of our moonmilk samples. At the same time, hydromagnesite or gypsum and calcite have been identified. Typical lines for monohydrocalcite are also to be found, being quite normal, as this cave mineral has been reported as a cold water deposit in a fine mist environment (**Hill, and Forti, 1986**).

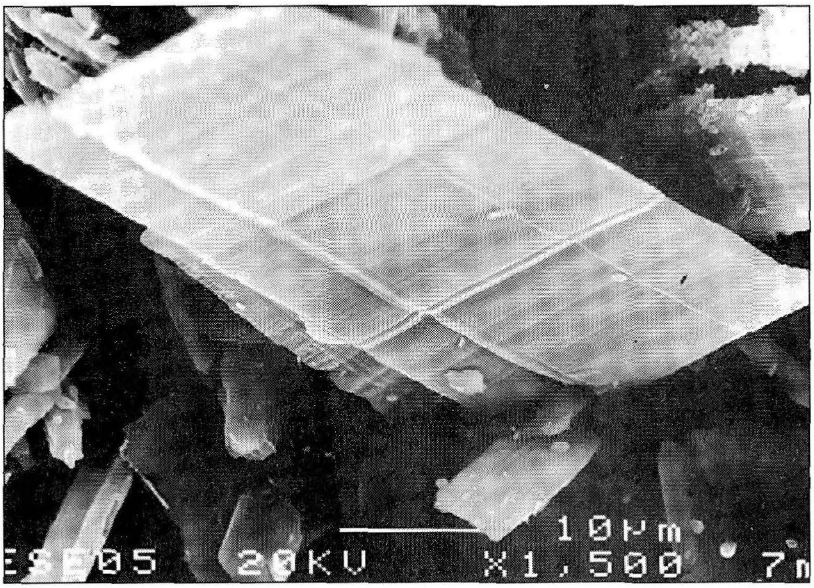

Fig. 2 - Striated (010) gypsum crystal (SEM)

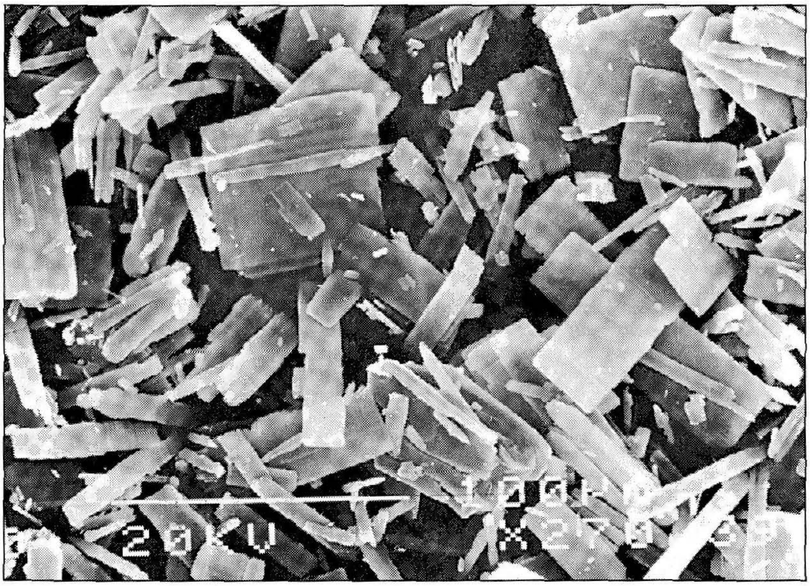

Fig. 3 - Lamellar gypsum crystals (SEM)

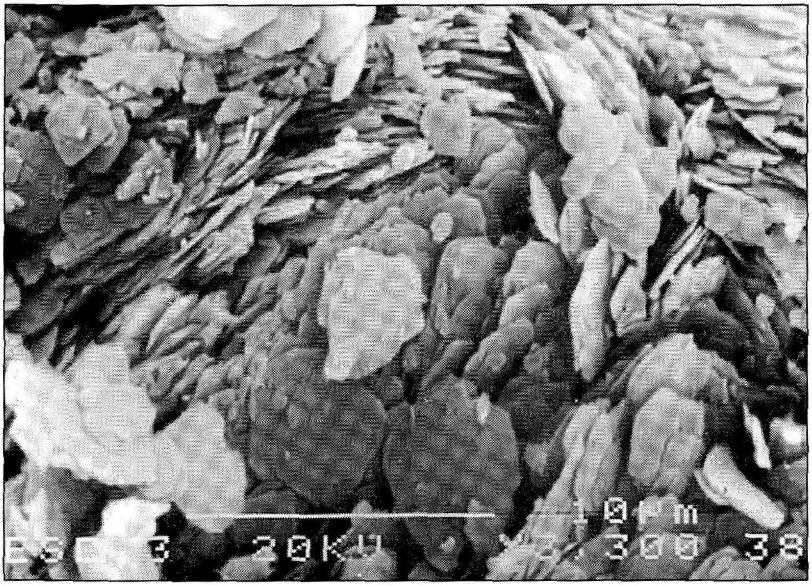

Fig. 4 - Plate like lamellae of gydromagnesite (SEM)

SEM Analysis

The crystalline phase of calcitic moonmilk as it is shown on the scanning electron microscope consists of threadshaped calcite crystals (**Bernasconi,1975**), having almost similar sizes (**Fig.1**); the surfaces of the crystals are covered with colloidal clayey particles which are probably responsible for the ability of the moon-milk to retain such an impressive amount of water. Some of these threadshaped calcite crystals are in fact pseudomorphs of calcite after monohydrocalcite.

In the moonmilk sample which had provided, through X-ray analysis, the presence of gypsum and calcite we identified threadshaped calcite crystals in association with specific striated (**010**) faces gypsum (**Fig. 2**). Lamellar gypsum crystals are also very common in the structure of the moonmilk (**Fig. 3**) we sampled from one of the caves.

Microscopic thin plate-like lamellae (**100**) of hydromagnesite (**Fig. 4**) were identified in only one moonmilk sample, collected from behind a gypsum "balloons" (**Onac, and Lauritzen**, in press).

DISCUSSION AND CONCLUSIONS

The direct precipitation from ground water is dependent on its degree of saturation, temperature and the pressure on which the deposition take place. The "punctiform" presence of the moonmilk speleothems along cave galleries could support this statement.

All components of the crystalline phase of calcitic moonmilk are formed from more or less calcium rich natural waters in intimate contact with the cave atmosphere, in which the pH of the system is controlled entirely by the carbonate equilibria. If there are rootlets in the soil through which the percolating water passes, or other sources of CO_2, there will be a corresponding increase in calcite solubility and a lowering of the equilibrium pH.

We believe that carbonate equilibrium from "mother" solution as well as its temperature, and passage ventilation have a major influence in the deposition of moonmilk.

If it is the nature of hydromagnesite to form as finely-microcrystalline or cryptocrystalline moonmilk deposits (**Hill, and Forti, 1986**) the crystalline phase of calcitic moonmilk can exhibit (**Bernasconi, 1975**) much more micro-crystalline forms (thread, lamellar, prismatic etc.). Their genesis can be assigned to the above mentioned conditons as well as to the thermodynamics of crystals growing (**Onac, in prep.**).

Owing to several cross sections made in some moonmilk speleothems we found 2 or 3, sometimes 4 different types of moonmilk layers. Close to bedrock it is almost dry, getting more and more wet in the outermost part of the deposit, corresponding to a depositional sequence from monohydrocalcite to calcite. This observation might prove **Fischer's (1987)** suggestion concerning the moonmilk genesis. In time, when seeping water supply decreases or disappears the whole moonmilk deposit becomes dry, building up a porous calcite crust.

In our opinion all the moonmilk speleothems we examined have a primary origin (**Diaconu, 1976**) precipitating directly from ground water as do other many speleothems.

ACKNOWLEDGMENTS

This work could not have been carried out without generous support of Stein-Erik Lauritzen (Bergen University) who provided some of the samples and gave useful comments on it. Magne Tyseland and Egil Eriksen (Bergen University) helped me with X-ray and SEM analysis. I owe them all my sincere thanks. Also, I wish to thank all my friends who supported my staying in Norway during the last 3 years.

REFERENCES

Bernasconi, R., 1975: Le mondmilch calcitique et ses formes cristallines. Stalactite 25, (2), 6-10.

Diaconu, G., 1976: Quelques considérations sur la génèse du mondmilch calcitique dans les grottes.Trav.Inst.Spéol."E.Racovitza" XV, 207-210, Bucuresti.

Fischer, H., 1987: Untersuchungen an der Mondmilch aus dem Mondmilchloch (Pilatus) und Modell der Mondmilch Genese. Stalactite 3-10.

Hill, C, Forti, P., 1986: Cave minerals of the world. NSS Huntsville, Alabama.

Horn, G., 1937: Uber einige Karsthöhlen in Norwegen. Mittl. Höhlen u. Karstforschung, 1-15.

Høeg, A., 1946: Cyanophyceae and bacteria in calcareous sediments of limestone caves in Nord-Rana, Norway. Nytt Magasin Naturvid. 85, 99-104.

Lauritzen, S.E., 1991: Karst resources and their conservation in Norway. Norsk geogr.Tidsskr., 45, 119-142, Oslo.

Onac, P.B, Farcas, T., 1992: Le moonmilk des grottes de Trollkjerka et de Reshellarn (Lavangsmarka, Nordland, Norvège). Trav.Inst. Spéol. "E.Racovitza", XXXI, 133-137, Bucuresti.

St.Pierre, S., 1967: Cave studies in Nordland, Norway. Studies in Speleology, 1, (5), 275-284.

MINERALOŠKI PODATKI O KAPNIKIH IZ JAMSKEGA MLEKA V JAMAH SEVERNE NORVEŠKE

Povzetek

V prispevku so predstavljeni izsledki mineraloških raziskav kapnikov iz jamskega mleka, nabranih v jamah na severnem Norveškem, onkraj polarnega kroga, v metamorfoziranih kalcitih in dolomitnih marmorjih. Vse jame so aktivne vodne jame. Vsi vzorci jamskega mleka so imeli temperaturo pod 5°C, zmožnost absorpcije vode pa je znašala med 58 - 91 %. Analize z x - žarki so pokazale prisotnost kalcita, monohidrokalcita, hidromagnezita in sadre. Kalcitno jamsko mleko se pod vrstičnim mikroskopom pokaže kot igličasti kristali, pokriti s koloidnimi delci gline, sadra pa v obliki lamel.

Avtor meni, da so ravnotežje karbonatov v "matični" raztopini, njena temperatura in prezračenost rovov, najpomembnejši dejavniki za odlaganje jamskega mleka. Sklepa tudi, da so preiskani kapniki iz jamskega mleka prvotnega nastanka, kar pomeni, da se je jamsko mleko precipitiralo neposredno iz podzemeljske vode.

ISOTOPIC ANALYSES AND ORIGIN OF CO_2 IN SOME MORAVIAN CAVES

IZOTOPSKE ANALIZE IN IZVOR CO_2 V NEKTERIH MORAVSKIH JAMAH

JIŘI ROBERT OTAVA

Izvleček UDK 551.44:551.584(437.1)

Jiři Robert Otava: Izotopske analize in izvor CO_2 v nekaterih moravskih jamah

Podani so rezultati preučevanja CO_2 v nekaterih breznih moravskega krasa, kjer so te količine izredno visoke. Izotopske analize so odkrile vsebnost ^{13}C, ki je običajen v kopenski flori. Z globino narašča CO_2, ustrezno pada količina O_2, medtem ko je količina N_2 stalna. Ta pojav je mogoče razložiti z izcedno vodo iz odlagališča odpadkov, ki je nad jamskim sistemom. Biogene reakcije (dezintegracija, razpadanje) sprožajo oksidacijo, za kar se porablja kisik v jami, sproščajo se hlapi, ki se dvigajo (CH_4), CO_2 pa ostaja v spodnjih delih jame.

Ključne besede: speleologija, jamska klima, plini v jamah, izotopske analize, onesnaževanje podzemlja, Češka republika, Moravski kras

Abstract UDC 551.44:551.584(437.1)

Jiři Robert Otava: Isotopic analyses and origin of CO_2 in some Moravian caves

The origin of a sudden contamination by carbon dioxide in several vertical systems of the Moravian Karst was studied. The isotopic analyses of carbon revealed ^{13}C contents common in terrestric flora. Increase of CO_2 content downwards was accompanied by reciprocal O_2 decrease, while the N_2 content remained constant. Such phenomena could be explained by in-washing of liquids from a large dump-hill, over 50m long, 10m wide and several meters high, situated above the system, into the cave. Oxidation caused by biogenic reactions as disintegration and/or mouldering resulted in the consumption of cave oxygen, production of volatiles which escaped upwards (as CH_4), while CO_2 stayed at the lower parts of the cave.

Key words: speleology, cave climate, gas in cave, isotopic analyses, pollution of underground, Czech Republic, Moravian Karst

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INTRODUCTION

Higher carbon dioxide contents in caves are quite well known and a relatively common phenomenon. The most important condition for CO_2 accumulation is a rather static room sealed in lower part e.g. by sump or by clay.

The origin of carbon dioxide could be natural or artifical. Natural carbon dioxide is known for instance from the north Moravian Zbrašov Cave where it is of juvenile origin (see the tab. No. 2). Artifical CO_2 accumulation could be caused by many sorts of human activities e.g. breathing, burning, pollutants, treatment with explosives and so on. Several years ago the speleological public was excited by fatal accident of Pavel Glozar in a cavity opened by the quarry of Mokra Cement Works in the southern part of the Moravian Karst. The abysmal cavity was surveyed too shortly after the explosions and the primary cause of death was the accumulation of higher carbon dioxide content at the bottom of the cavity.

CO_2 contamination has been proved in several vertical cave systems of the Moravian Karst in some cases with quite confused circumstances. That is why we paid attention to the problem.

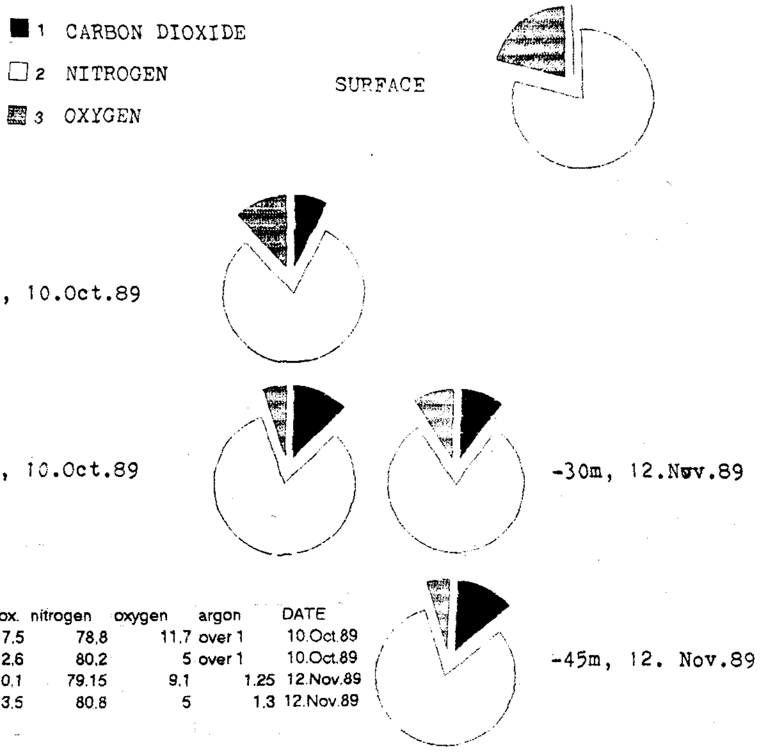
Lažánecký závrt No. 17, Vilémovice-Lažánky Plateau, the Moravian Karst

An abysmal cave system about 90m deep was discovered under the sinkhole at the Vilémovice-Lažánky Plateau of the Moravian Karst in 1988. No carbon dioxide content was observed during the discovering and surveying activities in 1988 and earlier. A group of cavers noticed higher carbon dioxide content at a depth of 25-30m in August 1989. The visitors quickly escaped upwards to the surface because of breath troubles and flame extinguishing. During cave-rescue team training actions (even with oxygen apparatus) several samples of the cave athmosphere were taken from depths of -25, -30 and -45m. The quantitative analyses revealed several interesting facts:

1/ Increase of carbon dioxide content in the deeper parts was always accompanied be reciprocal decresase of the oxygen content, while the content of nitrogen remained constant.

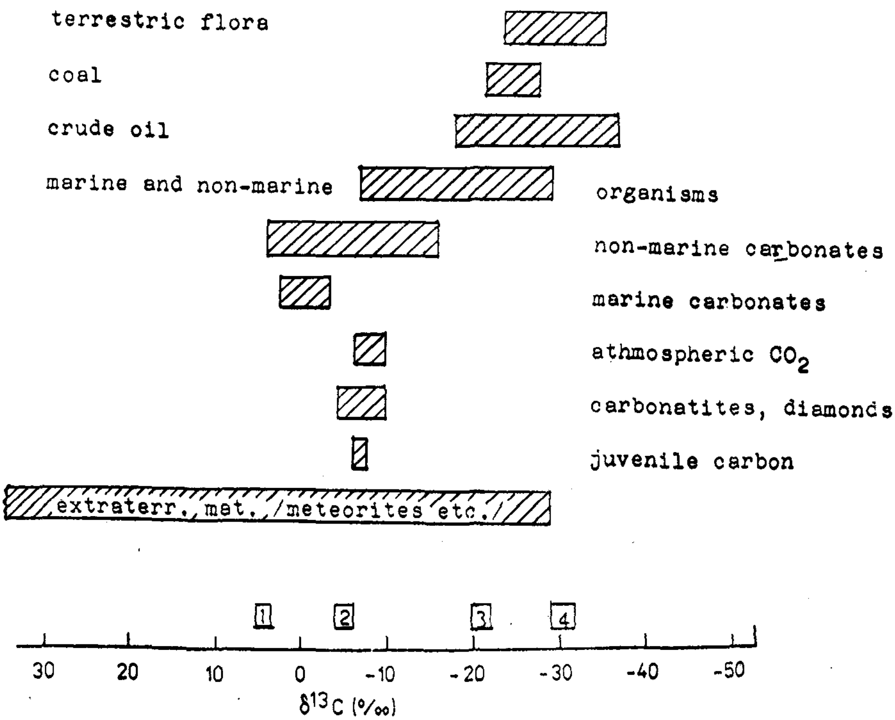
2/ Gradual decrease of carbon dioxide content and lowering of the CO_2 lake surface accompanied the decrease of ou ter temperatures.

However the origin of the gas remained unclear. It is known from the literature (e.g. Castany, 1963) that humic acids and other organic acids could



DEPTH	carb.diox.	nitrogen	oxygen	argon	DATE
25 m	7.5	78.8	11.7	over 1	10.Oct.89
30 m	12.6	80.2	5	over 1	10.Oct.89
30 m	10.1	79.15	9.1	1.25	12.Nov.89
45 m	13.5	80.8	5	1.3	12.Nov.89

Fig. 1 Lažánecký závrt N° 17 Cave. Comparison of the CO_2 content /1/, N_2 /2/ and O_2 /3/ contents at various depths and times. Anal. Z. Boháček, Czech geological survey, Brno.



N°	SITE	material	$\delta^{13}C$ value
1	Moravian Karst	devonian carbonates	0-5,5‰
2	Zbrašov Cave, c.Moravia	juvenile CO_2	-5‰
3	Sedma Cave M. Karst	CO_2	-21,0‰
4	Lažánecký z.17 Cave, MK	CO_2	-30,1‰

Anal. F. Buzek, Czech geological Survey, Prague.

Fig. 2 Variations of $\delta^{13}C$ values in various geological materials. After Hledíková, 1988, arranged.

Comparison with several values measured in the karst terrains of Moravia.

react with carbonates and release carbon dioxide. Other ways of CO_2 production are connected with breathing of plants and other biogenic and biochemical processes as mouldering, disintegration and fermentation. Rather of theoretical value were the chances of juvenile origin of the carbon dioxide, due to distinct N-S dislocation which strongly predisposed the cave system.

The variation of content of the ^{13}C stable isotope in various materials and environments inspired us to apply the isotopic analyse of the carbon stable isotops in solving the problem. The result confirmed the biogenic origin of CO_2 present in the cave (note Tab. No. 2).

The most probable way how to explain the contamination of the cave follows both from the isotope study and from the ratios of nitrogen, oxygen and carbon dioxide in various depths. We think, that the carbon dioxide did not replace the original cave-air, because the normal athmospheric ratio of O_2 : N_2 = approx. 1:4 changed to the ratio of 1:7at the depth of -25m and to the ratio of 1:16 at -30m (October 10th). Next month (November 12th) the O_2 : N_2 ratio was 1:9 in -30m and 1:16 in -45m. We have to suppose that the biogenic reactions consuming oxygen and producing carbon dioxide took part inside the cave. Disintegration seems to be the most relevant process in our case. It is defined as a stage in decomposition of vegetable and animal substances which takes place in the presence of oxygen and moisture. It may be regarded as a slow combustion of organic substance leaving no solid carbon compounds and producing only volatile substances, namely carbon dioxide and water. Mouldering is less suitable as it is characterized with inadequate air available for complete disintegration which, because it is incomplete, leaves small quantities of substances rich in carbon as residual. Fermentation needs only a small amount of oxygen and sometimes produces acids besides carbon dioxide.

The above described case is interesting not only from the scientific point of view, but for ecological purposes and for the safety of the cave visitors too. The deposition of dump-hills on the carbonate surface is dangerous not only for the ground water pollution, but also in special cases for CO_2 contamination of caves. It is further serious argument in favour of excluding dump-hills from the karst terrains or at least for arranging a waterproof deposition sealed e.g. by clay. The outwashing of liquids has to be blocked.

It is probably worthwhile to mention briefly the destiny of carbon dioxide contamination of the cave since the autumn 1989 sampling. During the check-descent at January 13th 1990 no carbon dioxide was noticed at the depth of -45m. In summer 1993 high concentrations of the gas were observed again at the depth of -25m.

The Sedma Cave and the Ve Ćlopech Cave, Babice Plateau, the Moravian Karst

The history of the abysmal Ve Ćlopech Cave includes repeated contamination by up to 8,5% of carbon dioxide. The details are described by Havel (1991) and the origin of the gas is again ascribed to the biochemic reactions and suitable morphology of the cave.

The other cave at the Babice plateau, the abysmal system of Sedma was discovered in 1991 and it contained since the beginning about 3% of carbon dioxide (Šeda, 1992). One sample of the cave air from the depth of about 40m was analysed both for carbon dioxide content and for the stable isotops of carbon composition:

The CO_2 content was 2,05%, N_2=78,1 and O_2=17,73%. It is clear, again that a part of the cave oxygen was converted to carbon dioxide by biogenic reactions inside the cave. The content of $\delta^{13}C$ = -21‰ is somewhat different from the value measured carbon dioxide of the former site. The final conclusion on the difference between the two samples could not be done from the two analyses, nevertheless there are at least two ways how to explain it. The first one considers the fact that the differences in isotopic composition of carbon in plant tissues are influenced by different mechanisms of photosynthesis. The other explanation could follow from mixing of carbon dioxide of different origin (athmosphere, soil, organic remnants, see tab.) which is favoured by relatively low concentration of the gas.

The recent investigations of the regional contamination of the ground water under the Babice plateau proved that it is connected not only with dump-hills but even more probably with industrial waste including oil derivates etc. The carbon dioxide contents in the local cave systems could be probably influenced by such a source too.

CONCLUSIONS AND ACKNOWLEDGEMENTS

Analyses of carbon dioxide, nitrogen and oxygen volume contents (partial pressures) and analyses of the isotopic composition of carbon enabled us to decipher the origin of carbon dioxide in several caves. Nevertheless the complicated history of the reappearing and disappearing of the contamination remains confused and surely needs much more regular observation, sampling and analysing.

Finally it is a pleasure for me to thank my colleagues, cavers from Suchý žleb and Babice Clubs and from the Cave Rescue Group, for help with the taking of samples. I am obliged to my geochemist colleagues for much valuable advice and analysis.

REFERENCES

Castany G. 1963: Traité pratique des eaux souterraines: Dunod, Paris 1963

Havel H. 1991: Jeskyně a oxid uhličitý, (Czech with English abstract), Speleoforum 91, Czech speleological society, Brno 1991

Hladiková J. 1988: Základy geochemie stabilních isotopù lehkých prvkù: skripta Př.f.UJEP (in Czech) 1988 Brno.
Šeda J. 1992: Discoveries at the Sedma sink-hole on the Babice plateau, (In Czech with English abstract): Speleoforum 92, Czech speleological society, Brno

IZOTOPSKE ANALIZE IN IZVOR CO_2 V NEKATERIH MORAVSKIH JAMAH

Povzetek

Prispevek podaja rezultate preučevanja CO_2 v treh breznih moravskega krasa, kjer so te količine izredno visoke. Izotopske analize so odkrile vsebnost ^{13}C, ki je običajen v kopenski flori, kar tudi potrjuje biogeni nastanek CO_2. Z globino narašča CO_2, ustrezno pada količina O_2, medtem ko je količina N_2 stalna. Ob padanju zunanje temperature se tudi količine CO_2 zmanjšujejo. V drugem primeru je ta pojav mogoče razložiti z izcedno vodo iz odlagališča odpadkov, ki je nad jamskim sistemom. Biogene reakcije (dezintegracija, razpadanje) sprožajo oksidacijo, za kar se porablja kisik v jami, sproščajo hlapljevine, ki se dvigajo navzgor (CH_4), CO_2 pa ostaja v spodnjih delih jame.

KARST PHENOMENA AND THE ORIGIN OF BAUXITE

KRAŠKI POJAVI IN NASTANEK BOKSITA

RAJKO PAVLOVEC

Izvleček UDK 553.492:551.44

Pavlovec Rajko: Kraški pojavi in nastajanje boksita

V Zunanjih Dinaridih so dobri primeri odvisnosti nastajanja krasa in boksita, ki se je kopičil v depresijah na apnenčevi podlagi. Večina boksitnega gradiva izhaja iz preperelih apnencev.

Ključne besede: geologija, kras, rudna ležišča, boksit

Abstract UDC 553.492:551.44

Pavlovec Rajko: Karst Phenomena and the Origin of Bauxite

The Outer Dinarids offer good examples of correlation as to the formation of karst and bauxite accumulating in the depressions on a limestone basement. Most bauxite material comes from limestones decay.

Key words: geology, karst, mineral deposits, bauxite

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Bauxite may appear as a result of magmatic and metamorphic rock decay. However, alumosilicates play a very important role in the process. On the other hand, bauxite may form from limestone, as well as from marl and claystone, if the latter contains a sufficient proportion of clay minerals (M. Drovenik, 1984). Croatian geologists, namely M. Kišpatić, F. Tućan and L. Marić had limestone in mind, and terra rossa as an intermetiate phase. Yet, pure limestone leaves over no more than 2% of insoluble residue, containing 0,04%

$Al_2 O_3$ means that incredibly huge amounts of limestone would have had to dissolved to result in bauxite strata. Besides aluminium oxides, terra rossa comprises a rather high percentage of quartz - nearly up to 40%. Bauxite usually does not have that much, therefore quartz would be supposed to have got lost somewhere in the course of bauxitisation. The bauxite ores in Herzegovina, at Lištica, for example, contain 2 to 11% of quartz and 44 - 54% of $Al_2 O_3$ while those in the area of Imotski have less than 1% of quartz in some places, 16% being the greatest quantity, the presence of $Al_2 O_3$ ranges between 40 to 60%, though (K. Sakač et al., 1984; K. Sakač et al., 1987).

The whole problem should be considered from another point of view as well. The majority of bauxite in Herzegovina, Dalmatia and Istria lies on a Cretaceous and Paleogene paleorelief (cf. M. Knez & R. Pavlovec, 1990). Here and there, bauxite appears on clastic structures, too, yet researches point to a transmission and subsequent processes in moors or in the sea (K. Sakač et al., 1984). The bauxite from the area of Drniš and other parts of Dalmatia disposes even of sea fossils (R. Pavlovec, 1959; K. Sakač, 1966). This facts could be regarded as a reliable proof for the bauxite mass having been transmitted to the sea, sustained furthermore by the occurrence the underlying and overlaying marine beds.

Let us have now a look at the bauxite lying on a paleokarstic relief. In the Outer Dinarids there are many cases lending themselves to a deliberation as to the origin of bauxite. In Istria the depositon of Cretaceous limestone led to a emersion, being followed by a karstification and the appearance of an uneven karstic surface as well as karstic caves (cf. G. Bignot, 1972; M. Knez & R. Pavlovec, 1990). Karstic forms are frequently filled with bauxite, which, as we may state now, undoubtedly appeared between the Upper Cretaceous period and Eocene, its position being secondary.

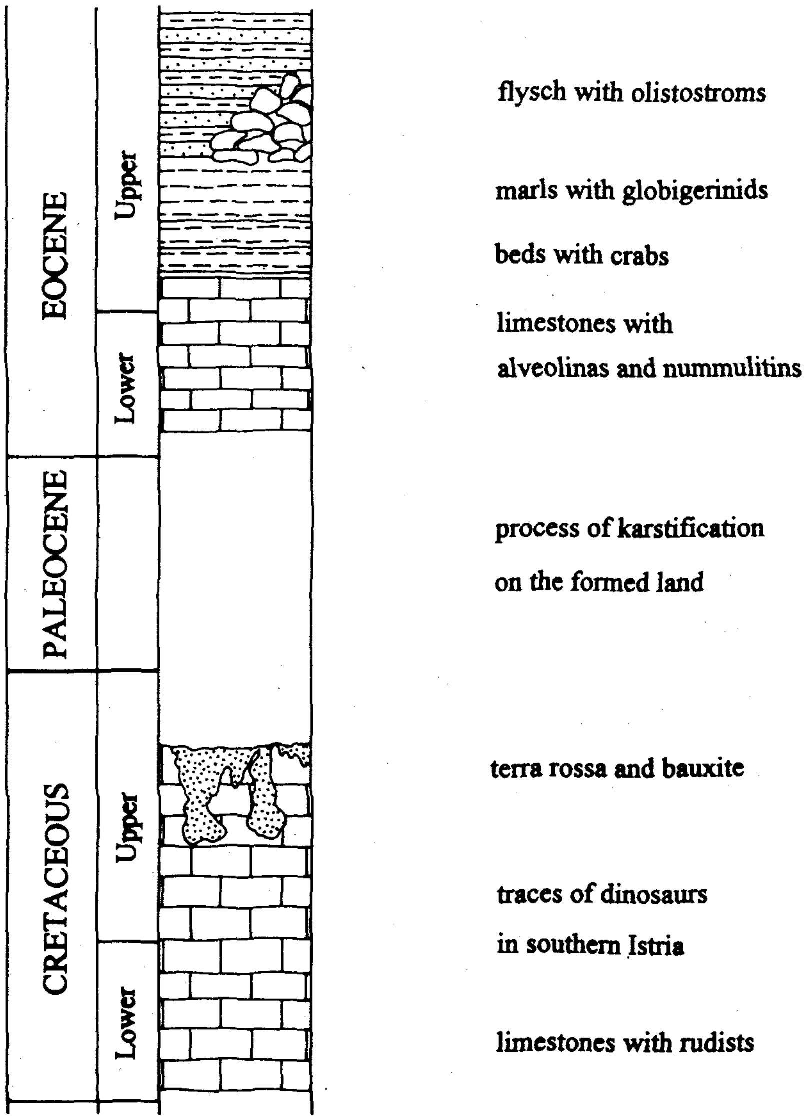

Fig. 1. Schematical vertical section through the Cretaceous and Paleogene beds in Istria.
Sl.1. Shematski stolpec krednih in paleogenskih plasti v Istri.

The bauxite genesis in Western Herzegovina was closely examined bay Croatian geologists (K. Sakač et al., 1987; I. Dragičević et al., 1986). They came to the conclusion that the bauxite from the surroundings of Lištica had started appearing by the end of the Cretaceous period and continued up to the end of Paleocene or the beginning of the Eocene during a land phase, on a rather level mainland where physical decay of the carbonate basement used to be outdone by chemical decay. The bauxite mass was transmitted in the negative relief. The transmission could have been complex, with the bauxite however being simultaneously affected by various physical and chemical processes. The appearance of bauxite near the place Studena vrela has been given a similar explication.

Thus, a conclusion may be drawn, namely, the bauxite in the Outer Dinarids was not in its primary position. Yet, we must exclude the supposed transmission of material from the magmatic or metamorphic rocks, such sequences being absolutely nonexistent even far away from the present deposits of bauxite in Istria, Dalmatia and Herzegovina. Violent tectonic moves in the Outer Dinarids - having brought older rocks, such as tuffs and others, to the surface of the platform - were thought of (cf. M. Drovenik, 1984). On the islands, this material was to have brought about the appearance

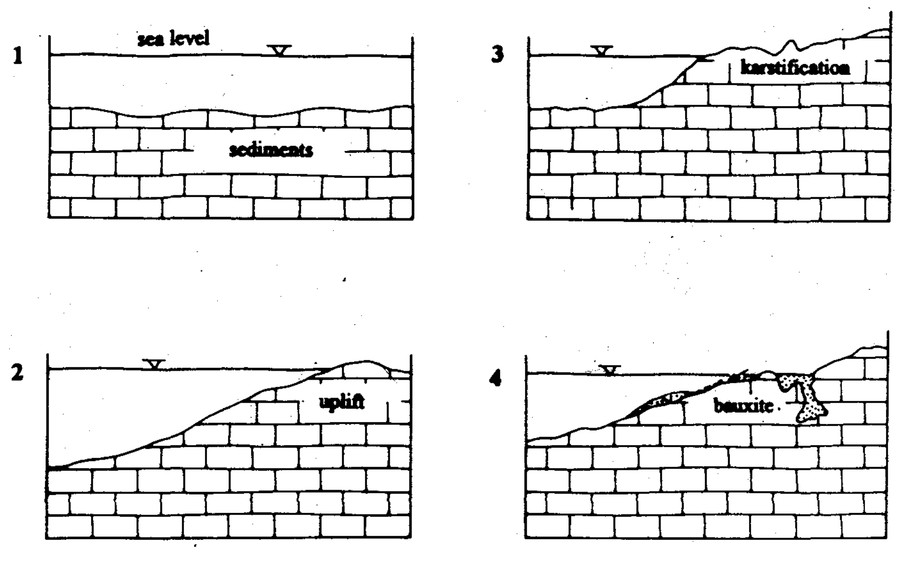

Fig. 2. Simplified model of the formation of bauxite in the Cretaceous and Paleogene in Outer Dinarids.
Sl. 2. Poenostavljen model v kredi in paleogenu Zunanjih Dinaridov.

of bauxite, later on washed off in a karstic relief. Yet, it is hardly believable that the majority of Cretaceous and Paleogene bauxite in the Outer Dinarids would have appeared in such a way, as there are no proofs of frequent moves of probably smaller bodies.

Because there is a comparatively small amount of insoluble residue left over in limestones of the Outer Dinarids we must consider the transmission of bauxite material from limestones, mostly, and to a lesser degree from other rocks; even the wind factor can not be totally neglected, though (cf. K. Sakač et al., 1987). The reason why bauxite used to accumulate only on karstified limestone surface and not on other rocks, can be explained by a karstic relief strongly expressed on limestones. Due to the fact that depressions or negative relief configurations, respectively, arose also as a result of tectonic moves on other rocks - usually devoid of bauxite - we may conclude as top the transmission of bauxite material from limestone rocks, not too distant, either.

Thus, we can draw logical inferences: *In the Outer Dinarids bauxite* occupies mostly the secondary places, its main origin being in the limestones. The transmission of the bauxite mass could not have been particularly long-lasting. We must, above all, keep in mind the washing off of the bauxite mass into funnels, abysses and other karstic forms.

Owing to the fact that bauxite deposits are to be found on the Cretaceous limestone with a Paleogene hanging wall strata, as well as inside the Paleogene limestones, we may come to the conclusion that the karstification occurred immediately after the emergence, should proper physical/chemical conditions, favourable to the appearance of karst, be given.

REFERENCES

Bignot, G. 1972: Recherches stratigraphiques sur les calcaires de crétacé supérieur et de l'éocene d'Istrie et des régions voisines. Essai de révision du liburnien.- Travaux Labor. Micropal., 2, 1-353, pl. 1-50, Paris.

Dragičević, I., Tišljar, J., Blašković, I. & Benić, J., 1986: Mehanizam taloženja krovinskih naslaga ležišta boksita kao odraz paleoreljefa podine (Depositional model for roof sediments of bauxite deposits as related to the paleokarst relief).- Naučne komunikacije, 1. Odd. teh. nauka, 1, ANU BiH, 1-37, Sarajevo.

Drobne, K. 1979: Paleocene and Eocene beds in Slovenia and Istria.- 16th Europ. micropal. Coll., 49-64, Ljubljana.

Drovenik, M. 1984: Nahajališča mineralnih surovin.- Fakulteta za narav. tehnol., Montanistika, 1-375, Ljubljana.

Knez, M. & Pavlovec, R. 1990: Paleokras v starejšem paleogenu Zunanjih Dinaridov (Paleokarst in Older Paleogene of the Outer Dinarids).- Rudar.-metal. zbornik, 37/3, 359-365, Ljubljana.

Pavlovec, R. 1959; Zgornjeeocenska favna iz okolice Drniša (The Upper Eocene fauna from the surroundings of Drniš in Dalmatia).- Razprave

4. razr. SAZU, 5, 349-416, tab. 1-2, Ljubljana.
Sakač, K. 1966: Marinski fosili u boksitu Dalmacije (Marine fossils in bauxites of Dalmatia).- Geol. vjesnik, 19, 131-138, tab. 1-2, Zagreb.
Sakač, K., Šinkovec, B., Babić, L., Sesar, T., Drobne, K. & Zupanič, J. 1987: O tektonici, sedimentima paleogena i ležištima boksita područja Lištice u Hercegovini (On Tectonics, Paleogene Sediments and Bauxite of the Lištica region in Herzegovina).- Geol. vjesnik, 40, 351-378, tab. 1-2, 1 pril., Zagreb.
Sakač, K., Šinkovec, B., Jungwirth, E. & Lukšić, B. 1984: Opća obilježja geološke gradje i ležišta boksita područja Imotskog (Common Features of Geological Structure and Bauxite Deposits in the Imotski Region (Dalmatia - Herzegovina, Yugoslavia)).- Geol. vjesnik, 37, 153-174, tab. 1-3, 1 pril., Zagreb.

KRAŠKI POJAVI IN NASTANEK BOKSITA

Povzetek

Boksit nastaja ob preperevanju magmatskih ali metamorfnih kamnin ter apnenca, redkeje laporja in glinovcev. Ob preperevanju apnenca dobimo tako malo netopnega ostanka (okrog 2%, od tega okrog 0,04% Al_2O_3), da celotne jerovice in boksita ne moremo razložiti samo s tem procesom. Prav tako je vprašanje, zakaj je v boksitu znatno manj kremena kot v jerovici, če bi proces potekal preko jerovice.

Te probleme moremo dobro opazovati v Zunanjih Dinaridih, to je v Istri, Dalmaciji in Hercegovini. Tam je največji del boksita na krednem in paleogenskem paleoreljefu v apnenčevih kamninah (M. Knez & R. Pavlovec, 1990). Nekateri boksiti so bili preloženi v močvirja ali morja (K. Sakač et al., 1984), kjer so se včasih pomešali z morskimi fosili (R. Pavlovec, 1959; K. Sakač, 1966). Za naša razpravljanja so zlasti zanimivi boksiti na paleokraškem reljefu. V Istri je prišlo po odložitvi zgornjekrednih apnencev do dviganja in sledilo je zakrasevanje (cf. G. Bignot, 1972; M. Knez & R. Pavlovec, 1990). V eocenu je bila nova transgresija (K. Drobne, 1979). Paleokraški prostori so v Istri marsikje zapolnjeni z boksitom, ki je torej na sekundarnem mestu. Tudi drugod se je kopičila boksitna masa v negativnih reljefnih oblikah, prenašanje je bilo lahko večkratno (K. Sakač et al., 1987; I. Dragičević et al., 1986). Ker pa so magmatske ali metamorfne kamnine sorazmerno daleč proč od Istre, Dalmacije ali Hercegovine, lahko izvor boksita iščemo na preperelih apnencih.

Iz tega sledi, da je večina boksita v Zunanjih Dinaridih na sekundarnem mestu. Glavni izvor materiala je v apnencih. Transport boksitne mase ni bil posebno dolg in misliti moramo predvsem na spiranje v vrtače, brezna in druge kraške oblike. Ker je boksit sredi apnencev, lahko sklepamo, da je prišlo do karstifikacije takoj po umiku morja, če so bili za nastajanje krasa primerni fizikalno kemični pogoji.

RUDISTID BIOSTROMS IN THE LIPICA QUARRY NEAR SEŽANA (SW SLOVENIA)

RUDISTNE BIOSTROME V KAMNOLOMU LIPICA PRI SEŽANI (JZ SLOVENIJA)

MARIO PLENIČAR
&
JOŽEF VESEL

Izvleček UDC 553.5(497.12 Sežana)

Mario Pleničar & Jožef Vesel: Rudistne biostrome v kamnolomu Lipica pri Sežani (JZ Slovenija)

Kamnolomi Lipica pri Sežani na primorskem krasu so sedaj največji kamnolomi naravnega kamna v Sloveniji. Stratigrafsko zaporedje plasti je sestavljeno iz treh litotipov: "Lipica fiorito" (Lipica rožasti), "Lipica unito" (Lipica enotni) in "glažavec". V vseh treh litotipih najdemo isto fosilno favno, značilno za santonijsko in campanijsko stopnjo. Favno in karbonatne litotipe v kamnolomu Lipica lahko primerjamo s podobnimi v Cava Romana pri Nabrežini v Italiji.

Ključne besede: Lipica, kamnolomi, karbonatni litotipi, santonijske in campanijske biostrome

Abstract UDC 553.5(497.12 Sežana)

Mario Pleničar & Jožef Vesel: Rudistid Biostroms in the Lipica Quarry near Sežana (SW Slovenia)

Of the great number of quarries in Karst, now only the Lipica quarry is active. There are two kinds of limestone suitable for ornamental purposes in the building industry, in the stonemasonry nominated "fiorito" and "unito". From bottom to top in the Lipica quarry section two lithological intervals are present: - lower interval ("fiorito") is one of the coarse grey micritic limestones with the period of hippuritid and radiolitid biostroms - upper interval ("unito") is the massive bedding bioclastic limestone with very fine rudist fragments. The fossil fauna is typical of the Upper Senonian age.

Key words: Lipica, quarry, carbonate lithotype, Santonian and Campanian biostroms

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A group of the quarries of the natural stone Lipica is about 6 km SE from Sežana in the area of the typical littoral karst. At present the blocks of the natural stone in two quarries Lipica-1 and Lipica-2 are exploited. Lipica-1 is at 0,6 km from the crossroads of the roads Sežana-Lokev and Sežana-Lipica. Lipica-2 is only 0,2 km from the same crossing.

In the quarry Lipica-1 more than 1000 m^3 of the blocks were exploited annually through some decades, and now it is the largest quarry of the natural stone in Slovenia.

Because of the flat topography the quarry is developed as deep open pit of 90 x 60 m, about 40 m deep.

The quarrying activity started 2000 years ago in the Roman age like in the Cava Romana near Aurisina.

The quarrying is carried out at different levels with the diamond wire saw, percussive drilling, hydraulic pushing, rarely delicate mining, with the mechanical and manual formulation and hoisting and loading with the derric crane.

The province of the Lipica quarries belongs to the so-called Nabrežina horizon.

Two deep quarries near Lipica are characterized by a series of grey micritic and bioclastic limestones. The open pit quarry Lipica-1 pertains to the northern flank of a small synclinal fold of axial direction NNW-SSE. The beds dip 10 to 35^0 southwestward. The stratigraphical sequence is constituted of three lithotypes:

Below is the lithotype "Lipica fiorito" (florid Lipica). The rock is light grey micritic limestone with very abundant bioclasts (Rudists) which are subparallel to the bedding. The rock is compact, solid or thickly bedded. The thickness of the level was estimated to 45 m.

Higher we observe the lithotype "Lipica unito" (unitary Lipica), the light breccious limestone (rudistid limestone) of massive bedding with the metric period. The unbroken shells of rudistids and the rudistid fragments have some mm to cm in size. The thickness of "Lipica unito" can be also about 40 m.

Both horizons, "Lipica fiorito" and "Lipica unito" are exploited as natural stone. Frequent lateral and vertical variations of facies can be detected.

The uppermost part of the Lipica sequence is the bioclastic grey to dark-grey limestone with rudist fragments, and bedding with the periods from 50 to 200 cm. This is the so-called "glaževec" (glassy stone) with the periodic repetitions of "Lipica fiorito" and "Lipica unito" lenses.

On the Triest-Komen Plateau the numerous patch reefs of the Senonian age are known. The "Lipica unito" has been formed in the area of fore-reef zone with the higher energy of the waviness, quite different of the "Lipica fiorito" and "glaževec" originating in the more calm water between the patch-reefs.

The later recrystallization of both types of the limestones was the favourable moment for the suitable physical - economical properties. The chemical composition of both limestones is quite similar. Both varieties are pure limestone. The carbonatic component exceeds 98%.

From the stratigraphical viewpoint, the sequence of the Lipica limestones is of Senonian age. All three lithotypes are extremely rich in rudists.

The shells are well preserved, but it is hard to obtain the undamaged fossil remains from the dense carbonatic rock. Frequently just numerous valve sections on the cutting surfaces of the limestone in the quarry can be observed and studied, especially in the vertical walls. The sections of the dark coloured shells are sometimes subparallel to bedding.

In the limestone of the lithotype "Lipica fiorito" the rudists are confined to the belts from 10 to 50 cm thick. The intermediate rocks are without rudists. The intervals rich in rudists represent the sections of biostroms, but sometimes the valves are accumulated also as fossiliferous breccias.

In the limestone of the lithotype "Lipica fiorito" the following rudist specimens typical for the backreef area were determined: Bournonia retrolata (Astre), B. cf. murensis Pejović, B. parva Pejović, Biradiolites zucchii Caffau & Pleničar, Katzeria hercegovinaensis Slišković, Pseudopolyconites sp. and Apulites sp.

Similar fauna but from the forereef zone was found in the "Lipica unito" lithotype with rudists: Hippurites sp., Bournonia parva Pejović, Biradiolites angulosissimus Toucas, Durania martellii Parona, Gorjanovicia costata Polšak, Pseudopolyconites hirsutus (Patrulius), Katzeria hercegovinaensis Slišković and Sauvagesia sp.

The biostrome in the uppermost lithotype, the "glažavec", represent periods from 50 to 200 cm. The frequent fossil remains represented by genera Bournonia, Gorjanovicia, Sauvagesia, Biradiolites and Katzeria confirm the Upper Senonian age.

In all mentioned carbonate lithotypes of the Lipica quarry occurs the same fossil fauna which pertains to the early Senonian age. The specimens: Bournonia parva Pejović, Katzeria hercegovinaensis Slišković, Gorjanovicia costata Polšak and Biradiolites zucchii Caffau & Pleničar but are typical fossils for the Santonian and Campanian stage.

The specimen Bournonia parva is characteristic after Pejović for Lower

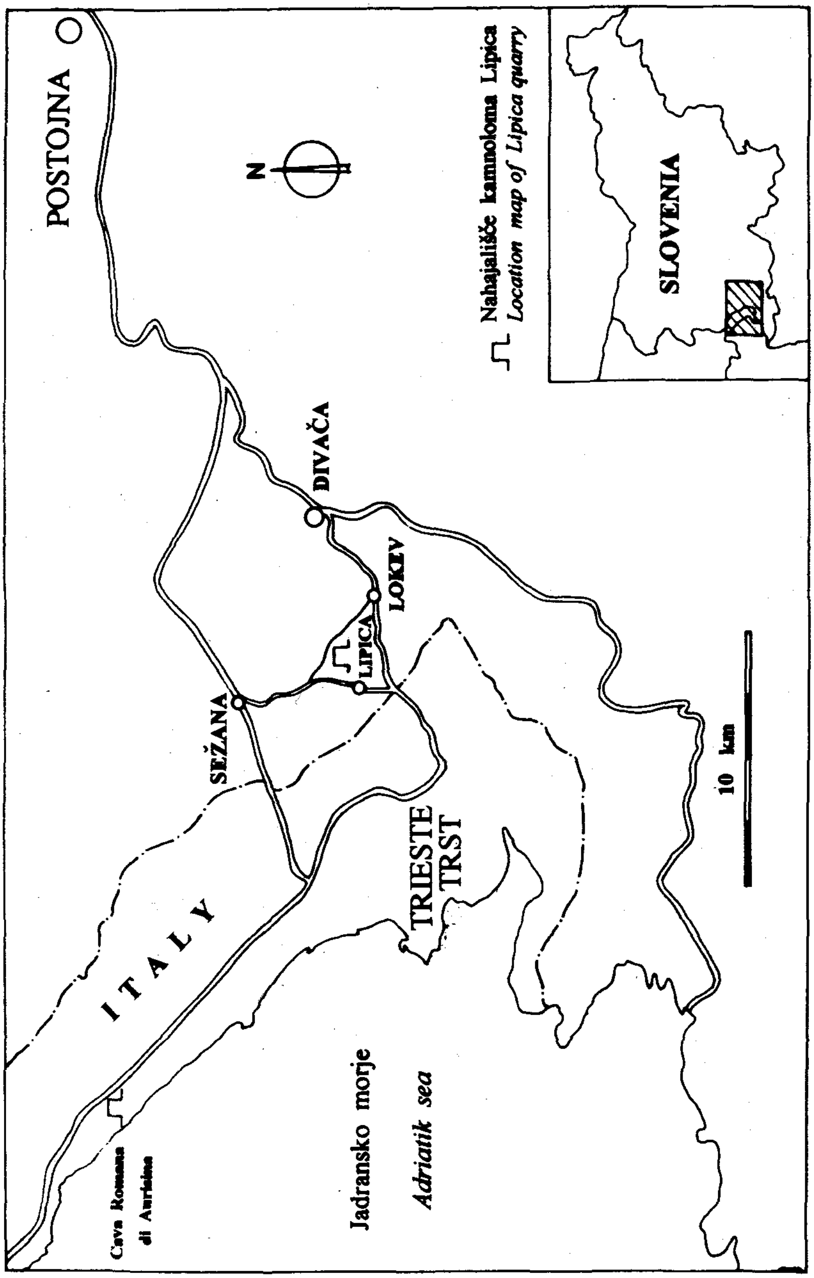

Fig. 1. Location map of Lipica quarry
Sl. 1. Nahajališče kamnoloma Lipica

Campanian of Brač island (Pejović 1988). Katzeria hercegovinaensis was ranged by Slišković and Polšak et al. in the Upper Campanian and in the Maastrichtian of Bosnia and Dalmatia (Slišković 1966; Polšak & Bauer & Slišković 1982). Gorjanovicia costata is typical after Polšak to Santonian and Lower Campanian stage of Istria (Polšak 1967). Biradiolites zucchii Caffau & Pleničar was found also in Cava Roman (Roman Quarry) near Aurisina (Italy, NW of Triest) in the upper part of the "Borgo Grotta Gigante Formation" which is of the Upper Senonian age (Caffau & Pleničar 1991).

The fauna and the carbonate lithotypes in the Lipica quarry can be compared with the similar or equal ones in the Cava Romana quarry near Aurisina. The stratigraphic sequence at Cava Romana is after Cucchi et al. constituted of lithotypes A to D of the "Borgo Grotta Gigante Formation" appertaining to the Upper Senonian. The fauna of the Cava Romana limestone consists of species: Hippuritella cf. castroi (Vidal), Hippurites nabresinensis Futterer, H. heritschi Kühn, Gorjanovicia costata Polšak, Rajka pejovicae Milovanović, Bournonia africana Douvillé, B. retrolata (Astre), B. parva Pejović and Katzeria hercegovinaensis Slišković (Cucchi et al. 1987). At least six species of radiolitids at Lipica and in Cava Romana are the same, and they are typical for Santonian and Campanian stage. The lithotype A in Cava Romana quarry can be compared with the "Lipica fiorito", the lithotypes B and C with the "Lipica unito", and the lithotype D with the "glažavec" in the Lipica quarry.

REFERENCES

Caffau, M. & Pleničar, M., 1991: Biradiolites zucchii n.sp. nella Cava Romana di Aurisina.- Geologija 33, 207-213, pls. 1-3, Ljubljana

Cucchi, F., & Pugliese, N. & Klingendrath, A. & Zucchi-Stolfa, M.L. 1987: Cava Romana Area.- Excursions - 4th June 1987, Karst of Trieste, Guidebook; International Symposium on the Evolution of the Carbonate Platform, Trieste June 1987, 14-24, Trieste

Pejović, D., 1988: New Bournonias from the Senonian of Brač.- Bull. de l'Acad. Serbe des Sciences et des Arts 95, Science natur. 28, 41-45, pls. 1-5, Beograd

Polšak, A., 1967: Microfaune Crétacé de l'Istrie Meridionale, Yougoslavie.- Palaeontologia Iugoslavica, JAZU 8, 218 pp. 85 pls., Zagreb

Polšak, A. & Bauer, V. & Slišković, T. 1982: Stratigraphie du Crétacé Supérieur de la Plateforme Carbonatée dans les Dinarides Esternes.- Cretaceous Research 3, 125-133, Academic Press Inc., London, Limited

Slišković, T., 1966: Katzeria hercegovinaensis n.gen. n.sp. aus den obersenonischen Ablagerungen der Südherzegowina.- Bull. Sc. Cons. Acad. Yougoslavie 11 (7-9), 177-178, figs. 1-2, Zagreb

RUDISTNE BIOSTROME V KAMNOLOMU LIPICA PRI SEŽANI (JZ SLOVENIJA)

Povzetek

V dveh kamnolomih v Lipici blizu Sežane izkoriščajo kot naravni kamen dve vrsti apnenca. Prvi je masivni oziroma zelo debelo skladnat mikritni in bioklastični apnenec, imenovan v kamnoseštvu "Lipica fiorito" (Lipica rožasti). Na njem leži bolj brečast "Lipica unito" (Lipica enotni). Tudi ta je masiven in primeren za kamnoseštvo. Oba izkoriščajo kot naravni kamen. Krovnino obeh predstavlja plastnati "glažavec", iz katerega zaradi razmeroma tanke plastnatosti in tudi manj ugodnih lastnosti ne pridobivajo blokov za prodajo. Oba kamnoloma pri Lipici sta izdelana v ravninskem svetu pod nivojem okolice. Bloke apnenca dobivajo z žično diamantno žago, udarnim vrtanjem, šibkim miniranjem ter ročnim in mehaničnim obdelovanjem. Iz kamnoloma dvigajo bloke z dvigali tipa derrick.

Obe vrsti apnenca, ki ju izkoriščajo kot naravni kamen, imata ugodne fizikalne in ekonomske lastnosti zaradi ponovne kristalizacije, ki sta jo doživela v globini. Vsebujeta nad 98% karbonatne komponente. Klaste predstavljajo lupine rudistov, pretežno radiolitov. Litotipa "Lipica fiorito" in "glažavec" sta nastajala v razmeroma mirni morski vodi v zagrebenski coni ali morda tudi med malimi grebeni (patch-reefs), ki so jih gradili rudisti. Litotip "Lipica unito", ki je bolj brečast, kaže na izvor v predgrebenski coni, kjer je bilo valovanje morja močnejše.

Iz goste karbonatne kamnine ne moremo izpreparirati celih lupin fosilov, pač pa preučujemo njih preseke na ravno odrezanih apnenčevih stenah v kamnolomu ali pa na blokih. Lupine so koncentrirane v pasovih. ki predstavljajo preseke biostrom. Vmes so pasovi apnenca brez fosilov. Temne lupine se lepo odražajo od svetlo sivega apnenca.

Vrste Bournonia retrolata (Astre), B. cf. murensis Pejović, B. parva Pejović, Biradiolites zucchii Caffau & Pleničar, Gorjanovicia costata Polšak, Pseudopolyconites hirsutus Patrulius in Durania martellii Parona so značilne za santonijsko in campanijsko stopnjo zgornjega senona.

Obe vrsti apnenca, ki ju izkoriščajo kot naravni kamen in tudi fosilno favno v kamnolomih Lipica, lahko primerjamo z apnencem, ki ga izkoriščajo na italijanski strani v kamnolomih Cava Romana pri Nabrežini. Apnenci pri Lipici kot v Cava Romana pripadajo "nabrežinskemu horizontu" zgornje krede.

FAUNA HUNTED BY PLEISTOCENE INHABITANTS OF THE INNER CARNIOLA AND LITTORAL KARST

LOVNE ŽIVALI PLEISTOCENSKIH PREBIVALCEV NOTRANJSKO-PRIMORSKEGA KRASA

VIDA POHAR

Izvleček UDK 569(119.1)(497.12)

Vida Pohar: Lovne živali pleistocenskih prebivalcev Notranjsko-Primorskega krasa

Pleistocenski prebivalci v votlinah puščali ostanke lovskega plena. Na Notranjsko-primorskem krasu je 10 takih nahajališč. Raziskave kažejo na zgornjepleistocenski čas. Favna v sedimentih starejšega zgornjega pleistocena je enovita. Poleg jamskega medveda (95 %), so volk, lisica, jamski lev in hijena, orjaški in navadni jelen in pleistocensko govedo. Ob otoplitvi sta se pridružila nosorog in divja svinja, ob ohladitvah svizec, planinski zajec, stepski bizon in severni jelen. V zgornjem würmu so lovci plenili severne jelene in svizce. V kasnem glacialu se je klima otoplila in je močno upadlo število predstavnikov arktično alpske favne.

Ključne besede: kvartarologija, pleistocenska favna, antropospeleologija, Slovenija, Notranjsko-primorski kras

Abstract UDC 569(119.1)(497.12)

Vida Pohar: Fauna hunted by Pleistocene inhabitants of the Inner Carniola and Littoral Karst

The Pleistocene man left behind the remains of his game in the Inner Carniola and Littoral Karst caves. Habitats were discovered so far in the Karst area. Researches of fossil fauna remnants point to Upper Pleistocene period. The fauna composition of the older period of Upper Pleistocene is rather unified. Besides cave bear (95 %), there were wolf, fox, cave lion and hyena, giant and red deer and Pleistocene bovid. In warmer times they were joined by rhinoceros and wild hog, during cooler climate marmot, mountain hare, steppe wisent and reindeer. During the Upper Würm the Pleistocene hunters chased reindeer and marmot. The Late Glacial improvement of climate conditions resulted in decline of the arctic-alpine fauna representatives.

Key words: Quaternary, Pleistocene fauna, anthropospeleology, Slovenia, Inner Carniola and Littoral Karst

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Der Großteil von Innerkrain und Küstenland wird von im Wasser leicht löslichen Karbonatgesteinen aufgebaut, so konnten sich neben anderen Karsterscheinungen auch Höhlen entwickeln. Im Pleistozän suchte der Eiszeitmensch darin oft Zuflucht und hinterließ uns Spuren seines Aufenthaltes auch in Form von Jagdbeute. Auf dem innerkrainisch-küstenländischen Karst sind bisher 14 solche Unterkünfte bekannt (Abb. 1 und 2). Gerade diese altsteinzeitlichen Fundstätten geben Aufschluß über die Tiere, die in einzelnen Pleistozänabteilungen den Karst besiedelt haben.

DIE GROßSÄUGETIERE DES ÄLTEREN PLEISTOZÄNS

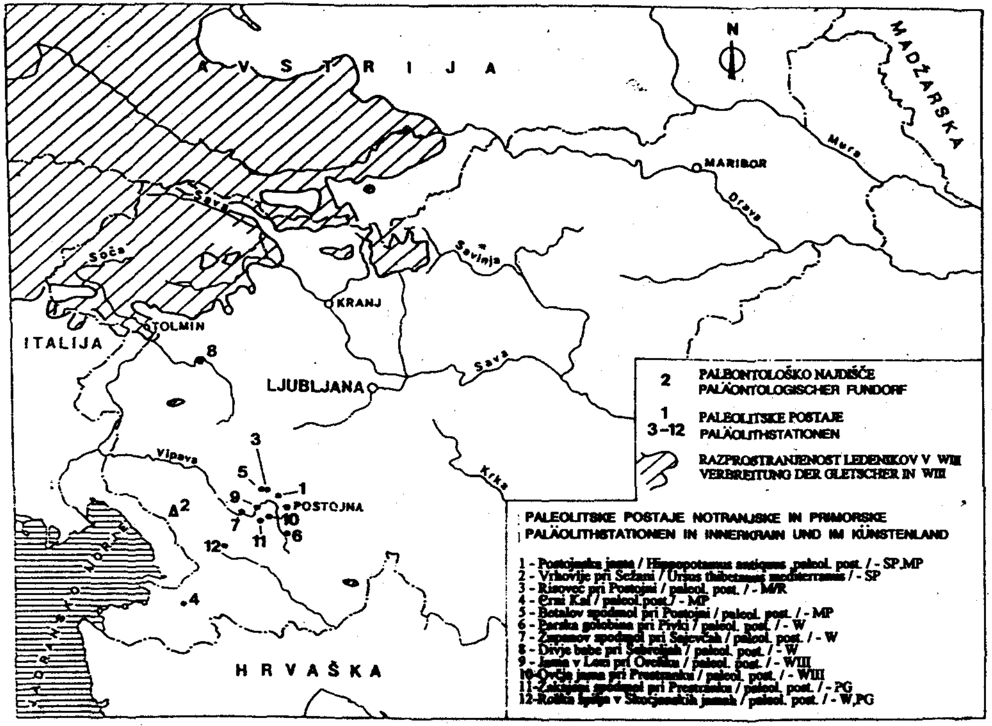
Über die Besiedlung des Karstes im älteren Pleistozän liegen keinerlei Angaben vor. Es scheint wenig wahrscheinlich, daß Mastodonten, die auf den Ufern des Pannonischen Meeres und des Sees im Tales Šaleška dolina (I. Rakovec 1968) lebten, auch auf den innerkrainischen und künstenländischen Karst geraten wären. Wahrscheinlicher scheint es, daß der Ur-Elch (*Praealces aff. gallicus*), dessen Reste auf dem Moor Ljubljansko barje gefunden worden sind (I. Rakovec 1954), auch auf den Graslichtungen des Karstes geäst hat.

DIE GROßSÄUGETIERE DES MITTLEREN PLEISTOZÄNS

An vielen Stellen des innerkrainisch-kuüstenländischen Karstes gab es im mittleren Pleistozän kleinere Seen, die Lebensbedingungen für die Flußpferde boten. I. Rakovec (1975, 229) schrieb in den Schotterschichten der Höhle Postojnska jama (Abb. 1/1) gefundene Knochenreste der Art *Hippopotamus antiquus* zu.

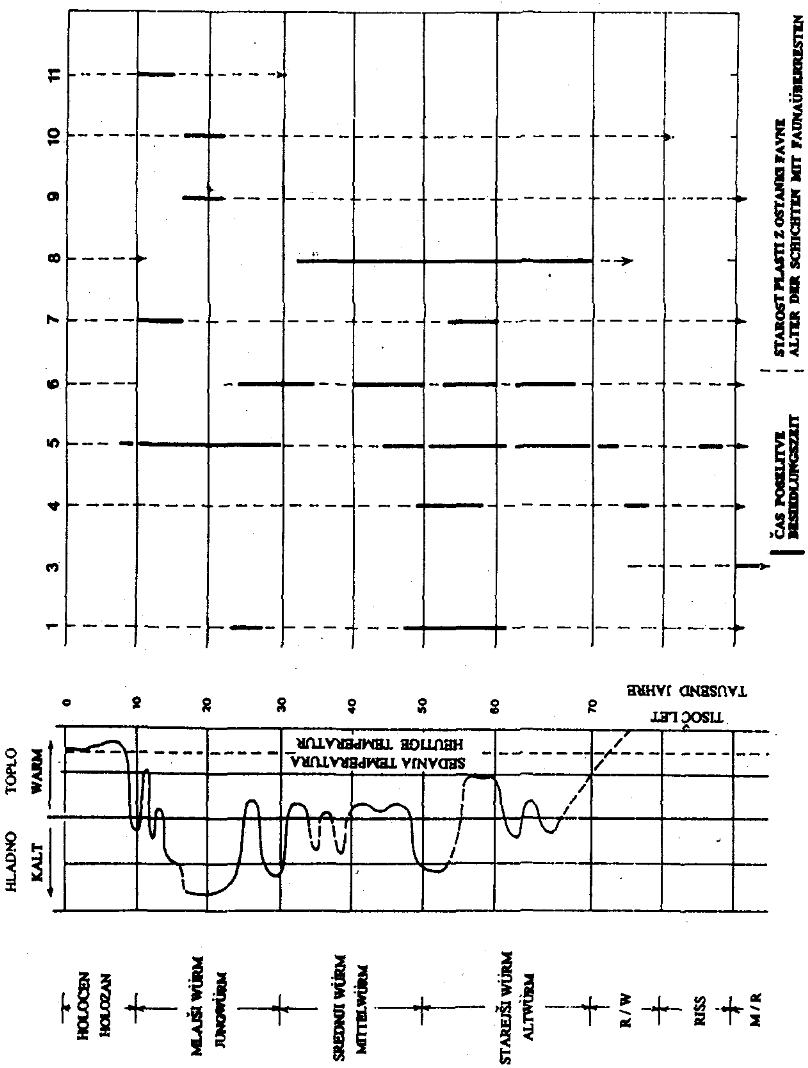
Aus derselben Zeit stammt ein Zahn eines Vorfahren des heutigen Schwarzbären der Art *Ursus thibetanus mediterraneus* (E. Thenius 1958), gefunden in einer Breccie, die Risse in Kreidekalken bei Vrhovlje nahe Sežana füllte (Abb. 1/2).

Gegen Ende des mittleren Pleistozäns taucht hierzulande erstmals der Eiszeitmensch auf. Die in der Paläolithstation Risovec bei Postojna (Abb. 1/3 und 2/3) entdeckten Reste seiner Jagdbeute gehören dem Biber, Elch, einem unbestimmbaren Geweihträger und dem Nashorn an.



Slika 1 : Najdišče pleistocenske favne na Notranjsko-primorskem krasu
Abb. 1 : Fundort der Pleistozänfauna auf dem innerkrainischen und Künstenländischen Karst

SP - srednji pleistocen-Mittleres Pleistozän , MR - mindelsko-riški interglacial-Mindel/Riss-warmzeit,
MP - mlajši pleistocen - Jungpleistozän , W - würmski glacial - Würmkaltzeit
WIII- tretji würmski stadial-drittes Würmstadial, PG - pozni glacial - Spätglazial
paleolitska postaja - Paläolithstation



Slika 2 : Kronološki pregled paleolitskih postaj Notranjske in Primorske
Abb. 2 : Chronologische Übersicht der Paläolithstationen in Innerkrain und im Küstenland

JAGDBARE TIERE IM JUNGPLEISTOZÄN

Nach P. Woldstedt (1958, 164-165, Taf. 8) umfaßt das jüngere Pleistozän zwei Kaltzeiten (Riss, Würm) und eine Warmzeit dazwischen. Für die chronostratigraphische Zuordnung der Würm-Fauna wurde die Gliederung der Würmkaltzeit (Abb. 2) von H. Gross (1964, 196) verwendet.

Die Funde von Fossilresten in Sedimenten der Paläolithstationen Črni Kal (Abb. 1/4 und 2/4) und Betalov spodmol (Abb. 1/5 und 2/5) beweisen, daß noch in der Risskaltzeit auf dem Karst Rehe der Art *Capreolus cf. süssenbornensis* (I. Rakovec 1958, 398) und Deningeri-Bären (*Ursus cf. deningeri*) gelebt haben. Neben den erwähnten sind auch einige wenige Reste des Höhlenbärs gefunden worden (I. Rakovec 1959, 304).

Trotz der Tatsache, daß auch aus der letzten, Riss/Würm-Warmzeit nur zwei Fundstätten bekannt sind, ist die im Höhlenlehm von Betalov spodmol und Črni Kal gefundene Fauna viel mannigfaltiger. Die Bestimmung der dort entdeckten Fauna bewies, daß zumindest in der Umgebung der beiden Paläolithstationen in der letzten Warmzeit Biber, Höhlenbären, Höhlenlöwen, Wölfe, Rothirsche und Riesenhirsche, Wildschweine und Waldnashorne (I. Rakovec 1975, Taf. 1) gelebt haben. Die aufgezählten Tiere besiedelten einen sehr lockeren, mit größeren und kleineren Weiden durchsetzten Laubwald (A. Šercelj, M. Culiberg 1985, 60).

Die Anwesenheit von Alpenhasen, Alpenmurmeltier und Rentier (V. Pohar, unveröffentlicht) in den Warmzeitsedimenten von Betalov spodmol legt eine kühlere Oszilation in dieser Warmzeit nahe.

Mit dem Eintritt der Würmkaltzeit wurde es zwar kälter, doch war der Tierbestand zumindest im Altwürm (WI) noch nicht extrem kaltzeitlich. Aus dieser Zeit sind schon 6 Paläolithstationen bekannt: die Höhle Postojnska jama (Abb. 1/1 und 2/1), Črni Kal (Abb. 1/4 und 2/4), Betalov spodmol bei Postojna (Abb. 1/5 und 2/5), Parska golobina bei Pivka (Abb. 1/6 und 2/6), Županov spodmol bei Sajevče (Abb. 1/7 und 2/7) und Divje babe bei Šebrelje (Abb. 1/8 und 2/8).

Von der Tierwelt des Altwürm steht der Höhlenbär (95 bis 99%) im Vordergrund. Neben dem Alpenmurmeltier kündigen auch der Alpenhase und der Wisent den Beginn von kühlerem Wetter an. Die übrige Fauna ist mehr oder weniger der der letzten Warmzeit gleich (I. Rakovec 1975). Reste von Feuerstätten der erwähnten Stationen zeigen, daß es in der Umgebung Kiefer- und Fichtenwälder mit einigen Laubbäumen gegeben hat (A. Šercelj, M. Culiberg 1985), das heißt, daß auch die Pflanzenwelt nicht ausgeprägt kaltzeitlich gewesen ist.

Im Mittelwürm (Interstadial WI/II) trat wieder eine leichte Erwärmung ein, doch gibt es bei der Tier- und Pflanzenwelt keine besonderen Veränderungen. Von den Tieren steht noch immer der Höhlenbär im Vordergrund, die übrigen Vertreter sind denen aus der Riss/Würm-Warmzeit gleich. In Črni Kal ist sogar das Waldnashorn gefunden worden (I. Rakovec 1958, 412). Etwas überraschend wurden in derselben Schicht auch Steinbock und Wildpferd gefunden (I. Rakovec 1958, 402, 396), die in Slowenien als Ankündiger der kalten Witterung gelten.

Das Jungwürm (Abb. 2) umfaßt zwei Stadiale (WII und WIII) und ein Interstadial dazwischen (WII/III). Weil die Wärmeschwankung (WII/III) meist nicht in einer Veränderung der Sedimentation zum Ausdruck kommt, können die beiden Stadiale nur dann unterschieden werden, wenn die Höhlenschichten faunistische und kulturelle Überreste enthalten. So konnten die Jungwürmschichten nur in Parska golobina genauer unterschieden werden (F. Osole 1961, 489). Unter der Fauna der Kälte-Oszillation (WII) herrscht noch immer der Höhlenbär vor (67%), das Vorkommen von Eisfuchs, Schneehase und Ren macht jedoch eine starke Verschlechterung des Klimas augenscheinlich (V. Pohar, man.).

Um nach den Überresten der Fauna (I. Rakovec 1962-63) und Flora (A. Šercelj 1970, A. Šercelj und M. Culiberg 1985) zu urteilen, wird sich das Klima in der Zeit der zweiten Kälteoszillation des Jungwürm (WIII) am stärksten abgekühlt haben. Dieser Zeit gehören die in der Höhle Jama v Lozi bei Orehek (Abb. 1/9 und 2/9) und in der Höhle Ovčja jama bei Prestranek (Abb. 1/10 und 2/10) gefundenen Tierüberreste an. Unter der Fauna stehen Überreste des Rens und des Alpenmurmeltiers im Vordergrund, nur einzeln sind Eisfuchs, Schneehase und Wisent vertreten. Das Vorkommen des Höhlenbärs ist auf einige wenige Funde in Ovčja jama und Betalov spodmol (V. Pohar, man.) zurückgegangen.

Im Spätglazial, das heißt in den Rückzugsphasen des dritten Würmstadials (Dryaszeiten, Alleröd- und Bölling-Schwankungen) besserte sich das Klima allmählich wieder. Die Funde aus Županov spodmol bei Sajevče (Abb. 1/7 und 2/7), Zakajeni spodmol bei Prestranek (Abb. 1/11 und 2/11) und Roška špilja in der Nähe der Höhlen Škocjanske jame (Abb. 1/12) weisen auf einen spürbaren Rückgang der Tundra-Vertreter hin (unter 5%). Unter der spätkaltzeitlichen Fauna ist das Alpenmurmeltier am häufigsten vertreten, immer häufiger kommen auch Biber und Wildschwein vor. Unter den Cerviden kommt der Rothirsch am häufigsten vor, an zweiter Stelle ist das Reh, das bisher unter der Würmfauna, außer in Črni Kal, der südlichsten slowenischen Paläolithstation, nicht in Erscheinung getreten ist. Der Höhlenbär und andere Raubtiere sind unter der spätkaltzeitlichen Fauna schwach vertreten, die großen Pleistozänkatzen sind hierzulande schon gegen Ende des Mittelwürms ausgestorben.

Im Großen und Ganzen gesehen hat sich der beschriebene spätkaltzeitliche Tierbestand mit jeder Wärmeoszillation vom Beginn des älteren bis zum Ende des jüngeren Dryas verändert. Mit der Zunahme der Zahl von Rothirsch- und Wildschweinexemplaren nimmt die Ähnlichkeit zum Holozänbestand zu.

Übersetzt von Doris Debenjak

LITERATURA

Gross, H. 1964: Das Mittelwürm in Mitteleuropa und angrenzenden Gebieten.-Eiszeitalter und Gegenwart 15, 187-198, Oehringen/Württ.

Osole, F. 1961: Parska golobina, paleolitska postaja v Pivški kotlini (Parska golobina, station paléolitique dans le Basin de Pivka).-Razprave 4. razr. SAZU 6, 437-498, tab. 1-8, Ljubljana.

Rakovec, I. 1954: Libralces aff. gallicus Azzaroli z viškega Brda pri Ljubljani (Libralces aff. gallicus Azzaroli from the Vič Terrace near Ljubljana).-Razprave 4. razr. SAZU 2, 277295, Ljubljana.

Rakovec, I. 1958: Pleistocenski sesalci iz jame pri Črnem Kalu (The Pleistocene Mammalia from the Cave Črni Kal in Northern Istria).-Razprave 4. razr. 4, 365-433, Ljubljana.

Rakovec, I. 1959: Kvartarna sesalska favna iz Betalovega spodmola pri Postojni (The Quarternary Mammalian Fauna from the Cave Betalov spodmol near Postojna).-Razprave 4. razr. 5, 287348, Ljubljana.

Rakovec, I. 1962-63: Poznowürmska favna iz Jame v Lozi in iz Ovčje jame (The Late Würmian Fauna from the Caves Jama v Lozi and Ovčja jama in Slovenia).-Arheol. vestn. 13/14, 241-272, Ljubljana.

Rakovec, I. 1968: O mastodontih iz Šaleške doline (The mastodonts from the Šalek Valley).-Razprave 4. razr. SAZU 11, 299-350, Ljubljana.

Rakovec, I. 1975: Razvoj kvartarne sesalske favne Slovenije (Über quartäre Säugetierfaunen Sloweniens).-Arheol. vestn. 24/1973, 225-270, tab. 3, Ljubljana.

Šercelj, A.-Culiberg, M. 1985: Rastlinski ostanki v paleolitskih postajah v Sloveniji (Pflanzenreste in den Paläolithstationen Sloweniens).-Poroč. o raziskov. paleol., neol. in eneol. v Sloveniji 13, 53-65, Ljubljana.

Šercelj, A. 1970: Würmska vegetacija in klima v Sloveniji (Würmeiszeitliche Vegetation und Klima in Slowenien). Razprave 4. razr. SAZU 13/7, 211-249, Ljubljana.

Thenius, E. 1958: Über einen Kleinbären aus dem Pleistozän von Slovenien.-Razprave 4. razr. SAZU 4, 633-646, Ljubljana.

Woldstedt, P. 1958: Das Eiszeitalter II, 1-438, Ferdinand Enke Verlag, Stuttgart.

LOVNE ŽIVALI PLEISTOCENSKIH PREBIVALCEV NOTRANJSKO-PRIMORSKEGA KRASA

Povzetek

Velik del Notranjske in Primorske gradijo karbonatne kamnine, ki jih vode razmeroma hitro raztapljajo. Tako so se v njih poleg različnih kraških pojavov razvile tudi jame. V pleistocenu se je vanje pogosto zatekal ledenodobni človek in v njih zapustil sledove svojega bivanja tudi v obliki ostankov lovskega plena. Na Notranjsko-primorskem krasu poznamo doslej 14 takih bivališč (sl. 1 in 2). Prav te starokamenodobne postaje predstavljajo glavni vir podatkov o živalih, ki so naseljevale Kras v posameznih obdobjih pleistocena.

Kdaj je človek prišel na Kras, ne vemo natančno. Dosedanje najdbe iz obrobja Pivške kotline (sl. 1/9, 2/9, 1/3, 2/3) kažejo, da se je pojavil proti koncu srednjega pleistocena. Zato tudi ni znano, katere živali so poseljevale Kras v starejšem pleistocenu.

Sesalska favna srednjega pleistocena

Na mnogih krajih Notranjsko-primorskega krasa so se v srednjem pleistocenu razprostirala manjša jezera, ki so omogočala življenje povodnim konjem. I. Rakovec (1975, 229) je pripisal kostne ostanke odkrite v prodnih naplavinah Postojnske jame (sl. 1/1) vrsti *Hippopotamus antiquus*.

Iz istega obdobja je zob prednika današnjega črnega medveda vrste *Ursus thibetanus mediterraneus* (E. Thenius 1958), ki so ga našli v breči, ki je zapolnjevala razpoke v krednih apnencih pri Vrhovljah blizu Sežane (sl. 1/2).

Ostanki lovskega plena ledenodobnega človeka, odkriti v paleolitski postaji Risovec (sl. 1/3 in 2/3), kažejo, da so poleg omenjenih živali živeli na Krasu še bober, los in drugi cervidi ter nosorogi.

Lovne živali v mlajšem pleistocenu

Po P. Woldstedtu (1958, 164-165, tab. 8) obsega mlajši pleistocen dva glaciala (riški in würmski) in vmesni interglacial. Za kronostratigrafsko uvrstitev favne würmske starosti pa smo uporabili H. Grossovo (1964, 196) razdelitev würmskega glaciala (sl. 2).

Najdbe fosilnih ostankov v sedimentih paleolitskih postaj Črni Kal (sl. 1/4 in sl. 2/4) in Betalov spodmol (sl. 1/5 in sl. 2/5) dokazujejo, da so še v riškem glacialu živele na Krasu srne vrste *Capreolus cf. süssenbornensis* (I. Rakovec 1958, 398), in medvedi vrste *Ursus cf. deningeri*. Poleg naštetih so dobili tudi pičle ostanke jamskega medveda (I. Rakovec 1959, 304).

Čeprav sta tudi iz zadnjega (riško-würmskega) interglaciala znani le dve najdišči, je favna, ki so jo našli v jamskih ilovicah Betalovega spodmola in Črnega Kala, veliko pestrejša. Determinacija tam odkrite favne je pokazala, da so vsaj v okolici obeh paleolitskih postaj v zadnji medledeni dobi živeli bobri, jamski medvedi, jamski levi, volkovi, navadni in orjaški jeleni, divje svinje in kirchberški nosorogi (I. Rakovec 1975, tab. 1). Naštete živali so naseljevale

močno razredčen listnat gozd, ki so ga prekinjali večji ali manjši pašniki (A. Šercelj, M. Culiberg 1985, 60).

Prisotnost planinskega zajca, alpskega svizca in severnega jelena (V. Pohar, neobjavljeno) v interglacialnih sedimentih Betalovega spodmola kaže morda na hladnejšo oscilacijo v tej medledeni dobi.

Z nastopom würmskega glaciala se je sicer ohladilo, vendar živalski sestav vsaj v starejšem würmu (WI) še ni bil ekstremno mrzlodoben. Iz tega obdobja je znanih 6 paleolitskih postaj: Postojnska jama (sl. 1/1 in sl. 2/1), Črni Kal (sl. 1/4 in sl. 2/4), Betalov spodmol pri Postojni (sl. 1/5 in sl. 2/5), Parska golobina pri Pivki (sl. 1/6 in sl. 2/6), Županov spodmol pri Sajevčah (sl. 1/7 in sl. 2/7) in Divje babe pri Šebreljah (sl. 1/8 in sl. 2/8).

Med živalstvom starejšega würma prevladuje jamski medved (95 do 99%). Poleg alpskega svizca sta redka znanilca hladnejšega podnebja še planinski zajec in stepski bizon. Ostala favna je v glavnem enaka interglacialni (I. Rakovec 1975). Ostanki kurišč iz omenjenih postaj kažejo, da so se v okolici najdišč razprostirali borovi in smrekovi gozdovi z udeležbo listavcev (A. Šercelj, M. Culiberg 1985), kar pomeni, da tudi rastlinstvo ni bilo izrazito mrzlodobno.

V srednjem würmu (interstadial WI/II) se je podnebje nekoliko otoplilo, vendar se rastlinstvo in živalstvo ni bistveno spremenilo. Med favno še vedno prevladuje jamski medved, ostali predstavniki so enaki živalim iz rišsko-würmskega interglaciala. V Črnem Kalu so odkrili celo kirchberškega nosoroga (I. Rakovec 1958, 412). Nekoliko pa preseneča dejstvo, da so v isti plasti dobili še kozoroga in divjega konja (I. Rakovec 1958, 402, 396), ki v naših krajih veljata kot znanilca mrzlega podnebja.

Mlajši würm (sl. 2) obsega dva stadiala (WII in WIII) in vmesni interstadial (WII/III). Ker se toplotni presledek (WII/III) največkrat ne kaže v spremembi sedimentacije, lahko oba stadiala ločimo le, če vsebujejo jamske plasti favnistične in kulturne ostanke. Tako se je mlajšewürmske plasti dalo podrobneje ločiti le v Parski golobini (F. Osole 1961, 489). Med favno starejšega hladnega sunka (WII) prevladuje še vedno jamski medved (67,1%), pojavljanje polarne lisice, snežnega zajca in severnega jelena pa že kaže na poslabšanje podnebja (V. Pohar, neobjavljeno).

Glede na ostanke favne (I. Rakovec 1962-63) in flore (A. Šercelj 1970, A. Šercelj in M. Culiberg 1985) se je podnebje najbolj zaostrilo za časa drugega hladnega sunka mlajšega würma (WIII). V to obdobje sodijo živalski ostanki odkriti v Jami v Lozi pri Orehku (sl. 1/9 in sl. 2/9) in v Ovčji jami pri Prestranku (sl. 1/10 in sl. 2/10). Med favno prevladujejo ostanki severnega jelena in alpskega svizca, le s posameznimi primerki so zastopani polarna lisica, snežni zajec in stepski bizon. Prisotnost jamskega medveda se je skrčila na vsega nekaj najdb v Ovčji jami. V Betalovem spodmolu so medvedji fosilni ostanki nekoliko številnejši (V. Pohar, neobjavljeno).

V poznem glacialu, to je v umikalnih fazah tretjega würmskega stadiala (najstarejši dryas, böllinški interstadial, starejši dryas, allerödski interstadial, mlajši dryas), se je podnebje polagoma izboljševalo. Najdbe iz Županovega spodmola pri Sajevčah (sl. 1/7 in 2/7), Zakajenega spodmola pri Prestranku (sl. 1/11 in sl. 2/11) in Roške špilje v Škocjanskih jamah (sl. 1/12) so pokazale občutno zmanjšanje zastopnikov tundre (pod 5%). Med poznoglacialno favno je tako najštevilneje zastopan alpski svizec, vedno pogostejša postajata tudi bober in divja svinja. Med cervidi je najštevilneje zastopan navadni jelen, na drugem mestu je srna, ki je doslej med würmsko favno nismo zasledili, razen v Črnem Kalu, naši najjužneje ležeči paleolitski postaji. Jamski in rjavi medved ter ostale zveri so med poznoglacialno favno šibko zastopane, velike pleistocenske mačke pa so pri nas izumrle že konec srednjega würma.

Generalno gledano, se je opisan poznoglacialen živalski sestav spreminjal z vsako otoplitvijo od začetka starejšega pa do konca mlajšega dryasa. S povečevanjem števila osebkov navadnega jelena in divje svinje, je postajal vedno bolj podoben holocenskemu.

INVENTORY OF THE ŠKOCJAN WORLD HERITAGE SITE

INVENTAR ŠKOCJANSKE SVETOVNE DEDIŠČINE

DANIEL ROJŠEK

Izvleček UDK 502.6(497.12)

Daniel Rojšek: Inventar Škocjanske svetovne dediščine

Po predstavitvi predloga za zavarovanje naravne dediščine na matičnem Krasu v letu 1987, smo dopolnili prvi inventar naravne dediščine Krasa in po novi metodologiji izdelali inventar Škocjanskega jamskega spleta, kjer smo obdelali 62 enot naravne dediščine. Članek prinaša kratko poročilo o zavarovanju naravne dediščine Krasa in inventarju Škocjanskega jamskega spleta.

Ključne besede: inventarizacija naravne dediščine, inventarni list, kraški pojavi, Slovenija, matični Kras, Škocjanski jamski splet, UNESCO

Abstract UDC 502.6(497.12)

Daniel Rojšek: Inventory of the Škocjan World Heritage Site

After report on the natural heritage of Matični Kras in 1987 the first inventarisation of the Kras natural heritage has been upgraded and new inventory of 62 units of the Škocjan Cave System recorded. A short report about protection of the Kras natural heritage after 1987 and the inventory of Škocjan Cave System are introduced in this paper.

Key words: inventarisation of natural heritage, inventory foil, karst phenomena, Slovenia, Classical Karst, Škocjan Cave System, UNESCO

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INTRODUCTION

Natural heritage inventories of the Classical Karst and the Velika Voda - Reka drainage area were upgraded (Sušnik-Lah & Klemenčič/Eds. 1990; Gorkič et al. 1990). In the Škocjan World Heritage Site the first inventarisation of natural phenomena was made after improved methodology (Rojšek 1989, 1994).

Access to some parts of the Škocjan Cave System is not easy and there are some problems to organise a team of cavers and experts for inventarisation of natural heritage and a financial support. To the end of September 1992 146 natural phenomena were registered in the protected area, after September 62 units have been sufficiently processed and presented in resumption, but many of natural features are not yet registered.

The most recent recognitions of natural heritage inventarisation methodology are also published (Rojšek 1994) and recommended for easier understanding of the present paper.

A BRIEF NATURAL HERITAGE INVENTORY OF THE CLASSICAL KARST

After a report about the natural heritage of the Classical Karst (Rojšek 1987) an upgraded brief inventory of the Sežana commune natural heritage was achieved (Sušnik-Lah & Klemenčič /Eds. 1990) where 754 units are registered to be protected by a regional plan in the Kras region of Slovenia.

Assembly of the Sežana commune proclaimed the natural features (1992) cited in the report (Rojšek 1987).

Cave Register at the Karst Research Institute ZRC SAZU, Postojna, registered 564 speleological objects (at this occasion I should like to acknowledge J. Hajna and A. Mihevc) on the Classical Karst in November 1995 or 127 more than eight years earlier. 16 new registered speleological objects per year in the area seem a lot, however the whole area was not checked equally. The question remains open at the contact of the Brkini, Materija and Kras (Rojšek 1987, 258-259).

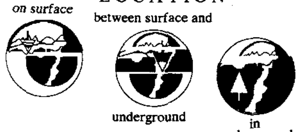
Among the last inventarisations of the important natural heritage the surface hydrogeographical ones have to be mentioned. There were 72 units registered in the Kras "waterless" area in 1990. 14 of them are called "lokev"

Škocjanski jamski splet[*1] - The *Škocjan* Cave System

I. I. II. III. III. III. IV.

LOCATION

on surface | between surface and underground | in underground



settlement **Škocjan** -commune: Sežana -Local community: Divača -cadastre district: Naklo
No. of Slovene cave cadastre: 735, 1098, 5791, 5934, 5935 No. of former Italian cave cadastre VG: 112
synonym/s: Škocjanske jame
G/K coordinates **Y**: 5421.980 **X**: 5058.350 **Z** =a.s.l. (- Z=sea depth): 425[*2] m
Z max. = the highest point a.s.l.: 425 Z min. = the lowest point a.s.l.: 214[*2]
map (name) TK 25/G: Divača (028-4-2) TTN 5: Sežana 35, 36, 46

SIGNATURE: Beginnig of *Velika voda - Reka* cave system's drainage zone. Cave system is composed of 11 spelaeological objects: *Škocjanska jama* with*Okroglica* and *Rov*, *Velika* and *Mala Koščakova jama*, *Vodnjak*, *Miklov skedenj*, *Jama* and *Jamica nad jezerom*, *Tominčeva jama*, *Ozka špilja*, *Jama strahov* and *Šumeča jama* with *Pruker* and *Tihi rov*.

DIMENSION/S: - lenght: about 5500[*3] m - depth: 211 or 103[*3] m

EVALUATION

EARTH SCIENCE CRITERIA >

> COMPLEXITY:

a composed small system[*4] *or a composed middle system*[*4] or *a composed big system*[*4] *of natural heritage*
A natural heritage unit as a part of phisical-geographical region, abundant of natural heritage

> ECOLOGICL CRITERIA:

high degree preserved ecosystem ecosystem with large variety of habitats (stable ecosystem) rare ecosystem
ecosystems with botanical and zoological endangered, relic and endemit species, with *locus classicus* - in disjunctional, azonal, ekstrazonal and/or marginal area
area of many diverse ecosystems
vegetation of characteristic pedological profile

> MATHEMATICAL CRITERIA:

very rare very big unit of natural heritage (maximal two dimensions) natural heritage unit of active processes
exceptional quantity of water and ratio of runoff stationary phenomena - periodic phenomena *zelo redek pojav zelo velika enota naravne dediščine (absolutne*

CULTURAL-ANTHROPOLOGICAL CRIT

witnesstand or interbraid of natural and cultural heritage
symbolic sense picturesqueness exceptional shapeness
natural heritage unit, important landscape element

PLANE - JURISTIC STATUS>

- republic obligatotry starting-point in planning Conservation status: protected
Juristic act: *Odlok o zavarovanju Škocjanskih jam (U.l. SRS 17/80 z dopolnitvama)*

> CONSERVATING GROUP/S

of R Slovenija: natural monument & nature reserve of IUCN: I, III & IV European community: A, B & D

FUNCTION/S:

- 'monumental' or witnesstand - reserve - scinetific-researchal - biotopic - breeding-educational - recreational

[*1]remarks can be found on the other side.

Fig. 1.

BRIEF DESCRIPTION: Underground course of *Velika voda - Reka* in *matični Kras* beginns in the *Škocjan* Cave System. The course can be reached in *Kačja jama* and in *Lobodnica* in Italy, only 100 m from border and 14 km from the ponor above *Škocjan*. In airline of 4 km above *Kačja jama* 7.5 km water gallerys have been discovered. On the surface *Reka* can be traceed by blowing holes in Povir and in *Sežanski Kras*. Majority of *Velika voda - Reka* springs in *Brojnice* above *Nabrežina*, some of it however in Timav springs. In aquifair of *matični Kras* waters from few drainage zones are mixed. In submarine *Brojnice* springs and in *Timav* springs are flowing waters through *Kras* from: * *Pivka* flisch (*Bistrica* and *Podsenjšek* springs from upper Pivka basin and Mt. *Snežnik* massive *Lokva* and *Šmihelski potok* through Mt. *Nanos*); * *Slavina--Košana kras (karst brook Rakuljščica springs in high water level through estavelle Gabranca in Sušica* brook in the *Reka* drainage basin (D. Rojšek, 1987: 20, 22); * river network of Vipava respectively from *Vipava* and *Senožeče* flisch and from other impermeable semiimpermeable rocks (*Raša* and other brooks; *Vipava* above *Miren* (o.c: 7) and * groundwater of *Gorica* plain, which is fed largely by *Soča* river (l.c).

Active and fossile spelaeological objects: caves, pits, galleries, halls halfhalls or huge abris are intervolven with surface part of the cave system, which is represented by huge chasm of *Mala* and *Velika dolina* with runnig water. Lenghts of dolines is not counted to the total lenght of the system. Separate parts are intervolven by water and/or by location inside surface circumference of entry parts.

Data of system components and other natural heritage units are presented in individual inventory foils.

Date/s of visit/s: more than 40 visits pending May 1973 and

Date of last visit: 9.06.93

STATUS: preservation: > D. Rojšek, 1990, Human Impact on Škocjanske jame System, Studia casologica 2: 120-132, Brno.

Basic source/s: Notes and computations of the caves surveys notes of terrain sights and plans of spelaeological objects in cadastres of *Društvo za raziskavanje jam Ljubljana* and *Inštit za raziskovanje krasa ZRC SAZU*

Author/s of data: Daniel Rojšek Author/s of description: Daniel Rojšek

Processed by: Andrej Pokorn & Daniel Rojšek Date/s of processing: 15.12.91, 31.8.1992, 12.09.92, 27.02.93, 02.03.93

Date of the last change/s: 11.03.93

*1 By the name *Škocjan* Cave System 11 locationaly and geneticaly intervolven spelological objecs are designated. There are same problems by names of the parts. German names were given by official discoverers from German-austrian alpine club, but some Slovene toponyms and names of brave men were noticed. Cave administration of CAI SAG italianised the spelaeo-names, Slovene origin names were dedlited. The system have not been undertook sistematically for a long time by Slovene cavers and spelaeologsts after association to motherland, but improper names have not been solved, yet. German names *grotte* and *höhle* have been translated to *jama*, unaccording to spelaeotype of cavern (for example: *Tiha jama* is not cave, but gallery, *Schmidlova jama* is not cave, but hall and so on). Names of the system parts are used as are enforced by locals and cave guides, respectful original names as it is possible and by regarding Slovene spelaeomorphogenetical terms. Local hireling cavers, virtual discoverers were probably given names by ther own, but A. Hanke was put down only official german names to the first cave plane.

*2 Y, X in Z coordinate are taken by cave cadastre of *Inštitut za raziskovanje krasa ZRC SAZU* and centre of *Okroglica* entrance is noticed. Level of *Martelovo jezero* is surveyved by laser theodolit.

*3 The system has not been discovered, yet. The lenght is a sum of the singular parts quoted in the signature, the depth is a altitude difference beetven the lowest point of *Velika dolina* circumference (425 m), the ponor level (317) and everage water level in *Martelovo jezero* (214). The lowest points of runoff syfon and of the newest discoveries after the syfon should be noticed, but enough exact data have not been available, yet.

*4 The system can be treated as a part of *Velika voda - Reka* proper and wider channel networks or as a part of *Timav* karst hinterland with the *Soča* drainage area.

Fig. 2.

1 Škocjanski jamski splet - *Škocjan* Cave System:
I. geol., I. geom., II. hidrl., III. bot., III. den., III. for., IV. zoo.
2 Škocjanska jama - *Škocjan* Cave:
I. geol., I. geom., II. hidrl., IV. zoo.
3 Mahorčićeva dvorana - *Mahorčić* Hall:
I. geol., I. geom., II. hidrl., IV. zoo.
4 Jezero v Mahorčićevi dvorani - Lake in *Mahorčić* Hall: II. hidrl.
5 *Czörnig*ova dvorana - *Czörnig* Hall:
I. geol., I. geom., II. hidrl., IV. zoo.
6 *Marinitsch*eva dvorana - *Marinitsch* Hall:
I. geol., I. geom., II. hidrl.
7 Škocjanski prelom - *Škocjan* Break: I. geol., I. geom.
8 Rov - Gallery: I. geol., I. geom., II. hidrl.
9 Sigove tvorbe Rova - Cave Corals of *Rov*: I. geol., I. geom.
10 Mala dolina - Small Doline:
I. geol., I. geom., II. hidrl., III. bot., IV. zoo.
11 Kalonca Betancova -
Farmhouse Small Entry of *Betanc*: I. geom., III. bot.
12 Reka v Mali dolini -
Velika voda - *Reka* River in Small Doline: II. hidrl.
13 Rečni "vodnjak" -
River's "Well - Pothole": I. geol., I. geom., II. hidrl., III. bot.
14 Most med Malo in Veliko dolino -
Natural Bridge beetwen Small and Big Doline:
I. geol., I. geom., II. hidrl., III. bot., IV. zoo.
15 Miklov skedenj - *Mikulić* Hay Store:
I. geol., I. geom., II. hidrl., III. bot., IV. zoo.
16 Jezero pod Miklovim skednjem -
Lake above *Mikulić* Hay Store: II. hidrl.
17 Zgornje okno pod Miklovim s. -
Upper Window above *Mikulić* H.S.: I. geol., I. geom.
18 Korita pod Miklovim skednjem -
Eversion Channels above *Mikulić* H.S.:
I. geol., I. geom., II. hidrl., III. bot.
19 Spodnje okno pod Miklovim s. -
Lower Window above *Mikulić* H.S.: I. geom., II. hidrl.
20 Stranski rov Miklovega s. -
Side Gallery of *Mikulić* H.S.: I. geom.
21 Slap pod Miklovim skednjem -
Waterfall above *Mikulić* H.S.: II. hidrl.
22 Lepi jeglič (*Primula auricula*) -
Primula auricula Growing Site: III. bot.
23 Velika dolina - Big Doline:
I. geol., I. geom., II. hidrl., III. bot., IV. zoo.
24 Slap v Veliki dolini - Waterfall in Big Doline: II. hidrl.
25 Jezero v Veliki dolini - Lake in Big Doline: II. hidrl.
26 Podorne skale v Veliki dolini -
Boulders in Big Doline: I. geom.
27 Jama strahov - Cave of Ghosts: I. geol., I. geom.
28 Pruker - *Pruker* or Abri of the *Brucker* Family:
I. geol., I. geom.
29 Tominčeva jama - *Tominc* Cave: I. geol., I. geom.
30 Sigove tvorbe na stenah Velike doline -
Cave Corals of Big Doline Walls: I. geol., I. geom.
31 Šumeča jama in Tihi rov - Rustle Cave and Silent Gallery:
I. geol., I. geom., II. hidrl., III. bot., IV. zoo.
32 *Schmidl*ova dvorana - Schmidl Hall:
I. geol., I. geom., II. hidrl., III. bot., IV. zoo.
33 Sigove tvorbe v *Schmidlovi*. d. - Cave Corals of
Schmidl Hall: I. geol., I. geom., III. bot.
34 Venerini laski - (*Adiantum capillus veneris L.* Growing Site: III. bot.
35 Rudolfova dvorana - Rudolf Hall:
I. geol., I. geom., II. hidrl., IV. zoo.
36 Jezero v Rudolfovi dvorani -
Lake in Rudolf Hall: II. hidrl.
37 Dvorana Ponvic - Hall of Rimestone Pools:
I. geol., I. geom., II. hidrl.
38 Ponvice - Rimestone Pools: I. geol., I. geom., II. hidrl.
39 Svetinova dvorana - *Svetina* Hall: I. geol., I. geom., II. hidrl.
40 Jezero v Svetinovi dvorani -
Lake in *Svetina* Hall: II. hidrl.
41 Valvasorjev rov - Valvasor Gallery:
I. geol., I. geom., II. hidrl.
42 Slap v Valvasorjevem rovu -
Waterfall in Valvasor Gallery: II. hidrl.
43 *Müller*jeva dvorana - Müller Hall:
I. geol., I. geom., II. hidrl.
44 Jezero v *Müller*jevi dvorani -
Lake in Müller Hall: II. hidrl.
45 Orjaške ponvice v *Müller*jevi dvorani -
Giant Rimestone Pools in Müller Hall:
46 Tihi rov - Silent Gallery:
I. geol., I. geom., II. hidrl., IV. zoo.
47 Velika dvorana - Big Hall:
I. geol., I. geom., II. hidrl.
48 Orjaki - Giants: I. geol., I. geom., II. hidrl.
49 Orgle - Organ: I. geol., I. geom., II. hidrl.
50 Paradiž - Paradise: I. geol., I. geom., II. hidrl.
51 Hankejev kanal - Hanke Channel:
I. geol., I. geom., II. hidrl.
52 Slon - Elephant: I. geol., I. geom.
53 Sibirija - Sibiria: I. geol., I. geom., II. hidrl.
54 Dvorana planinskega društva - Alpine Club Hall:
I. geol., I. geom., II. hidrl.
55 *Rinaldini*jeva dvorana - *Rinaldini* Hall:
I. geol., I. geom., II. hidrl.
*56 Putick*ova dvorana - *Putick* Hall:
I. geol., I. geom., II. hidrl.
57 Orjaški kapniški polsteber - Giant Sinter Pilaster:
I. geol., I. geom., II. hidrl.
58 Orjaške podorne skale v *Putick*ovi dvorani -
Giant Boulders in Putick Hall: I. geom.
59 Martelova dvorana - Martel Hall:
I. geol., I. geom., II. hidrl.
60 Orjaški kapniki - *Giant Stalagmites: I. geol., I. geom.*
61 Orjaške ponvice v Martelovi dvorani -
Giant Rimestone Pools in Martel Hall:
I. geol., I. geom., II. hidrl., IV. zoo.
62 Martelovo jezero - Martel Lake: II. hidrl.

I. group of natural heritage units - some elemets of relief or geological (I. geol.) and geomorphological (I. geom.) heritage;
II. group of natural heritage units - hydrological (II. hidr.) and nival-glacial or hydrological heritage;
III. group of natural heritage units - some elemets of soil and vegatation or pedological and botanical, botanical (III. bot.), dendrological (III. den.) and fotestal (III. for.) heritage;
IV. group of natural heritage units - some elemets of animality or zoological (IV. zoo.).
There is no units of V. group - natural heritage with anthropological elements or formed heritage (parks, gardens and collonades of trees)

Fig. 3. a **SLOVENE AND TRANSLATED NAMES, POSITIONS, GROUP AND SPECIES OF NATURAL HERITAGE UNITS OF THE *ŠKOCJANSKI JAMSKI SPLET***

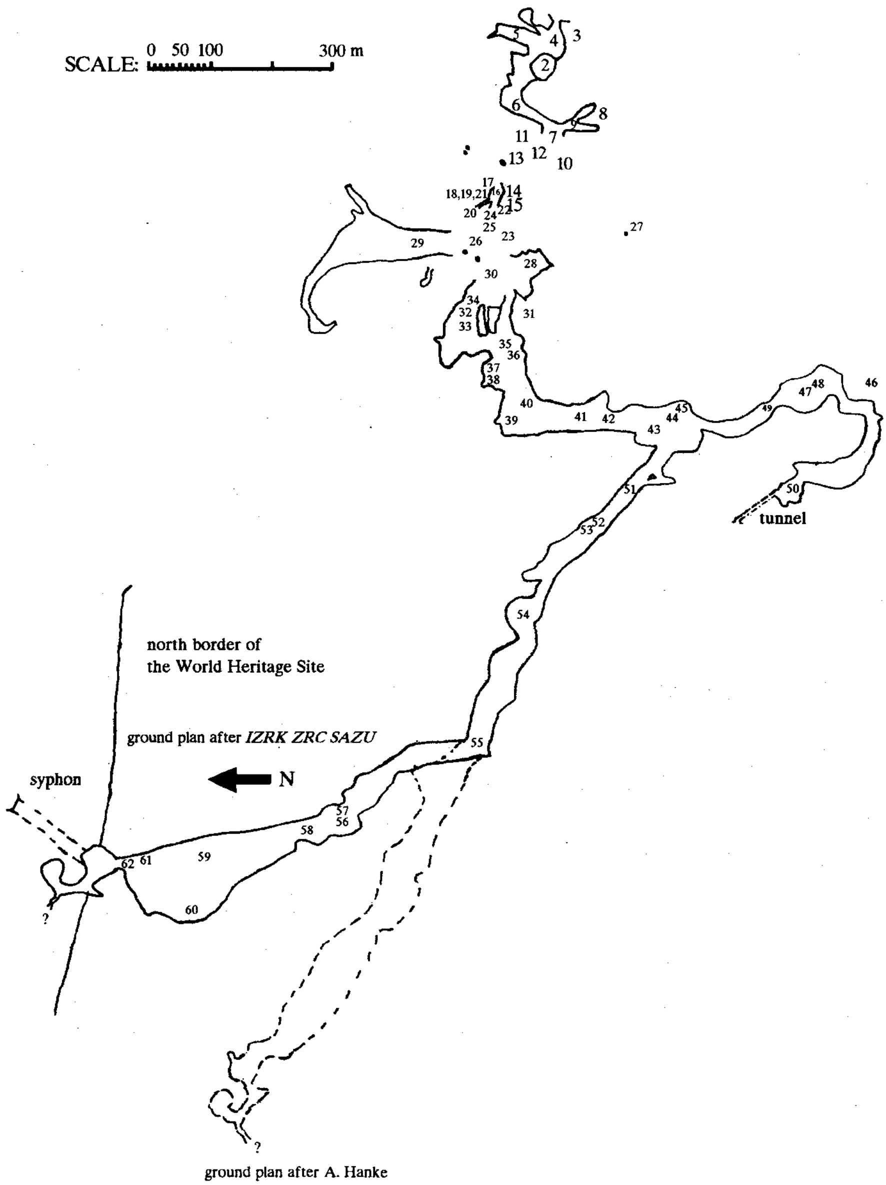

SCALE: 0 50 100 300 m
north border of
the World Heritage Site
ground plan after *IZRK ZRC SAZU*
N
syphon
tunnel
ground plan after A. Hanke

Fig. 3. b

and 58 "kal", but Gams (1973, 11) all of them quoted by English term "sinkhole pond".

"Lokev" is man-made shallow-hole, the most interesting hydrogeographical unit where epikarst water is captured. In the past this water was used for drinking. Nowadays, due to water supply they are no more kept but some of them are used for children swimming or water games.

On the other side all the preserved samples of "kal" were registered too; they are man-made also and maintain open water fed by rain only and are used as drinking water for cattle.

Both phenomena are important from the ecological point of view or as units of the second, the third or the fourth group of natural heritage; in some cases as the first group even.

NATURAL HERITAGE INVENTORY OF THE ŠKOCJAN CAVE SYSTEM

Brief inventory of natural heritage of the Škocjan World Heritage Site was done by brief methodology of inventarisation (Rojšek 1989). After the first inventory of the Site methodology of inventarisation has been improved and new inventory prepared (Rojšek 1994). Parts of the system were determined (Fig. 1) and 62 unit of the heritage processed (Fig. 3).

The system consists of 11 speleological objects linked by the Velika Voda - Reka river or by position inside huge collapse dolines (Velika and Mala Dolina) as follows: Škocjanska Jama (1) with Okroglica (1a) and Rov (1b), Velika (2) and Mala (3) Koščakova Jama, Rečni Vodnjak (4), Miklov Skedenj (5), Jama (6), and Jamica (7) Nad Jezerom, Tominčeva Jama (8), Ozka Špilja (9), Jama Strahov (10), and Šumeča Jama (11) with Pruker (11a) and Tihi Rov (11b). The parts of the system are displayed on Fig. 1.

The most frequent units (21 specimen) of the first and the second group of the natural heritage (Rojšek 1994-2, Fig. 2) appear in the inventory: 14 units belong to the first group only; 11 to the second group; 6 to the first three groups; 4 to the first four groups; 2 to the first or the third group; 2 to the first and the fourth group; 1 to the first, second and fourth group and 1 to the third group only. There are no units of the fifth group registered in this area.

Among the units of the first group belong the huge cave chambers (a volume of Martelova Dvorana (Fig. 3, No. 59) is estimated to 2.100.000 m^3), stalagmites (Orjaki height (Fig. 3, No. 48) up to 15 m), and massive gours (Fig. 3, No., 45). Evorsion channels and fast deposition of flowstone are very important too. There are 8 river lakes (7 underground lakes, up to 110 m long and 50 m large) and 3 waterfalls (5 m, 12 m, 6 m) belonging to the second group. Growing sites of Alpine species *Primula auricula L.* and Mediterranean fern *Adinatum capillus veneris L.* are the most exceptional units of the third group. Some endangered bird and bat species are noticed within the fourth group.

The most important feature is Šumeča Jama with Pruker and Tihi Rov (Fig. 1. No. 11 & Fig. 3, No. 28, 31-62) where 32 or more than half of the units were processed, but it is known that the majority of the system natural heritage units is located in this cave. Access to these units in the cave is the most difficult as the cave's volume is one of the greatest on the Earth.

After the last inventarisation the unique site of cave pearls was discovered in Tominčeva Jama (Fig. 1, No. 8 & Fig. 3, No. 29).

The inventory is graphically introduced by a printed specimen inventory foil presenting the System (Fig. 2); Fig. 3 provides groundplan of locations and the names of the units.

CONCLUSION

Nemo propheta in patria, however we daresay that more than 200 units of natural heritage may be inventoried in the Škocjan Cave System, not including the natural heritage in the Škocjanski Kras and Vremska Dolina - the extended Sites of Škocjan.

A team of cavers and experts for the inventarisation should be organized to confirm or to deny the prediction if the responsible organs of the Republic of Slovenia recognize a need to support such inventarisation of the protected area.

REFERENCES

Cave Register, Situation November 1995; Inštitut za raziskovanje krasa ZRC SAZU, Postojna

Drašček, E. & Gorkič, M. & Osmuk, N. & Rojšek, D. & Sušnik, M., & Svetina, J., 1989: Krajinske zasnove Škocjan (Landscape Plan Škocjan). Typeprint of branch base for natural and cultural heritage conservation in the World Heritage Site, the first natural heritage inventory of wider protected area. Zavod za varstvo naravne in kulturne dediščine Gorica v Novi Gorici

Gams, I./Ed. 1973: Slovenska kraška terminologija. Ljubljana

Gorkič, M. & Markič,. M. & Jamnik, A. & Pokorn, A. & Rojšek, D. & Sušnik-Lah, M., 1990: Inventar naravne dediščine občine Ilirska Bistrica. Zavod za varstvo naravne in kulturne dediščine Gorica v Novi Gorici

Odlok o razglasitvi naravnih znamenitosti in kulturnih spomenikov na območju občine Sežana, 1992. Primorske novice - Uradne objave, 13/17.4.1992, Koper

Rojšek, D., 1987: Natural Heritage of the Classical Karst. Karst and Man, Proceedings of the Int. Symp. of Human Influence on Karst, 255-265,

Ljubljana
Rojšek, D., 1989: Methodology and inventory of geological, geomorphological and hydrogeographical heritage of the World Heritage Site. In Drašček et al.
Rojšek, D., 1990: Human Impact on Škocjanske jame System. Studia Carsologica, 2, 120-132, Brno
Rojšek, D., 1994-1: Geografsko vrednotenje naravne dediščine na primeru Škocjanskega jamskega spleta z okolico in varstvo okolja. Third degree Thesis, FF, Ljubljana
Rojšek, D., 1994-2: Inventarisation of the Natural Heritage. Acta carsologica 23, 111-121, Ljubljana
Sušnik-Lah, M. & Klemenčič, B./Eds., 1990: Strokovne osnove za varstvo naravne in kulturne dediščine za izdelavo prostorskih ureditvenih pogojev za občino Sežana. Zavod za varstvo naravne in kulturne dediščine Gorica v Novi Gorici

INVENTAR ŠKOCJANSKE SVETOVNE DEDIŠČINE

Povzetek

Po predstavitvi predloga za zavarovanje naravne dediščine na matičnem Krasu (Rojšek 1987) smo na Zavodu za varstvo naravne in kulturne dediščine Gorica v Novi Gorici dopolnili prvi inventar naravne dediščine Krasa (Sušnik-Lah & Klemenič/Eds. 1990) s pripravo strokovnih osnov za varstvo naravne in kulturne dediščine pri izdelavi prostorskih ureditvenih pogojev za tedanjo občino Sežana. Registrirali smo 754 enot naravne dediščine, med katerimi izstopajo hidrogeografski pojavi.

Tedaj smo namreč na Krasu, "brezvodni" pokrajini, registrirali 72 vodnih pojavov, štirinajstim pravijo lokev, oseminpetdesetim pa kal. Gams (1973, 11) pojava enači, vendar gre za dve različni umetni hidrogeografski kraški tvorbi. Lokev je plitva izkopana vodna globel, ki jo napaja epikraška voda. V preteklosti so jo uporabljali za pitno vodo. Registrirali smo vse ohranjene kale, ki predstavljajo umetno narejene in vzdrževane zbiralnike deževnice za napajanje živine. Oba pojava sta pomembna z ekološkega vidika.

Skupščina občine Sežana je razglasila vse naravne znamenitosti (odlok 1992), ki jih navajamo v poročilu (Rojšek 1987).

Za izdelavo krajinske zasnove smo pripravili kratek inventar naravne dediščine zavarovanega ozemlja Škocjanske svetovne dediščine (Rojšek 1989). Po tem prvem inventarju smo izboljšali metodologijo in izdelali nov inventar naravne dediščine Škocjanskega jamskega spleta (Rojšek 1994). Na zavarovanem ozemlju smo registrirali 146 enot naravne dediščine, strokovno pa smo jih obdelali 62 (Sl. 3). Določili smo tudi dele jamskega spleta (Sl. 1). Tega sestavlja 11 speleoloških objektov: Škocjanska jama (1) z Okroglico (1a) in

Rovom (1b), Velika (2) in Mala (3) Koščakova jama, Rečni vodnjak (4), Miklov skedenj (5), Jama (6) in Jamica (7) nad jezerom, Tominčeva jama (8), Ozka špilja (9), Jama strahov (10) in Šumeča jama (11) s Prukerjem (11a) in Tihim rovom (11b). Ponikalnica Velika voda - Reka in lega znotraj oboda Velike in Male doline jih povezujeta v jamski splet.

Največ enot (21 primerkov) pripada prvi in drugi skupini naravne dediščine (Rojšek 1994-2; Sl. 2); 14 enot sodi samo v prvo, 11 pa samo v drugo skupino; 6 v prvo, drugo in tretjo; 4 v prvo, drugo, tretjo in četrto; 2 v prvo in tretjo; 2 v prvo in četrto; ena v prvo in četrto in ena v tretjo skupino naravne dediščine. Na zavarovanem ozemlju ni enote naravne dediščine, ki bi sodila v peto skupino.

V prvi skupini omenimo največje jamske dvorane, stalagmite in ponvice v Sloveniji, korita in hitro odlaganje sige. Osem jezer in trije slapovi sodijo v drugo skupino. Rastišča lepega jegliča (*Primula auricula L.*) in venerinih laskov (*Adinatum capillus veneris L.*) so med največjimi posebnostmi v tretji skupini, v četrti pa omenimo ogrožene vrste ptičev in netopirjev.

Najpomembnejši naravni pojav je Šumeča jama s Prukerjem in Tihim rovom, kjer smo obdelali 32 ali dobro polovico vseh enot naravne dediščine Škocjanskega jamskega spleta. Predvidevamo, da leži večina enot naravne dediščine ravno v tej jami. Dostop do posameznih naravnih pojavov spleta je v njej najtežavnejši, kajti njena prostornina sodi med največje na Zemlji.

Po zadnji inventarizaciji smo v Tominčevi jami (Sl. 1, št. 8 & Sl. 3, št. 29) odkrili edino znano nahajališče jamskih biserov.

Inventar predstavljamo grafično s primerkom inventarnega lista Škocjanskega jamskega spleta (Sl. 2) in tlorisom lokacij enot naravne dediščine z imeni (Sl. 3).

Nemo propheta in patria, vendar si upamo napovedati, da Škocjanski jamski splet vsebuje več kot 200 enot naravne dediščine, skupaj z naravno dediščino Škocjanskega krasa in Vremske doline pa je teh enot še precej več. Skupina jamarjev in strokovnjakov za inventarizacijo bi napoved potrdila oziroma ovrgla, če bi se odgovorni organi Republike Slovenije zavedli svoje dolžnosti in finančno podprli inventarizacijo zavarovanega ozemlja.

"OPERAZIONE CORNO D'AQUILIO": AN EXAMPLE OF CLEANING OPERATION, EXPLORATION AND SCIENTIFIC ANALYSIS OF A KARST SYSTEM

"OPERAZIONE CORNO D'AQUILIO": PRIMER ČISTILNE AKCIJE, RAZISKAV IN ZNANSTVENIH ANALIZ V KRAŠKEM SISTEMU

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Izvleček UDK 551.44(450)"1988/1992"

Ugo Sauro*, Marco Menichetti+ and G. Troncon++ "Operazione Corno d'Aquilio": primer čistilne akcije, raziskav in znanstvenih analiz v kraškem sistemu

"Operazione Corno d'Aquilio" je primer združenih jamarskih raziskav ter raziskovalnega projekta nekega kraškega sistema, pri katerem je sodelovalo 30 jamarskih skupin v letih 1988 - 1992. Poleg jamarskih topografskih in fotografskih raziskav v kraškem sistemu Spluga della Preta (Monti Lessini, Beneške predalpe, Italija), je bila organizirana tudi čistilna akcija. Zbranega je bilo mnogo novega znanstvenega gradiva in podatkov, zelo pomembnih za razumevanje dinamike kraškega sistema.

Ključne besede: speleologija, hidrologija krasa, prenikajoča voda, čistilna akcija, Italija, Beneške predalpe, Spluga della Preta

Abstract UDC 551.44(450)"1988/1992"

Ugo Sauro*, Marco Menichetti+ and G. Troncon++: Operazione Corno d'Aquilio: an example of cleaning operation, exploration and scientific analysis of a karst system

Operazione Corno d'Aquilio (O.C.A. Operation) is an example of integrated exploration and research project of a karst system. About 30 Speleo Groups have taken part to this project between 1988 and 1992. Beside exploration, topographical and photographical survey of the karst system of Spluga della Preta (Lessini Mountain, Venetian Pre-Alps, Italy) a cleaning operation and a lot of new scientific material spanning from geological, geomorphological, hydrological and environmental data have been collected, very important for the understanding of the character of the system.

Key words: speleology, karst hydrology, percolation water, cleaninig operation, Italy, Venetian Prealps, Spluga della Preta

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Operazione Corno d'Aquilio (O.C.A) è un interessante esempio di integrazione fra un progetto di esplorazione, un operazione di disinquinamento e la raccolta di dati scientifici su un sistema carsico. Circa 30 Gruppi Speleologici hanno preso parte a questo progetto fra il 1988 e il 1992.

Oltre all'esplorazione, al rilievo topografico e fotografico del sistema carsico della Spluga della Preta (Monti Lessini, Prealpi Venete, Italia), è stata realizzata un operazione di pulizia e raccolti materiali scientifici e nuovi dati di notevole importanza per la comprensione della dinamica dei sistemi carsici.

The speleological expedition: "Operazione Corno d'Aquilio" (O.C.A. which in Italian language means "goose") is one of the most remarkable example of an undertaking, related to a karst system, where exploration, geographical and environmental documentation, ecological restoration and educational projects have been planned and developed in co-operation between speleologists, research workers and local political Institutions.

The main focus of this project has been the karst system of Spluga della Preta, one of the world-wide known karst system, especially for the history of speleological explorations. In fact the first explorations of the system begun in the twenties and, due to an over-estimation of the real depth, during the thirties and the forties the system was considered the deepest of the World (fig. 1, 2, 3).

The early project was firstly born inside GASV (Gruppo Attività Speleologica Veronese) and GSM (Gruppo Speleologico Mantovano) during 1987. In a few months it was discussed and revised in particular by Soresini Aldo and Troncon Giuseppe.

In April 1988, 21 Speleological Groups from seven Italian regions met together and established a Commission to manage the operations, composed by a member from each Group. Also a Scientific Working Group was constituted.

Here follow the main items of the project:

1) exploration of the Preta underground system,
2) research of caves in the surrounding area,
3) unblocking of selected points of the system,
4) clean up and decontamination of the residuals of over 50 years of explorations inside the Spluga della Preta,
5) photographic survey,

6) new topographical survey of the system,
7) geological and geomorphological research inside and outside the karst system,
8) hydrological research on the area.

Giuseppe Troncon was appointed as Secretary of the OCA.

Each Speleological Group was requested to furnish material and men for the operations. The Commission remained open also to contributions of others Speleological Groups. Some political and administrative institutions were asked to support the undertaking.

During 1989 the publication of a photograph, taken during the cleaning operations, as a cover of "Speleologia", the magazine of S.S.I. (Italian Speleological Society) has given to OCA a national resonance. In fact the cleaning operation has been the largest ever realised in Italy in a large karst

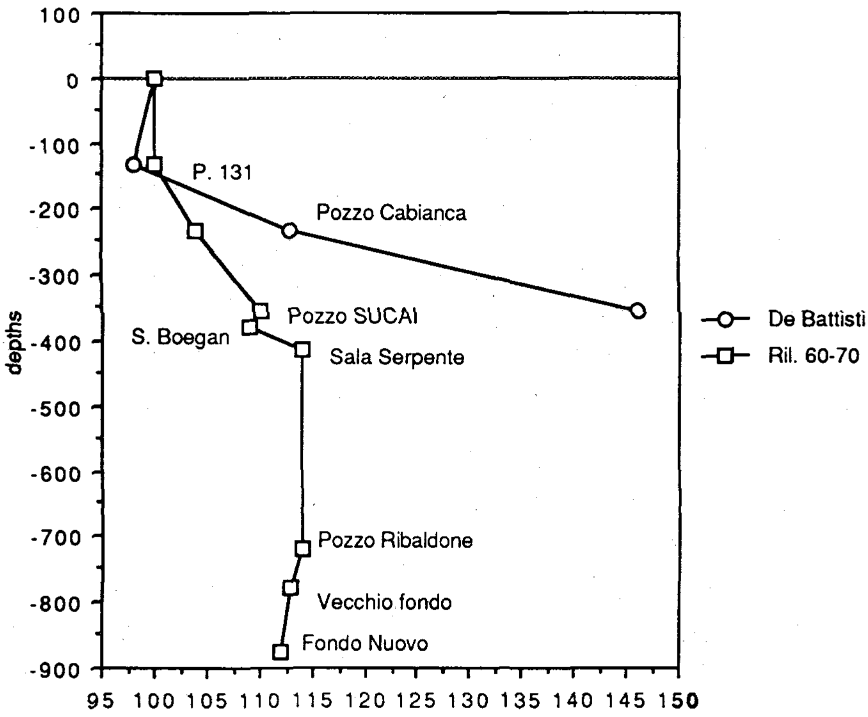

Fig. 1. - Over-estimations of some depths in old plots of Spluga della Preta (plan De Battisti of 1926; and two similar plans of 1960s) in comparison with the recent O.C.A. instrumental plot. In vertical axis the depths of the system in horizontal axis the deviations of the depths in the old plots expressed as % in comparison with the intrumental ones.

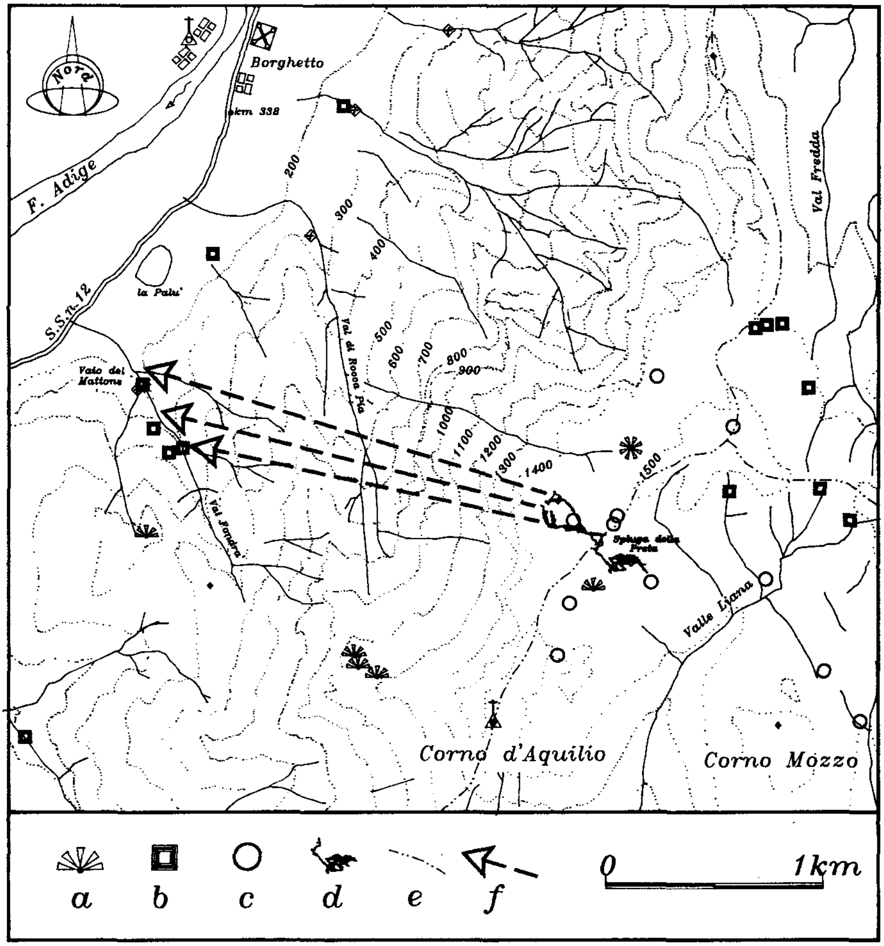

Fig. 2. - Hydrological connections of the Spluga della Preta. Legend: a) caves, b) springs, c) artificial ponds, d) topographical plot of Spluga della Preta, e) main topographical water divide, f) some subterranean water ways proved with tracing tests.

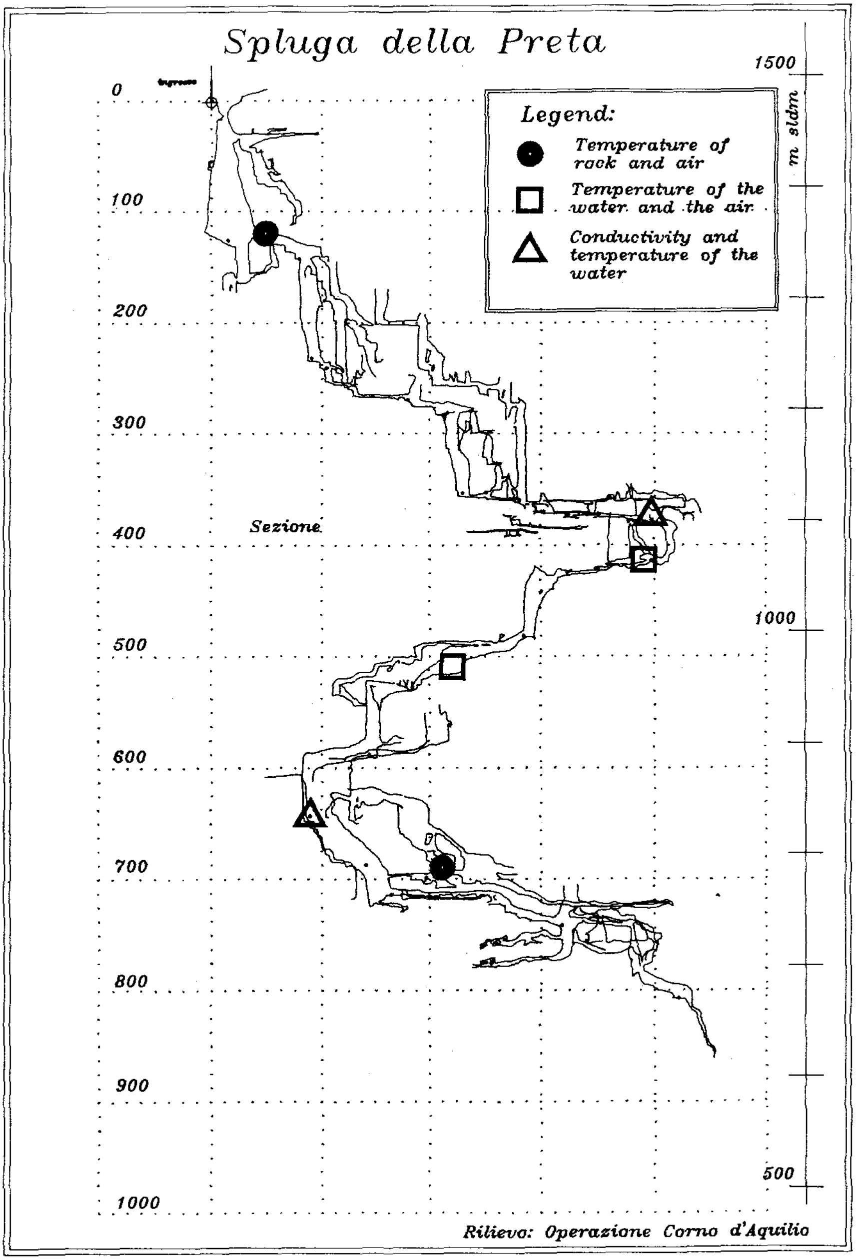

Fig. 3. - Monitoring system of environmental parameters inside the karst system of Spluga della Preta.

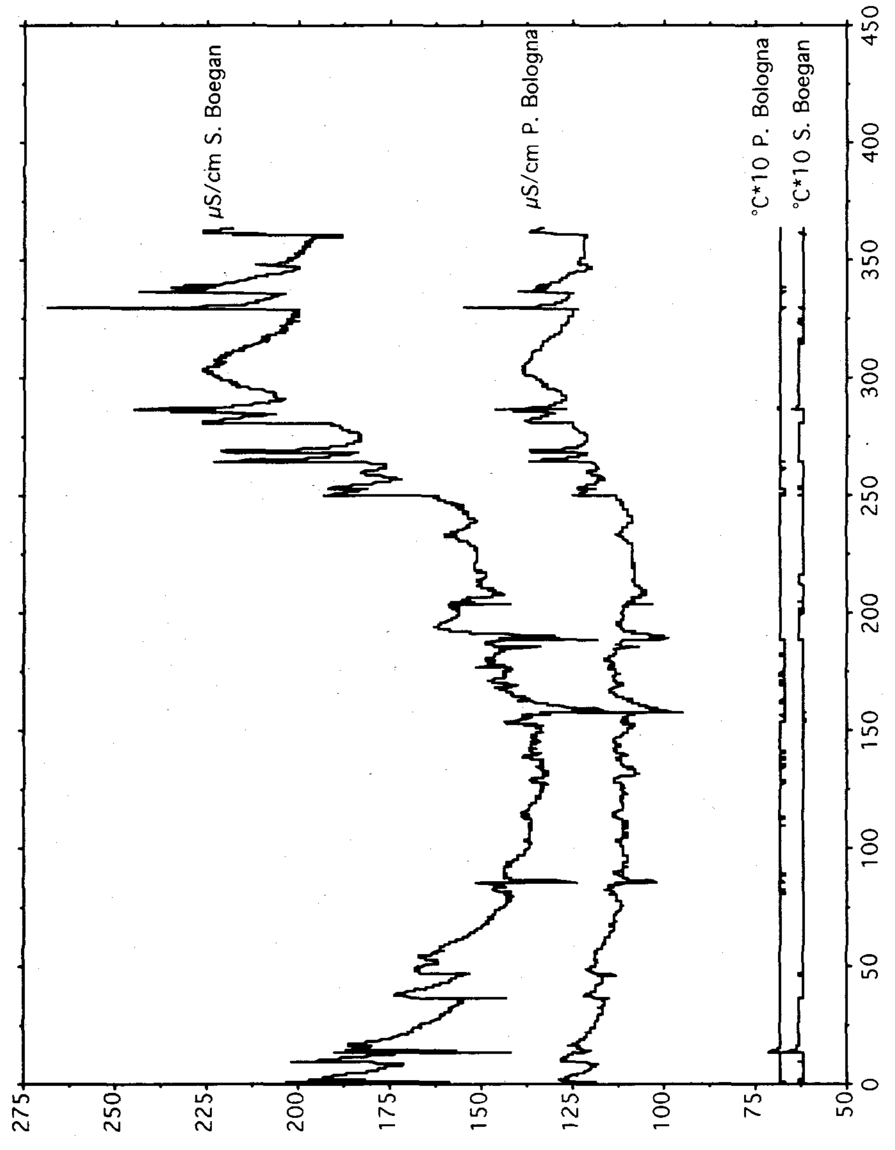

Fig. 4. - Changes in water temperature (expressed in tenths of C) and conductivity (μS/cm) at two different depths inside the karst system of the Spluga della Preta. The different amplitude of the two curves of conductivity are due to the different calibration of the sensitive elements. In the X axis there are the days from the 30th of September 1992.

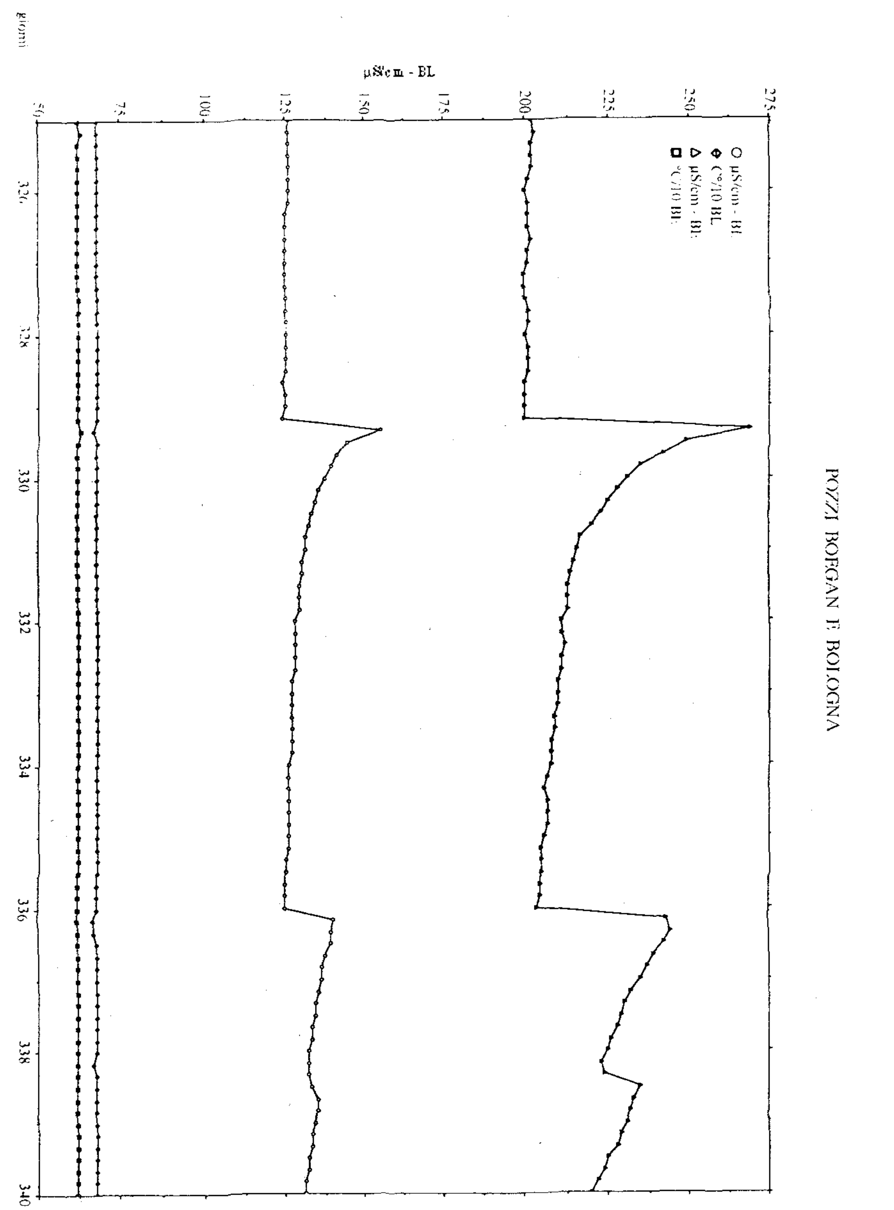

Fig. 5. - Synchronous increasing of conductivity in the Boegan Room (- 360 m) and in the Bologna Pit (- 630 m), probably linked with the rapid expulsion of the "old" water from the fissures opening near the main subterranean voids due to the piston effect inside the epikarst determined by abundant rainfalls after long period without precipitation. (326 corresponds with August 20, 1992).

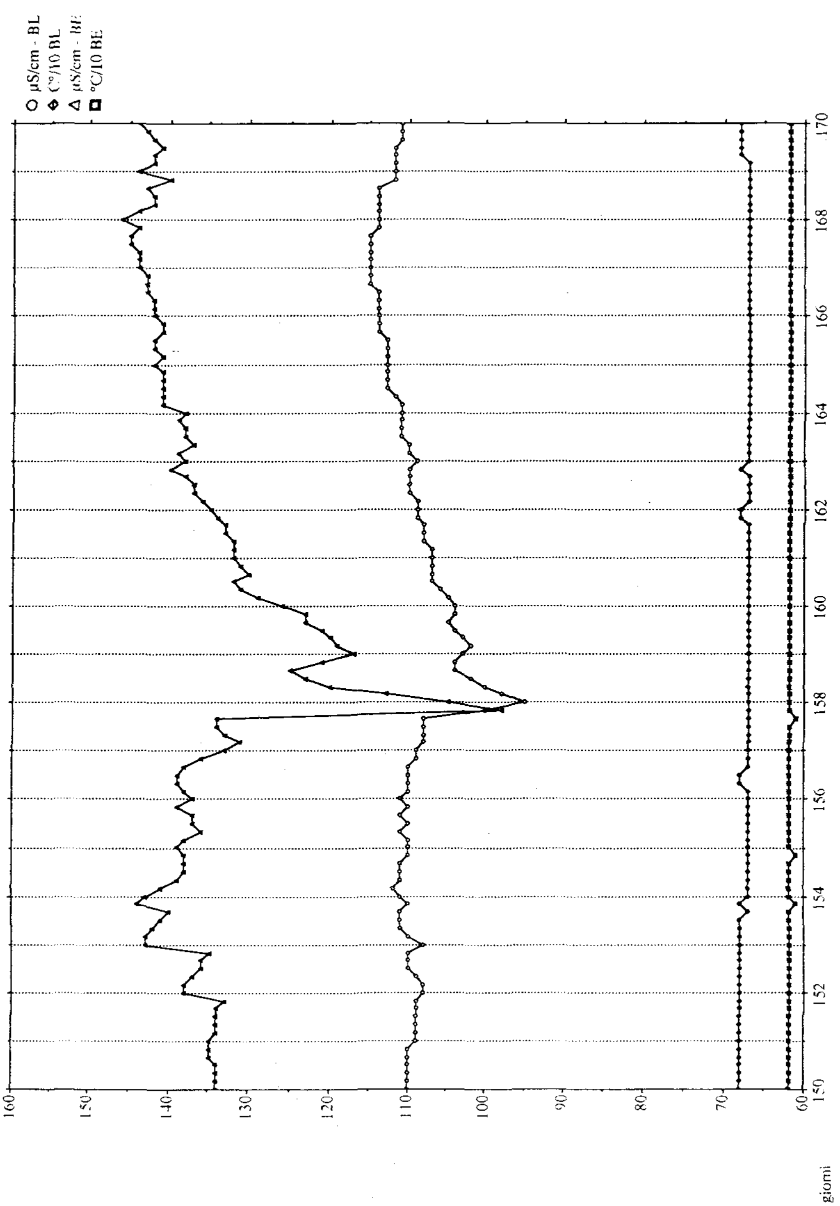

Fig. 6. - Not synchronous decrease in conductivity probably due to a flood of the underground water courses caused by snow melting (150 is February 26, 1992).

system.

After this, OCA purposes were mostly devoted to documentation and scientific research work.

The official ending of the undertaking was the 25 January 1992; in fact the operations continued for at least one more year and some are still continuing, as the publication of the documentation and the scientific results.

Searching to trace a balance of the OCA, some of the more significant points follow here:

- members of about 30 speleological groups have taken part in the operation with a total time in the cave estimated as about 30.000 hours (about 3 and half years of interrupted man-time). About half of this time was employed by the cleaning operations, during which 810 sacks of solid waste, with a total weight of about 4 MT (metric tons) were transported to the surface,
- from the exploitive point of view about one kilometre was added to the development of the cave, beside the 2,5 km previously explored,
- a new precise topographical survey was made, which has allowed correction of the total difference in elevation of the system to 875 m, against the 985 m previously estimated (fig. 1, 3),
- a photo-survey of about 5000 photographs was made,
- unknown karst caves in the surrounding areas were detected and explored,

With reference to the scientific research work the main results are listed below:

- new geologic surveys both of the area and of the underground system,
- geomorphological survey,
- analyses of the underground sediments (difractometry, pollen research, ...),
- thermal infrared analysis of the Adige Valley left slope, near to the karst system,
- tracing tests to recognise both the hydrological connection with karst springs and the main internal network of the karst water (fig. 2),
- chemical analyses of the karst water,
- monitoring for one year of some parameters (temperatures of the air, water, rock, conductivity) inside the system (fig. 3);
- biological researches during which some new species of invertebrate were discovered.

With reference to the monitoring operations, the air temperature was measured at the surface of the plateau, the bottom of P. 131, the Serpenti room, the Bertola Room, and the Vecchio Trippa branch; the water temperature was measured in the Serpenti room, and in the Bertola Room; the rock temperature was measured at the base of P. 131 and the Vecchio Trippa branch. The water conductivity was measured in the Boegan room and in the Bologna Pit (fig. 3).

In this way about 20.000 data were collected (about 2000 for each station with a lapse of 4 hours for the time of about 1 year).

It will take a long time to examine all these data. Here we make only some preliminary observations.

The temperature curves do not show significant changes between the different components of the system. The air temperature vertical rate is of about 0,4 C/100 m; the water temperature vertical rate is of only 0,22 C. A curious variation of temperature during springtime has been observed at the base of P. 131. If this change is confirmed by further work it could perhaps be explained by a chimney effect due to the warmer air coming from the well exposed rocky bluffs of the nearby slope of the Adige Valley. The starting of this chimney effect could perhaps be determined by the piston effect inside the epikarst of the snow melt water combined with the spring rainfalls.

Very interesting are the curves of the water conductivity measured in the Boegan room (- 380 m) and in the Bologna Pit (- 640 m).

The differences in conductivity between the two curves are not real and mostly due to the different sensitivity ranges of the electrodes.

Between the many observations deducible from the analysis of the curves these are noteworthy:

- an annual cycle of conductivity is clearly recognisable linked with the runoff regime (fig. 4);
- some rapid increases in conductivity are nearly synchronous in the two station and probably linked with the rapid expulsion of the "old" water from the fissures opening near the main subterranean voids due to the piston effect inside the epykarst, determined by abundant rainfalls after long period without precipitation (fig. 5);
- on the contrary there is a lapse time of about 4-12 hours in the decreasing of conductivity between the two stations; this is clearly linked with the arrival of younger water during the flooding of the underground water courses.

Surely many of these aspects necessitate further research work (fig. 6).

In any case OCA is a good example of an undertaking developed in co-operation between speleologists and research workers which has allowed both an ecological restoration of a large karst system and the storing of a lot of new data and unexpected scientific results.

REFERENCES

BERTOLANI M., BERTOLANI-MARCHETTI D. & MOSCARDINI C. (1963) - Osservazioni scientifiche effettuate nel corso della spedizione esplorativa alla Spluga della Preta del 5-18 Agosto 1962. Atti IX Congr. Naz. Speleol. (Trieste 1963), Mem. 7 di Rass. Speleol. It., 20pp.

CORRA' G. (1975) - La Spluga della Preta, cinquant'anni di esplorazioni. Natura Alpina, 3: 1-239.

GRUPPO SPELEOLOGICO BOLOGNESE C.A.I., GRUPPO SPELEOLOGICO

"CITTA' DI FAENZA". GRUPPO SPELEOLOGICO PIEMONTESE C.A.I.-U.G.E.T. e SPELEO CLUB BOLOGNA E.N.A.L. (1963) - Spedizione 1963 alla "Spluga della Preta". Atti IX Congr. Naz. Speleol. Trieste, Mem. Rass. Spel. Ital., 8: 1-37.

HABBE K.A. (1969) - Die würmzeitlische Vergletscherung des Gardasee-Gebietes. Freiburger Geographische Arbeiten, 3, 253 pp.

MAGALDI D. & SAURO U. (1982) - Landforms and soil evolution in some karstic areas of the Lessini Mountains and Monte Baldo (Verona, Northern Italy). Geogr. Fis. Dinam. Quat., 5 , 82-101.

MAUCCI W. (1954) - Analisi morfogenetica della Spluga della Preta. Atti VI Congr, Naz, Speleol., Trieste: 40 pp.

MENEGHEL M. , SAURO U., BACIGA M. L., FILECCIA A., FRIGO G., TONIELLO V. e ZAMPIERI D. (1986)- Sorgenti carsiche ed erosione chimica nelle Prealpi Venete. Studi Trentini di Scienze Nat. , 62, A.G.: 145-172.

MENICHETTI M, O.C.A. (1990) - Attiività di ricerca svolte durante l'Operzione Corno d'Aquilio. XVI Congr. Naz. Speleol., Udine.

MIETTO P. & SAURO U. (1989) - Grotte del Veneto: paesaggi carsici e grotte del Veneto. Regione del Veneto e La Grafica Editrice (Vago di Lavagno-VR), 415 pp.

NICOLIS E. (1898) - Circolazione interna e scaturigini delle acque nel rilievo sedimentario-vulcanico della regione veronese e della finitima. Accademia di Verona, v. 54, s. 3, f. 1, 209pp.

NICOLIS E. (1901) - Geologia ed idrologia della regione veronese. In "La Provincia di Verona" a cura di Sormani-Moretti, vol. 1 , 60pp.

PASA A. (1954) - Carsismo ed idrografia carsica del Gruppo del Monte Baldo e dei Lessini Veronesi. C.N.R., Centro Studi Geogr. Fis. , Ricerche sulla morf. idrogr. cars., 5: 150 pp

PASA A., DURANTE PASA M. V. & RUFFO S. (1960) - L'ambiente fisico e biologico Veronese. In "Verona ed il suo territorio" I, Istituto Studi Storici Veronesi, 5-36 Verona.

ROSSI G. e SAURO U. (1977) - L'Abisso di Lesi: analisi morfologica e ipotesi genetiche. Le Grotte d'Italia, (4) 6 (1976): 73-100.

SAURO U. (1973) - Il Paesaggio degli alti Lessini. Studio geomorfologico. Museo Civ. di St. Nat. di Verona, Mem. f. s. , 6, 161 pp.

SAURO U. (1974) - Aspetti dell'evoluzione carsica legata a particolari condizioni litologiche e tettoniche negli Alti Lessini. Boll. Soc. Geol. It. , 93, 945-969.

SAURO U. (1979b) - Morfologia carsica. In "Geomorfologia", G.B. Castiglioni Ed., UTET, 208-254.

TRONCON G. & SORESINI A. (1991) - Operazione Corno d'Aquilio: Atto finale. Speleologia 25, 59-60.

TRONCON G. (1988) - Operazione Corno d'Aquilio. Speleologia 19, 44-46.

TRONCON G. (1989) - L'abissale spazzatura della Spluga della Preta. Speleologia, 20, 4-7.
TRONCON G. (1990) - Nel segno del Corno d'Aquilio. Speleologia 22, 50-54.

"OPERAZIONE CORNO D'AQUILIO": PRIMER ČISTILNE AKCIJE, RAZISKAV IN ZNANSTVENIH ANALIZ V KRAŠKEM SISTEMU

Povzetek

"Operazione Corno d' Aquilio" je primer združenih jamarskih raziskav ter raziskovalnega projekta nekega kraškega sistema. Akcija je bila usmerjena v brezno Spluga della Preta (Monti Lessini, Beneške predalpe, Italija), ki je nekaj časa veljalo celo za najglobljе na svetu. 1988 se je zbralo 21 jamarskih skupin in izbralo posebno komisijo za vodenje akcije ter sestavilo delovno skupino znanstvenikov. Akcija je bila uradno zaključena 25. januarja 1992. Tekom akcije so bili člani 30 jamarskih skupin okoli 30 000 ur pod zemljo (polovico časa so porabili za čiščenje - na površje so zvlekli 810 vreč, okoli 4 tone, trdnih odpadkov). Izmerili so okoli 1 km novih rovov (prej je bilo brezno dolgo 2,5 km), napravili nov natančen načrt (po njem je globina 875 m, prej 985 m), posneli okoli 5 000 fotografij in preiskali okoliški kras.

Najpomembnejši rezultati znanstvenih raziskav so geološke raziskave brezna in okolice, geomorfološki pregled, analize sedimentov, infrardeče termoanalize bližnjega pobočja, sledenje vode, kemijske analize kraške vode, leto dni trajajoč monitoring v breznu (temperature zraka, vode in skale, električna prevodnost) in biološke raziskave, ki so odkrile nekaj novih vrst nevretenčarjev.

Operacija "Corno d'Aquilio" je lep primer sodelovanja med jamarji in znanstveniki, ki je omogočilo ekološko sanacijo velikega kraškega sistema, tekom akcije pa je bilo zbranih veliko novih podatkov, ki so dali tudi nepričakovane znanstvene rezultate.

CAN ONE DEFINE POLJES?

ALI JE MOGOČE DEFINIRATI POLJE?

EMIL SILVESTRU

Izvleček UDK 551.435.83:001.4

Emil Silvestru: Ali je mogoče definirati polje?

Krasoslovje je znanost, ki je nastala z združitvijo številnih znanstvenih vej. Zato je veliko število današnjih posebnih terminov privzetih iz "starejših" znanosti. Često krasoslovci take termine napačno uporabljajo ali so celo sprejeti v krasoslovje. Verjamem, da je nastopil čas, ko je k tem vprašanjem treba pristopiti drugače, na trdnih temeljih. Ko obravnavamo kraško ozemlje ali kraški relief, morajo geologija, hidrogeologija in geomorfologija predstavljati osnovo raziskavam. Potemtakem morajo biti kriteriji za vpeljavo termina ali za klasifikacije: geološka osnova, funkcionalnost (preoblikovalni dejavnik in hidrogeološka funkcija) in morfologija. Kot najbolj razvita kraška oblika je polje idealni primer težav z definicijo. Po pregledu dosedanjih definicij predlagamo novo, na zgoraj omenjenih osnovah.

Ključne besede: krasoslovje, morfologija krasa, kraško polje, terminologija

Abstract UDC 551.435.83:001.4

Emil Silvestru: Can one define poljes?

Karstology was built as a science by joining together a large number of research fields. This is why an important number of specific terms are actually adopted from "older" sciences. Pretty often such terms are misused by karstologists or have even been accepted in karstology. We believe that time has come for a different approach, on firm grounds. We consider that, when approaching karst terrains and their relief, the very basics of research must deal with geology, hydrogeology, and geomorphology. Therefore the main criteria to be used when introducing a term or making classifications, are: substratum, functionality (i.e. modelling agent and hydrogeological function) and morphology. As the most evolved karst pattern, poljes are an ideal example for the difficulties in definition. After reviewing previous definitions we suggest yet another one, on the above-mentioned basis.

Key words: karstology, karst morphology, karst polje, terminology

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Karstology was built as a science by joingin together a large number of research fields. Prevailing however are, geomorphology, hydrogeology and geology. There is one more, extremely important characteristic which makes karstology almost unique: long before being a self-standing science, geography was already coining terms that subsequently became standard karstological terms, without being actually re-defined according to new criteria. More specifically: J. CVIJIĆ (1895) was describing the very archeotype of karst - the Kras region - using simple descriptive criteria and quite often, regional terms.

Polje is such a term, which originally menas field. Of course, in the middle of a rather rugged landscape, the presence of surprisingly flat, large and fairly wet areas, ideal for farming, is a very special pattern and the inhabitants had no need to define it with more than one word - polje (field). Yet, there is for example another field in eastern Serbia - Kosovo Polje (The Blackbird's Field) - which has entirely different connotations. A simple date (1389) added to this toponym, would suffice for specialists to define it. For the rest of the world however, many more specifications are needed in order to clearly define this information. Similarly, the particle karstic has been added to the term polje in the Kras area. However, this simply means a large, flat area in karstic landscapes.

CVIJIĆ (1960) did not actually define a polje. He simply stated that "a polje is a flat-bottomed karstic depression, always displaying a long axis". He also added several specifications:

- a polje differs from a blind valley by being much larger, having festooned borders and its long axis paralleling important structural features,
- some flat-bottomed, elongated uvalas may be considered a transition form between dolines and poljes; 1 km in diameter seems to be the threshold value between the two,
- the presence of a surface stream inside the depression is not a necessary feature for poljes.

Practically, all further definitions dealt more or less with these issues. This shows CVIJIĆ's keen sense of observation on one hand, and the general trend to stress morphological rather than genetical and functional features, on the other hand.

A short review of some of the most important definitions advocates for such a statement:

B. GEZE (1973): large, closed karstic depression, characterised by a flat bottom which joins the usually barrens slopes in an angle. Its drainage is subterranean. It may be dry, crossed by a stream of permanently or temporarily flooded.

M. SWEETING (1973): a depression in karst limestone, whose long axis is developed parallel to major structural trends and can reach tens of kilometres in length. On the floor accumulates superficial deposits, and it si drained either by surface water-courses (when the polje is said to be open) or by swallow holes (a closed polje). Their development is encouraged by any impedance in the karst drainage.

G. T. WARWICK (1976, in FORD & CULLINGFORD): the larger dolines grade into large flat-floored depressions known as polja (singular, polje), the base being covered with alluvium of non-limestone origin. The sides are usually steeply sloping, bur rarely cliffed, and may be breached by inflowing streams which sink into the polje floor. Most of them are elongated but there is a wide variety in plan.

I. GAMS (1977): a polje is an extensive (closed) basin with a flat bottom, karstic drainage and steep slope, at least on one side. If the slopes are mostly steep, with a break at the transition to the bottom, and a sinking river, the flat bottom is 400 m wide at least.

J. CHOPPY (1985): vast, closed and elongated depression, ranging up to several hundred square kilometres, with a clear break between the flat bottom and the slopes, which are mostly barren; its drainage is subterranean.

GAMS (1977) did however much more that propose a new definition. He separated 5 basic types of polje: border polje, peripheral polje, overflow polje, polje in the piezometric level, piedmont polje. The criteria used for this separation clearly included hydrogeological functioning (and conditioning) of poljes. Geology is also taken into consideration. We consider this an extremely important step towards a karstological understanding and defining of poljes. Another important step was taken by RUSU (1973, 1975, 1988) by introducing a new category: the karstic catchment depression (kcd) defined as:

open depression-type karstic form, developed along a valley track, upstream a subterranean catchment (sinking) point, marked by an antithetic step[2].

This category was the result of RUSU's work in the Pădurea Craiului Mountains karstic areas, where polje-like depressions are quite frequent. However, when compared to true poljes, these depressions revealed several differences:

- the kcds are always open upstream (CVIJIĆ's open polje, GAMS's border polje)

[2] term coined by BLEAHU (1957) for the more or less vertical step that sometimes marks a sinking point in the very river bed of a sinking stream.

- the most obvious break between the slopes and the flat bottom is always at the downstream end of the kcd,
- the surface water-courses always have their sources outside the limestone terrains.

In the other words, RUSU's karstic catchment depressions are a special type of blind valleys, which have created an alluvial plain upstream and around their sinking area.

The question is: are these forms true poljes? The above-mentioned author answers "no", because of the differences mentioned previously.

We tend to agree with this point of view, since we consider poljes as the most developed and complex karstic forms, specific to large and mature karst landscapes, of which Romania has no share.

Moreover, as far as we could figure it out, poljes (at least the Dinaric type) are present in areas not very far from the sea which, as a regional base level would induce much more dramatic changes (following climate changes), such as SWEETING's "impedance", in the karst drainages, as compared to river-type base levels. Such changes are most likely to account for the genesis of landforms the magnitude of poljes.

DISCUSSION

As we have previously stated, there is a true need for a karstological definition of poljes, a definition that would stress the functional, hydrogeological, geological and finally morphological elements.

If we take a close look at the previously mentioned definitions, we may notice that these elements are all there but need to be summed up. On the other hand, simply merging them into one one-page definition is by all means non-scientific.

FORD (1992) found an original way to avoid this. He first states that poljes are: "large, flat floored enclosed depressions in karst terrains". He than reduced GAMS's categories of poljes to three describing the following:

- border poljes - allogenic input dominated.
- structural poljes - dominated by geological control. "They are inliers of a normal fluvial landscape within an otherwise karstic terrain"
- baselevel poljes - water table dominated. Actual "windows on the water table" and "the purest kind of poljes".

The way FORD describes these categories makes definitons sound obsolete and even . . . degrading, Yet those simple sentences like: "inliers of a normal fluvial landscape . . ." are as a matter of fact, the best definitons. If it were for the karstologists only, these would suffice; however, as parts of karstology (especially the geomorphology of karst terrains) are normally introduced in general treatises, we are still left with the need for general definitions. This brings us back to our main topic: can one really define poljes?

There is one good possibility of simplifying thins, if we introduce RUSU's karstic catchment depression (kcd) as a self-standing karst landform category. This would eliminate some of the poljes described before - namely the border or open poljes. Generally speaking, all poljes that are not enclosed depressions should no more be considered as poljes. They should be called karstic catchment depressions. Genetically they are closer to blind valleys, regardless the size and shape.

The (en)closed depressions on the other hand, represent a special case in karst terrains and argue for a complex genesis, unlike the kcds for which the surface streams are the main genetic factor. There is one mention to be made: one should make a difference between dolines and uvalas on one hand - which display a predominantly conical shape, and "depressions" on the other hand. We consider depressions in karst to be defined by more or less flat bottoms (truncated shape). Size is less significant. It is quite possible that the original excavation was of doline type (solutional) and that there subsequently existed a grading from dolines to poljes (as WARWICK puts it). The most important thing is the flat-bottomness which in most of the cases had been achieved by alluviation, up to covering an irregular topography. In the Duvanjsko Polje, the sediment reaches 2 000 m in thickness (FORD, 1992). No known present karst drainage can account for such an input of alluvia into a closed depression in karst and therefore one may assume that, the karstification processes that shaped poljes were somewhat different from the ones we can presently investigate. The climate during the Neogene period (when most of the sediments have accumulated) was considerably wetter and warmer (FRAKES, 1979) and the solutional and alluvial rates must had been very different from the present ones. This is why we consider poljes to be dying remnants of a different (most probably ante-Quaternary) type of karstification. Under such circumstances, it is very difficult to define the main hydrogeological factor to control their genesis. The present hydrogeological function is somewhat secondary - a polje drains a subterranean stream it had cut during its evolution. Is is questionable if the same stream is responsible for the genesis of the polje. Yet, such a feature (even if secondary) is in a way intrinsic to a polje . . .

Geology is one important controlling factor, as considered by many authors, by providing "the infrastructure" within a limestone terrain. However, what really seems to be important is the character of "holokarst" (CVIJIĆ, 1924): massive and pure limestones with predominantly vertical fracturing which results in large (surface) streamless karst surfaces. The tectonic features may be of great importance for the final morphology and function of the polje, but not necessarily for the very existance of it.

At this point, what do we have left? A polje should be:

an ante-Quaternary enclosed depression with a predominantly flat, alluviated bottom, in a large massive limestone area.

It may drain a temporary or permanent karst stream (a stream that has at least one karstic character: karst source or/and sink).

Size is irrelevant since the mechanism(s) that generated poljes implied a sort of self-regulating "size-control", probably due to alluvia input.

REFERENCES

BLEAHU, M. D., 1957: Captarea carstică şi importanţa ei pentru evoluţia morfologică a regiunilor carstice.- Probleme de Geografie, Bucureşti, Ed. Academiei R. P. r., pp. 55-99.

CVIJIĆ, J., 1895: Karst.- Geografska monografija. Beograd.

CVIJIĆ, J., 1924: Types morphologiques des terrains calcaires.- Glasnik Geogr. društva. Beograd 10, pp. 1-7.

CVIJIĆ, J., 1960: La Géographie des terrains calcaires.- Acad. Serbe des Sciences et Arts. Monographies t. CCCXLI. Belgrade, 212 p.

CHOPPY, J., 1985: Dictionaire de spéléologie physigue et karstologie.- Spéléoclub de Paris, 150 p.

FORD, T. D. & CULLINGFORD, C. H. D., 1976: The Science of Speleology.- Academic Press. London*New York*San Francisco, 593 p.

FORD, D. C. & WILLIAMS, P. W., 1992: Karst Geomorphology and Hydrology.- Chapman & Hall, London*New York*Tokio*Melbourne*Madras, 601 p.

FRAKES, L. A., 1979: Climate Throughout Geological Time.- Elsevier Scentific Publishing Cy. Amsterdam-Oxford-New York, 310 p.

GAMS, I., 1977: Towards the Terminology of the Polje.- Proceedings of the 7th International Speleological Congress, Sheffield, pp. 201- 202.

GEZE, B., 1973: Lexique des termes français de spélólogie physique et de karstologie.- CNRS, France, t. 28/1, pp. 1-20.

RUSU, T., 1973: L'évolution des vallées karstiques des Monts Pădurea Craiului.- Trav. Inst. Spéol. "E. Racovitza". Bucureşti. t XII, pp. 311-335.

RUSU, T., 1975: La depression de capture karstique de Pusta Călăţea (Monts Pădurea Craiului).- Trav. Inst. Spéol. "E. Racovitza", Bucareşti. t. XIV, pp. 157-168.

RUSU, T., 1988: Pe urmele apelor subterane - carstul din Munţii Pădurea Craiului.- Ed. Dacia, Cluj-Napoca, 253 p.

SWEETING, M., 1973: Karst landforms.- Columbia University Press, New York, 362 p.

ALI JE MOGOČE DEFINIRATI POLJE?

Povzetek

Krasoslovje je znanost, ki je nastala z združitvijo številnih znanstvenih vej. Zato je veliko število današnjih posebnih terminov privzetih iz "starejših" znanosti. Često krasoslovci take termine napačno uporabljajo ali so celo sprejeti v krasoslovje. Cvijić je polje le opisal, ni ga pa definiral. Gams pa ni le predlagal nove definicije, ampak tudi klasifikacijo na pet osnovnih tipov polj, kar je Ford skrčil na tri. Stvari je mogoče poenostaviti, če upoštevamo Rusujevo "karstic catchment depression". Nova definicija polja naj bi bila: polje je predkvartarna zaprta depresija s prevladujočim ravnim, aluvijalnim dnom, v večjem apnenčevem masivu. Po njem lahko teče občasni ali stalni kraški tok (mora imeti vsaj eno kraško značilnost: kraški izvir in/ali ponor).

FACETS - AN IMPORTANT TRACE OF SHAPING AND DEVELOPMENT OF THE KARST CAVERNS

FASETE, POMEMBNA SLED OBLIKOVANJA IN RAZVOJA KRAŠKIH VOTLIN

TADEJ SLABE

Izvleček UDK 551.441(497.12)

Tadej Slabe: Fasete, pomembna sled oblikovanja in razvoja kraških votlin*

Fasete so ena najbolj poznanih jamskih skalnih oblik. Nastajajo zaradi vrtinčenja vodnega toka ob hrapavi površini topljive kamnine. Po zbranih vzorcih s terena sem ugotavljal, da je oblika mreže faset in njihova velikost predvsem posledica hidravličnih razmer v različno oblikovanih in velikih rovih. Na nastanek in oblikovanje faset pomembno vpliva tudi sestava in pretrtost kamnine, ki jo obliva vodni tok. Pri razlagi oblikovanja faset sem si pomagal z laboratorijskimi poskusi z mavcem.

Ključne besede: speleomorfogeneza, kraška votlina, jamska skalna oblika, faseta, Slovenija, Dinarski kras

Abstract UDC 551.441(497.12)

Tadej Slabe: Facets - an important trace of shaping and development of the carst caverns*

Current markings are one of the most significant rock forms. Their origin is controlled by swirling water flow against the rough surface of the soluble rock. On collected samples stated that the current markings net shape and their size depend on hydraulic conditions in the channels of the various shape and size. The composition and structure of the rock overflown by water are one of the important factors influencing to the origin and shape of current markings. The explanation of facets formation was backed up by the laboratory experiments inplaster.

Key words: speleomorphogenesis karst cavern, rocky cave feature, facets, Slovenia, Dinaric Karst

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AEROPHOTO INTERPRETATION OF GEOLOGICAL STRUCTURES ON THE SURFACE ABOVE THE PREDJAMA CAVE

AEROFOTO INTERPRETACIJA GEOLOŠKIH STRUKTUR NA POVRŠJU NAD PREDJAMO

STANKA ŠEBELA

Izvleček UDK 551.442:778.35(497.12)

Stanka Šebela: Interpretacija geološke strukture površja nad Predjamo z letalskimi posnetki

Stereoskopsko opazovanje letalskih posnetkov v merilu 1:5000 je zelo dobra predhodna informacija pri določitvi geoloških strukturnih elementov na terenu. Značilne morfološke strukture kot doline, nizi dolin kažejo na potek tektonsko pretrih con. Tudi litološke razlike, kot meja med apnencem in flišem je opazna kot značilna morfološka stopnja. Določljiva je tudi narivna meja med triasnim dolomitom in krednim apnencem.
Ta metoda je najbolje preiskušena s podrobnim tektonsko-litološkim kartiranjem na terenu v merilu 1:5000. Primer Predjame kaže nekatere razlike pri primerjavi obeh metod.

Ključne besede: letalski posnetki, geološka struktura, tektonsko porušene cone, diagram polrozete, Predjama, Slovenija.

Abstract UDC 551.442:778.35(497.12)

Stanka Šebela: Aerophoto interpretation of geological structures on the surface above the Predjama Cave

Stereoscopic observing of aerophoto images on the scale 1:5000 is very good information to determine preliminary geologic structural elements in the field. Characteristic morphological structures like dolines, and series of dolines show positions of tectonic crushed zones. Also a lithological difference such as the border between limestone and flysch is visible as a characteristic morphologic step. The nappe border between Triassic dolomite and Cretaceous limestone is determined also. This method is best confirmed with detailed tectonic-lithological mapping in the field on the scale 1:5000. The case of Predjama shows some differences in comparing both methods.

Key words: aerial photography, geological structure, tectonic crushed zones, half-rosette graph, Predjama, Slovenia.

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INTRODUCTION

Predjama cave lies about 7 km NW from Postojna. 7571 m long, it is among the longest horizontal caves in Slovenia.

For studies of development of cave channels (Šebela, 1991; Šebela & Čar, 1991) it was necessary to determine geological properties of underground and surface. Like previous researches for detailed tectonic lithological mapping of surface at the scale 1:5000 according to method of Čar (1982, 1984) we used aerophoto of the surface above Predjama cave at the scale 1:5000, being a new approach, because till now we mostly used snapshots in the scale 1:30.000 or 1:17.500.

The interpretation of aerial photography of the surface is an advantageous method for preliminary field researches and at the same time an important base for detailed tectonic-lithological mapping of the surface.

This article talks about comparison of directions of tectonic crushed zones on the surface above Predjama cave which were determined by interpretation of aerial photography and by detailed tectonic lithological mapping at the scale 1:5000.

GEOLOGICAL DATES

According to L. Placer (1982) in the SW part of Slovenia the old Tertiary tectonics and neotectonics are distinguished. At the end of the Eocene or in the Oligocene the alpine-dinaric region was subject to extensive thrusting. In Miocene and Pliocene the thrusting was associated with folding. Under the term neotectonics Placer (1981) understands steep faults of NW-SE direction which are different to overthrust deformations.

In a tectonic sense the area around Predjama belongs to wider fault zone of the Predjama fault of which inner fault zone passes probably a bit to the west of Predjama.

During detailed tectonic mapping on the surface and by the observation of the aerial photography we distinguished two kinds of tectonic deformations, namely older overthrust and younger fault deformations.

According to data of BGM, sheet Postojna (Buser & Grad & Pleničar 1967) on the treated area there are Triassic dolomites (T_3^{2+3}) thrusted over

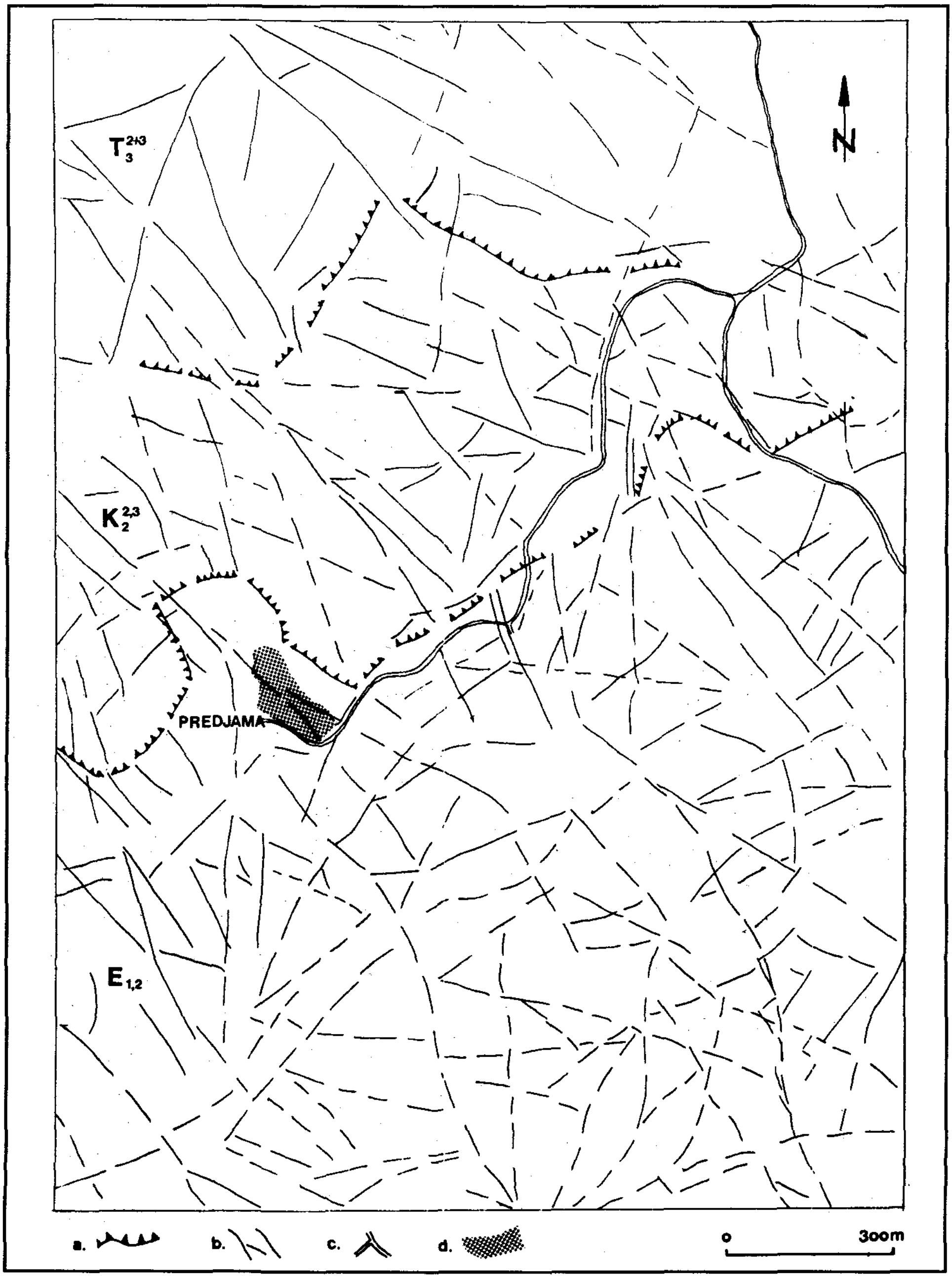

Fig.1. Interpretation of tectonic crushed zones in aerial photography. *a-overthrust line determined by surface mapping, b-tectonic crushed zones determined by aerial photography, c-roads, d-village.*

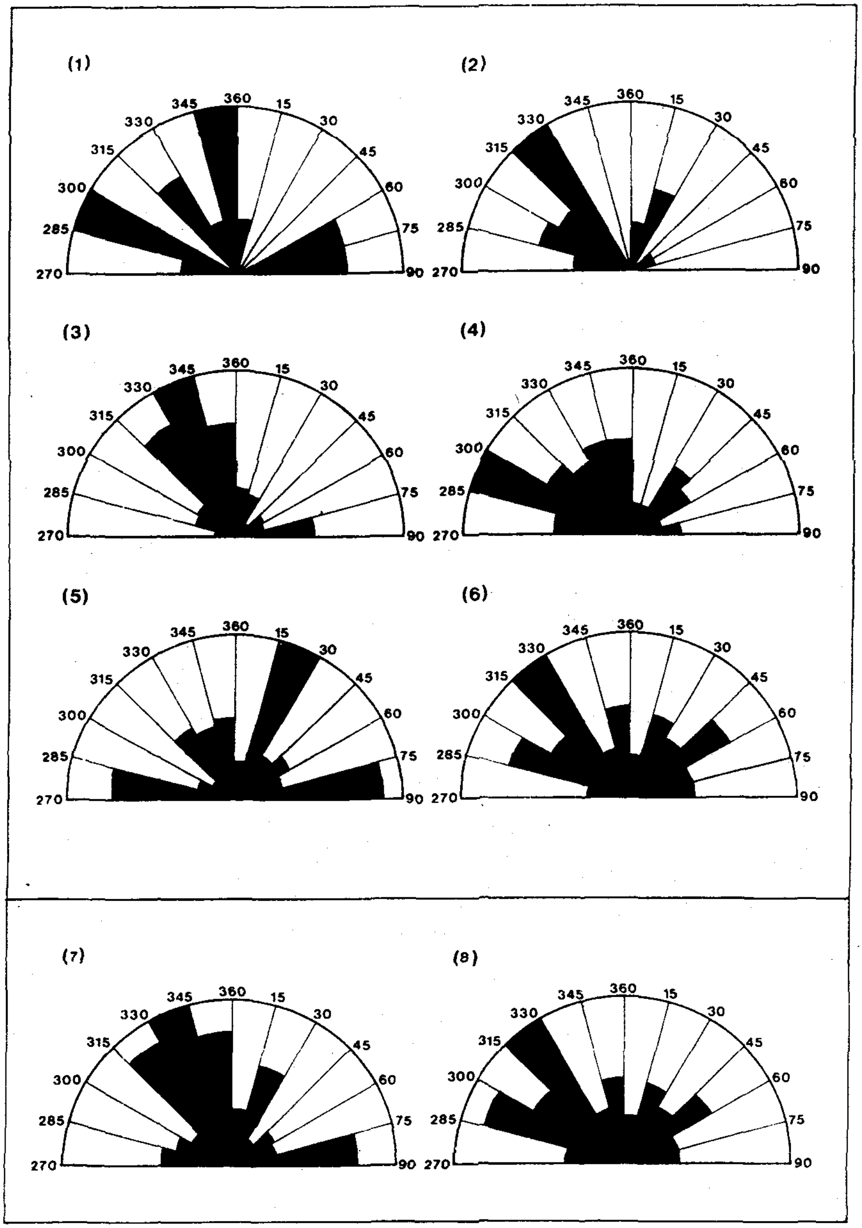

Fig.2. Graphs half-rosettes showing the strike of tectonically crushed zones. (1)dolomite; surface mapping n=15, (2) dolomite; aerial photography n=49, (3) limestone; surface mapping n=187, (4) limestone; aerial photography n=93, (5) flysch; surface mapping n=123, (6) flysch; aerial photography n=248, (7) dolomite, limestone and flysch; surface mapping n=325, (8) dolomite, limestone and flysch; aerial photography n=390.

the Cretaceous limestones (K_2^{2+3}) and Cretaceous limestones thrusted to Eocene flysch ($E_{1,2}$) as is presented by Fig. 1. In tectonic sense the Hrušica tectonic unit is thrusted to the tectonic unit of Javorniki - Snežnik block. On the south there is the flysch of Postojna and Pivka basin. On the west there is the Nanos tectonic unit separated from the Hrušica by Predjama fault (Pleničar 1970).

By stereoscopic observations of two pictures of the same area we distinguished the morphological levels of the terrain which is controlled by the geological setting.

On the picture we defined 390 measurements of directions of tectonic crushed zones, what means 49 in dolomite, 93 in limestone and 248 in flysch. We couldn't distinguish between overthrust and fault deformations, which are in our case also borders between different rocks and between different kinds of tectonic crushed zones according to classification of Čar (1982). All these data were determined later with detailed tectonic lithological mapping in the field.

Interpretation of aerial photographs shows (Fig. 2) that on dolomite and flysch terrain most of the directions of tectonic crushed zones are between

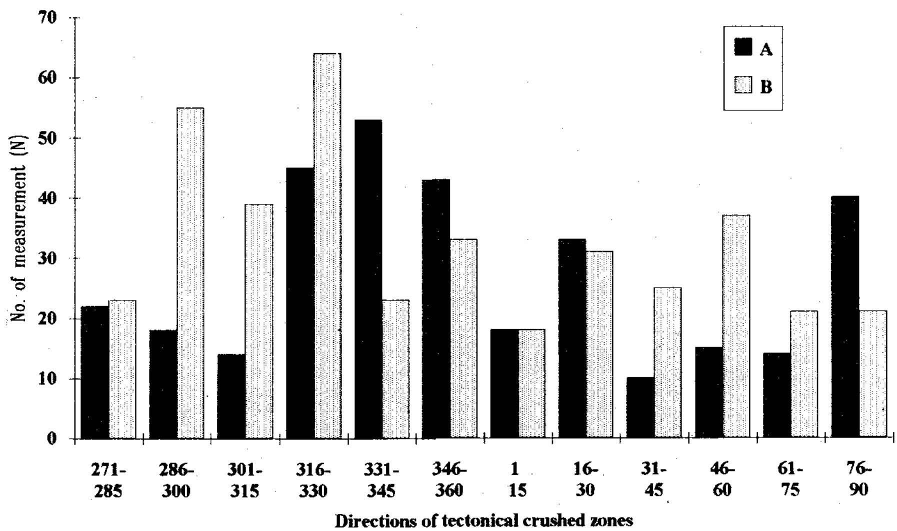

Fig.3.Diagram comparing data of tectonically crushed zones in aerophoto snapshots (A) and in the surface (B) above Predjama cave.

316-330^0 and on limestone terrain the most common are directions between 286-300^0. For the entire terrain the most common direction of tectonic crushed zones is between 316-330^0.

Detailed tectonic mapping of the surface in the scale 1:5.000 has shown complicated relations along the thrust lines. Thus the thrust line dolomite-limestone is dissected and partly displaced by younger fault deformations which is seen on the aerial photographs too. The thrust contact limestone-flysch is deformed as well by younger fault deformations in the east-west direction almost and the Dinaric direction.

Fault deformations were defined on the dolomitic, limestone and flysch terrain. But it must be stressed that the same fault zone is differently manifested within different rocks.

Some main fault zones of the Dinaric direction NW-SE, N-S and E-W predominate on the entire area. The oldest out of them are Dinarically oriented fault zones. Connecting zones among the most important fault zones are fissured or broken zones.

In field researches I included about 3 km^2, out of which 50% belong to flysch, 37.5% to limestone and 12.5% to dolomite.

Statistical processing (half-rosette graph, frequency of directions of the tectonically crushed zones) of the tectonic structural elements, got by the detailed tectonic mapping of the surface in the scale 1:5.000, is shown on Fig. 2.

On dolomitic terrain there are the most of tectonically crushed zones with strike between 286-300^0 and 346-360^0 which is close to the direction east-west, north-south respectively. These data included 15 measurements only (Fig. 2;1).

In limestone the tectonic zones with strike 331-345^0 prevail which correspond to the Dinaric direction. In Fig. 2 (3) 187 field measurements are included.

In flysch (123 measurements) the tectonically crushed zones prevail with strike between 16-30^0 corresponding to cross Dinaric direction (Fig. 2;5).

Graph (half rosette) of the tectonically crushed zones dip for all the three rocks (limestone, dolomite, flysch) on the surface shows that on the treated area the rocks are the most frequently crushed in the direction 331-345^0 which corresponds to the Dinaric direction (Fig. 2;7).

STATISTICAL COMPARISON OF THE DIRECTIONS OF TECTONICALLY CRUSHED ZONES ON THE FIELD AND ON THE AERIAL PHOTOGRAPHS

Comparing the aerophoto interpretation and the tectonic-lithological map (Scale 1:5.000) (Fig. 3) we infer that the main fault zones in Dinaric orientation agree. Partly correspond some cross broken or fault zones and thrust lines.

Statistical processing of the measured data of both methods indicates some characteristical differences.

Graphs half-rosettes showing the strike of tectonically crushed zones in the dolomite (Fig. 2) differ a lot. On the aerial photographs several measurements were seen, namely n=49, while on the field the determination was hindered due to morphology of the dolomitic terrain and grass vegetation. We have defined n=15 measurements only (Fig. 2;1).

The measurements in limestone in the field were more numerous (n=187) than those from the aerial photographs (n=93). The reason could be in wooded areas where the aerophoto interpretation is much more difficult. On the limestone the geological mapping (in spite of vegetation) is the easiest. Dinarically oriented tectonically crushed zones prevail. Both graphs do not agree perfectly, probably due to vegetation (Fig. 2;3,4).

On the flysch area, n=123 measurements were done and on aerophotos n=248. The graphs differ considerably (Fig.2;5,6). But we must consider that flysch is mechanically different from the limestone and dolomite, and that the strongest fault zones are situated in marked dolines and gullies, where flysch is due to tectonics and depositon of flysch material with streams heavily mechanically crushed and thus the measurements of main and, it is true the most important directions for the terrain, tectonically crushed zones are not possible. Accepting these statements the graphs are much better comparable.

CONCLUSION

Without doubt the interpretation of the aerial photographs in the scale 1: 5.000 requires a special knowledge and experience. The preliminary examination of the field properties by the aerophotos could be used for the introductory research and at the same time for later detailed field mapping (mostly of the terrains of difficult access or covered by vegetation). Above all structural geological data, namely tectonic crushed zones, got by the interpretation of the aerial photographs must be checked and classified in the field.

In the case of Predjama we included in the detailed tectonic-lithological mapping n=325 measurements (n=15 on dolomite, n=187 on limestone and n=123 on flysch) which were compared with n=390 measurements on the aerophoto snapshots (n=49 on dolomite, n=93 on limestone and n=248 on flysch). According to statistical data processing the average error of the correspondence of tectonically crushed zones for all the three rocks of the terrain (dolomite, limestone and flysch) and on the aerial photographs is 24,34%.

REFERENCES

Buser, S., Grad, K. & Pleničar, M. 1967: Osnovna geološka karta SFRJ Postojna 1:100.000.- Zvezni geološki zavod, Beograd.
Čar, J., 1982: Geološka zgradba požiralnega obrobja Planinskega polja.- Acta Carsologica SAZU 10 (1981), 75-105, Ljubljana.
Čar, J. & Gospodarič, R., 1984: O geologiji krasa med Postojno, Planino in Cerknico.- Acta Carsologica SAZU 12 (1983), 91-106, Ljubljana.
Placer, L., 1981: Geološka zgradba jugozahodne Slovenije.- Geologija 24/1, 27-60, Ljubljana.
Placer, L., 1982: Tektonski razvoj idrijskega rudišča.- Geologija 25/1, 1-208, Ljubljana.
Pleničar, M., 1970: Tolmač lista Postojna. Osnovna geološka karta SFRJ 1:100.000.- Zvezni geološki zavod Beograd, 62 str., Beograd.
Šebela, S., 1991: Površinske geološke strukture in njihov vpliv na oblikovanje Predjame.- magistrska naloga, 115 str. in 6 prilog, hrani se v knjižnici IZRK ZRC SAZU v Postojni.
Šebela, S. & Čar, J., 1991: Geološke razmere v podornih dvoranah vzhodnega rova Predjame.- Acta Carsologica SAZU 20, 205-222, Ljubljana.

AEROFOTO INTERPRETACIJA GEOLOŠKIH STRUKTUR NA POVRŠJU NAD PREDJAMO

Povzetek

Predjama leži okrog 7 km SZ od Postojne. S 7571 m dolžine spada med najdaljše horizontalne jame v Sloveniji.

Pri preučevanju razvoja jamskih rovov (Šebela,1991; Šebela & Čar, 1991) je bilo potrebno določiti geološko zgradbo podzemlja in površja. Kot predhodne raziskave za podrobno tektonsko-litološko kartiranje površja v merilu 1:5000 po metodi Čarja (1982, 1984) smo uporabili aerofoto posnetke terena nad Predjamo v merilu 1:5000, kar je novost glede na to, da smo do sedaj večinoma uporabljali posnetke v merilu 1:30.000 ali 1:17.500.

Ta članek obravnava primerjavo smeri tektonsko pretrtih con površja nad Predjamo, ki smo jih določili z interpretacijo aerofoto posnetkov in podrobnim tektonsko-litološkim kartiranjem v merilu 1:5000.

Pri podrobnem tektonskem kartiranju na površju kot tudi pri opazovanju aerofoto posnetkov smo ločili dve vrsti tektonskih deformacij, in sicer starejše narivne in mlajše prelomne deformacije.

Po podatkih OGK list Postojna (Buser, Grad & Pleničar, 1967) je na obravnavanem terenu triasni dolomit (T_3^{2+3}) narinjen na kredne apnence

(K_2^{2+3}) in kredni apnenci narinjeni na eocenski fliš ($E_{1,2}$) (slika 1). Na aerofoto posnetkih smo izvrednotili 390 merjenj slemenitev tektonsko pretrtih con, od tega v dolomitu 49, v apnencu 93 in flišu 248 (slika 2). Pri tem nismo mogli ločiti narivnih deformacij od prelomnih, ki so v našem primeru tudi meje med različnimi kamninami (dolomit, apnenec in fliš) ter vrste prelomnih con med seboj glede na razdelitev tektonsko pretrtih con na razpoklinske, porušene in zdrobljene po Čar (1982). Vse te podatke smo lahko izvrednotili šele z detajlnim tektonsko-litološkim kartiranjem na terenu.

Interpretacija aerofoto posnetkov je na dolomitnem in flišnem terenu pokazala, da je največ tektonsko pretrtih con s slemenitvijo 316-330^0, na apnenčastem terenu pa prevladujejo tektonsko pretrte cone s slemenitvijo 286-300^0. Na celotnem terenu velja, da so v vseh treh kamninah najpogostejše tektonsko pretrte cone s slemenitvijo 316-330^0 (slika 2).

S podrobnim tektonskim kartiranjem površja v merilu 1:5000 smo določili, da je narivnica dolomit-apnenec razsekana in deloma premaknjena z mlajšimi prelomnimi deformacijami, kar je vidno tudi na aerofoto posnetkih. Tudi narivni kontakt apnenec-fliš je deformiran in sicer z mlajšimi prelomnimi deformacijami smeri skoraj vzhod-zahod (kar je vzporedno s potekom narivnice) ter dinarskih smeri.

S terenskimi raziskavami sem zajela okrog 3 km^2 od česar odpade 50 % na flišni teren, 37,5 % na apnenčast teren in 12,5 % na dolomitni teren.

Diagrami-polrozete pogostosti smeri tektonsko pretrtih con, ki prikazujejo podatke iz terenskega kartiranja so prikazani na sliki 2. Na dolomitnem terenu je največ tektonsko pretrtih con s slemenitvijo med 286-300^0 in 346-360^0, kar se približuje smeri vzhod-zahod oziroma sever-jug. Ti podatki so zajeli le 15 meritev.

V apnencu prevladujejo tektonske cone s slemenitvijo 331-345^0, kar najbolj ustreza dinarski smeri. Pri tem sem upoštevala 187 meritev na terenu.

V flišu (123 meritev) pa prevladujejo tektonsko pretrte cone s slemenitvijo med 16-30^0, kar ustreza prečnodinarski smeri.

Diagram - polrozeta (slika 2) smeri vpada tektonsko pretrtih con za vse tri kamnine (apnenec, dolomit in fliš) na površju, ki sem ga dobila s podrobnim tektonskim kartiranjem 1:5000 kaže, da so na raziskanem terenu kamnine najbolj pogosto pretrte v smeri 331-345^0, kar ustreza dinarski smeri.

Če primerjamo aerofoto interpretacijo in tektonsko-litološko karto (M=1:5000), ugotovimo, da se glavne prelomne cone dinarskih smeri pokrivajo. Deloma si ustrezajo tudi določene prečne porušene ali prelomne cone ter narivnice.

Statistična obdelava merjenih podatkov obeh metod pa kaže nekatere značilne razlike.

Diagrama-polrozeti (slika 2), ki prikazujeta slemenitve tektonsko pretrtih con v dolomitu se precej razlikujeta. Na aerofoto posnetkih je bilo vidnih več meritev, in sicer n=49, medtem, ko je bilo na terenu določevanje, zaradi morfologije dolomitnega terena in poraslosti s travo otežkočano. Določili smo samo n=15 meritev.

Meritve v apnencu so bile na terenu številčnejše (n= 187), kot na aerofoto posnetkih n=93. Vzrok za to lahko iščemo v poraslosti z gozdom, kar močno otežuje aerofoto interpretacijo. Na apnenčastem terenu pa je geološko kartiranje (kljub poraslosti) najlažje. Prevladujejo dinarsko usmerjene tektonsko pretrte cone. Oba diagrama (slika 2) se verjetno prav zaradi poraslosti ne ujemata najbolje.

V flišu smo na terenu opravili n=123 meritev, na aerofoto posnetkih pa n=248. Diagrama (slika 2) se pri tem zelo razlikujeta. Pri tem je treba upoštevati, da je fliš mehansko drugačna kamnina od apnenca in dolomita, ter da najmočnejše prelomne cone potekajo po izrazitih dolinah in grapah v terenu, kjer je fliš zaradi tektonske pretrtosti, pa tudi odnašanja flišnega materiala s potoki močno mehansko zdrobljen in v njem ni možno meriti, za teren sicer glavnih smeri tektonsko pretrtih con. Če upoštevamo te ugotovitve, *sta diagrama-polrozete mnogo bolj primerljiva.*

Strukturni geološki podatki in sicer tektonsko pretrte cone, ki jih dobimo z interpretacijo aerofoto posnetkov morajo biti preverjene in klasificirane predvsem na terenu. Po statistični obdelavi podatkov (slika 3) je povprečna napaka skladnosti smeri tektonsko pretrtih con za vse tri kamnine (dolomit, apnenec in fliš) na površju nad Predjamo in aerofoto posnetkih 24,34%.

KARST WATER PROTECTION PROBLEMS INDICATED BY DRIPPING WATER ANALYSES IN BUDA THERMAL KARST AREA

TEŽAVE Z VAROVANJEM KRAŠKE VODE, KOT KAŽEJO ANALIZE PRENIKAJOČE VODE V TERMALNEM KRASU V BUDI

KATALIN TAKÁCSNÉ BOLNER

Izvleček UDK 556.38:551.23(439)

Katalin Takácsné Bolner: Težave z varovanjem kraške vode, kot kažejo analize prenikajoče vode v termalnem krasu v Budi

Da bi ugotovili izvor onesnaževanja termalnih izvirov v Budi, so pričeli 1987 redno opazovati kvaliteto prenikajoče vode v 5 večjih fosilnih jamah, ki so med sedanjimi izviri in urbanimi površinami madžarske prestolnice. Sezonske analize prenikajoče vode s skupno 25 mest so pokazale relativno stabilno kemično (kloridi, nitrati, sulfati) in/ali občasno bakteriološko (streptokoki fekalnega izvora, koliformne bakterije, *clostridium, pseudomonas*) onesnaženje na vseh mestih, ne glede na globino, skalno površino ali značaj okolja. Človekov vpliv, ki ga kaže to onesnaževanje, izvira iz zimskega soljenja cest, uporabe umetnih gnojil in pesticidov v vrtovih, poškodb plinovoda in kanalizacije, črnih odlagališč in gradbenih del, ki zajamejo velike površine. Vse to zahteva revizijo varovalnih ukrepov.

Ključne besede: Buda gričevje, fosilne termalne jame, prenikajoča voda, kemizem, bakteriologija, vpliv na okolje

Abstract UDC 556.38:551.23(439)

Katalin Takácsné Bolner: Karst water protection problems indicated by dripping water analyses in Buda thermal karst area

To determine the origin of contamination in Buda thermal springs, regular analyses of infiltrating water quality were started in 1987, in the five largest relict caves occupying a position midway between the modern springs and the urban surface environment of the Hungarian capital. Seasonal analyses of dripping waters representing altogether 25 sites have revealed rather stable chemical (chloride, nitrate, sulphate) and/or occasional bacteriological (faecal streptococcus, coliform, *clostridium, pseudomonas*) contaminations for all sites regardless of their depth, surface rock and environment character. The human impacts indicated by these contaminations are defrosting of roads by salting, fertilization and chemical treatment of gardens, damage to pipelines and sewage systems, illegal desiccation pits, and construction work disturbing large surfaces; which reflect to the necessary revision of current protective measures.

Key words: Buda Hills, relict thermal caves, dripping waters, chemistry, bacteriology, environmental impacts

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INTRODUCTION, GEOLOGICAL-HYDROGEOLOGICAL SETTING

The situation of the Buda thermal karst within the residental area of a capital city is unique in the world. Modern thermal spring activity is represented by several warm springs discharging waters of 20-60°C in two major groups along a significant tectonic line parallel with the Danube. The extended cave systems and freshwater limestone deposits elevated to 300 m above the current spring level mark the subsequent stages of a two million years karstic development.

Evolution of this thermal flow system started in the Neogene, when uplift of the Buda Hills area exposed the karstifiable Triassic and Eocene carbonates to karstic infiltration again; while the same carbonate formations were at considerable depths in the adjacent sedimentary basins. This geological and structural situation resulted in the evolution of a deep circulation system.

The thermal flow is fed by karstic infiltration of open karst areas in the northern part of the Buda Hills and farther units of the Transdanubian Mountain Range. The flow is maintained by pressure differences caused by different geodetic heights and by warming of waters at depth due to the above-average geothermal flux of 5°C/100 m. The ascending flow is directed by confining impermeable sediments towards the marginal carbonate outcrops of Buda Hills, which are at the same time the tapping points for normal descending karstic waters *(Fig. 1.)*. Most of the caves of the Buda Hills area are interpreted as relict spring conduits enlarged due to the corrosion effect of mixing ascending and descending waters with different temperature and chemistry.

The first signs of thermal spring activity are represented by Pliocene freshwater limestone deposits. Further uplift of the Buda Hills during the past two million years resulted in repeated repositioning of spring outlets, and thus the evolution of several freshwater limestone and cave levels. The most extended cave levels correlate with the elevations of Lower and Middle Pleistocene limestone deposits.

The most spectacular group of thermal karst features can be found in the 2nd district of Budapest, in the so called Rozsadomb region. Within this area of 10 kmý, there are about 70 caves with a total length of explored passages more than 29 km *(Fig. 2.)*. The largest systems are situated 1-2 kms to the NW of the largest group of modern thermal springs. Although the thermal springs and freshwater limestone deposits of the area were utilised already by the Romans, the presence of large caves has been discovered only since the beginning of the 20[th]century, as a result of human interferences - like quarrying or construction work - associated with the urban development of the region. More than the half of the currently known passage system was discovered only during the past fifteen years; while intensive building on the area started in the early seventies.

INVESTIGATIONS ON ENVIRONMENTAL IMPACTS

The position of the thermal springs and caves within a capital city offer unique possibilities for their touristic and therapeutic utilisation, but, on the other hand, the urban environment has several unfavourable effects on them. Discharge of the thermal spring group has decreased from 34.000 m^3/day to

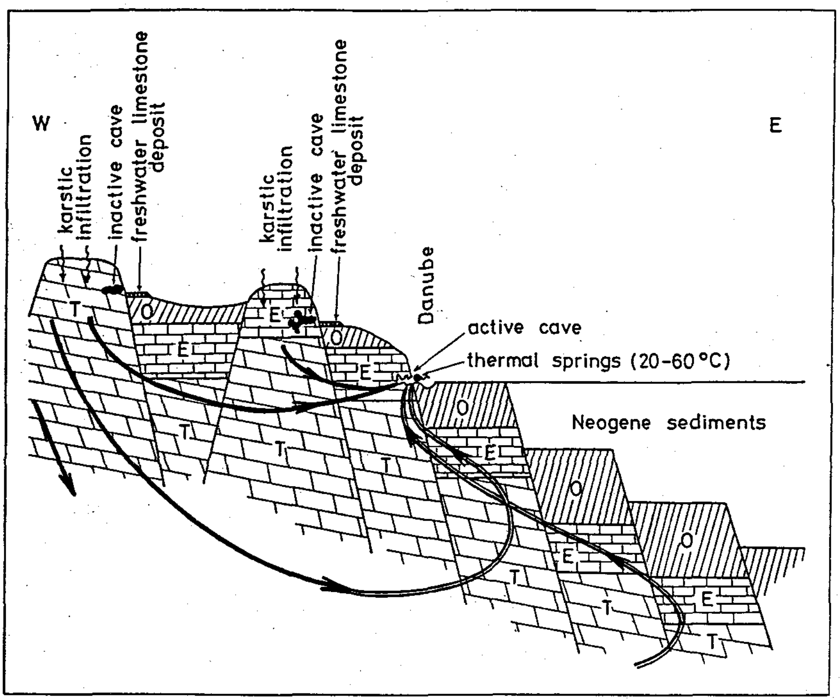

Fig. 1. Scematic profile of the hydrothermal activity of the Buda Hills (after Kovacs and Muller, 1980)

T = Triassic carbonatic formations; E = Eocene carbonatic formations; O = Oligocene clay and silt some 10.000 since the end of the last century; and in the past 40 years, since the beginning of regular water quality investigations, the water temperature has decreased by 4°C accompanied by a decrease of CO_2 and hydrogen carbonate ions. At the same time contaminations of nitrate, ammonium, chloride and sulphate have increased, and coli contamination have also occured. Although certain administrative measures were taken to protect the water quality of the springs, detailed studies on interrelations between the anthropogenous environment and the relict caves - occupying a position

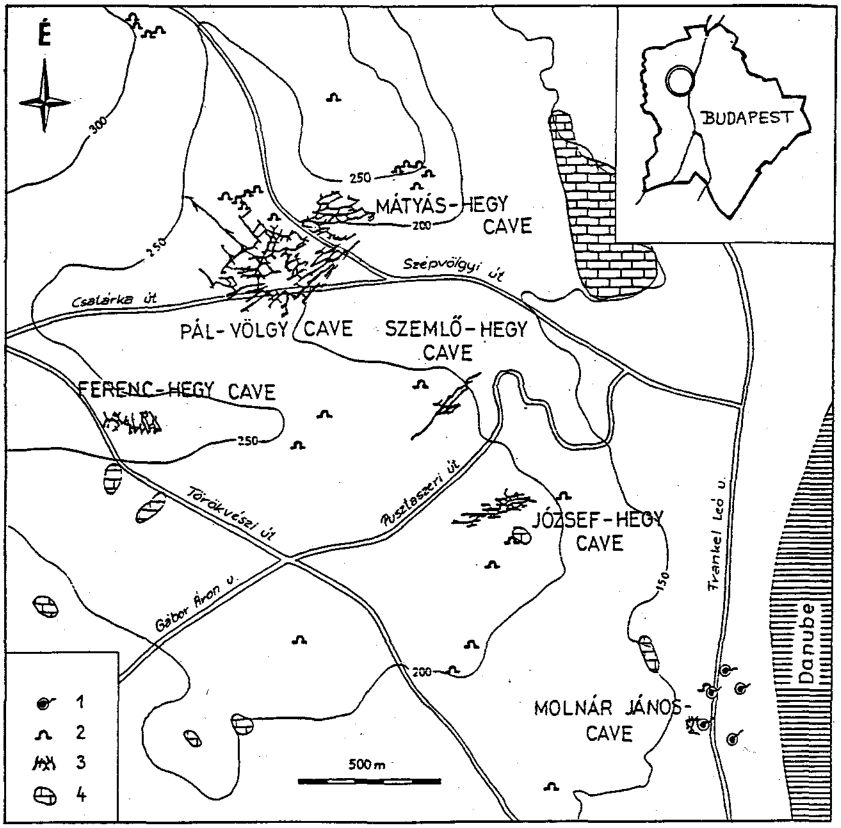

Fig. 2. Thermal karst features of Rozsadomb area
1 = thermal springs; 2 = caves; 3 = increased protected caves; 4 = freshwater limestone deposits

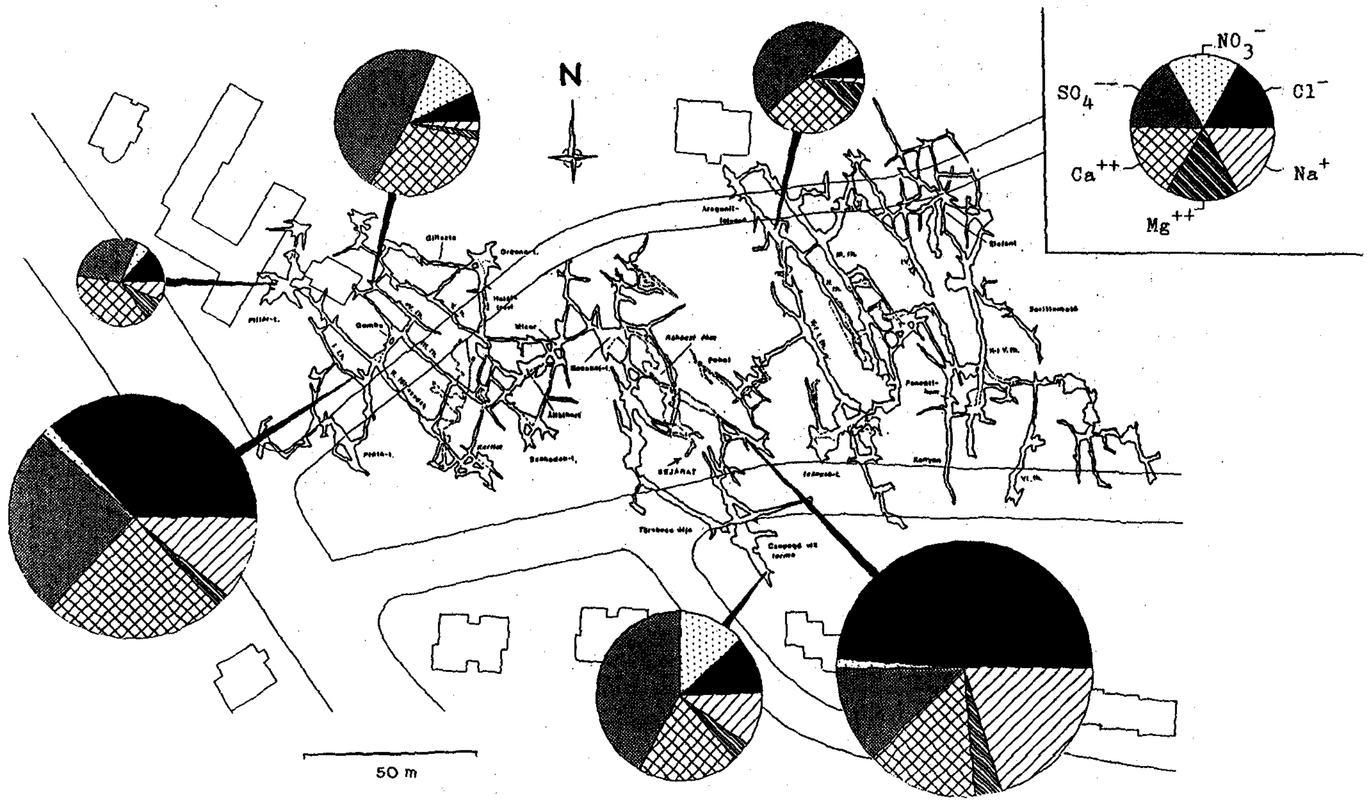

Fig. 3. Chemical composition of dripping water samples in Ferenc-hegy Cave (averages, 1987-1993; the pie areas are proportional with the mg/l values)

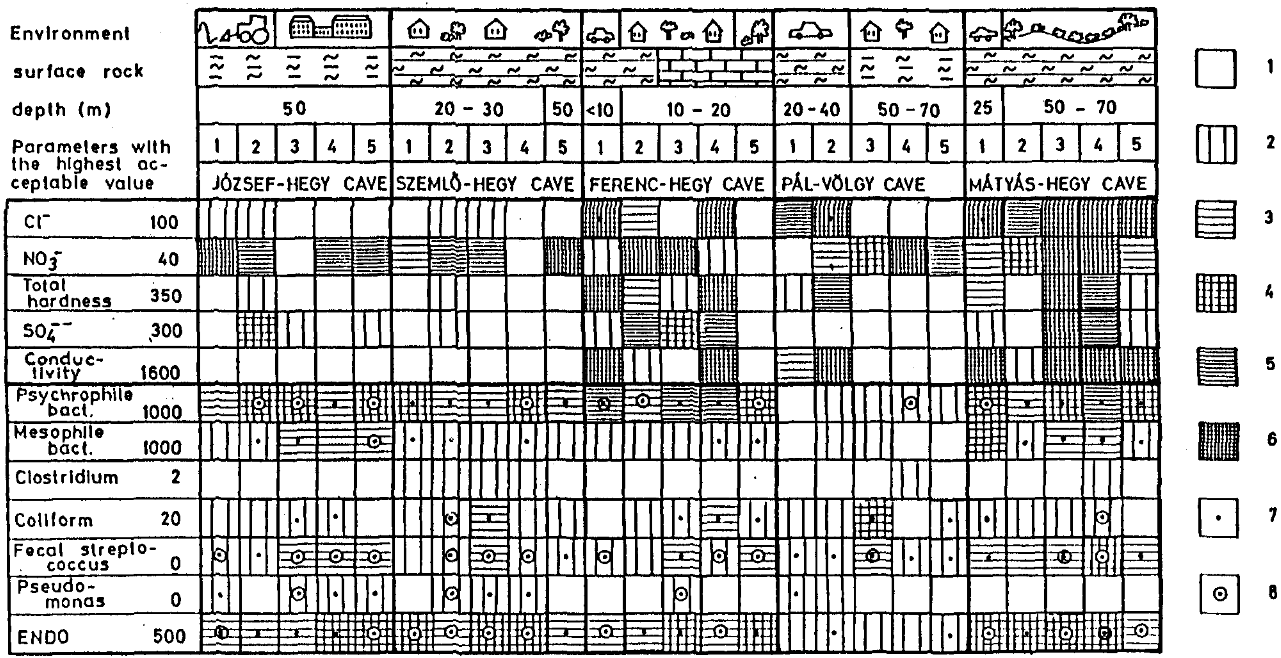

Fig. 4. Stability of contaminations at the different sampling sites (1987-1993)

1-6 = rate of contaminated samples: 1 = 0 % 2 = 1-25 % 3 = 26-50 % 4 = 51-75 % 5 = 76-99 % 6 = 100 %; 7 = occurrence of values exceeding the limit 10-fold; 8 = occurrence of values exceeding the limit 100-fold

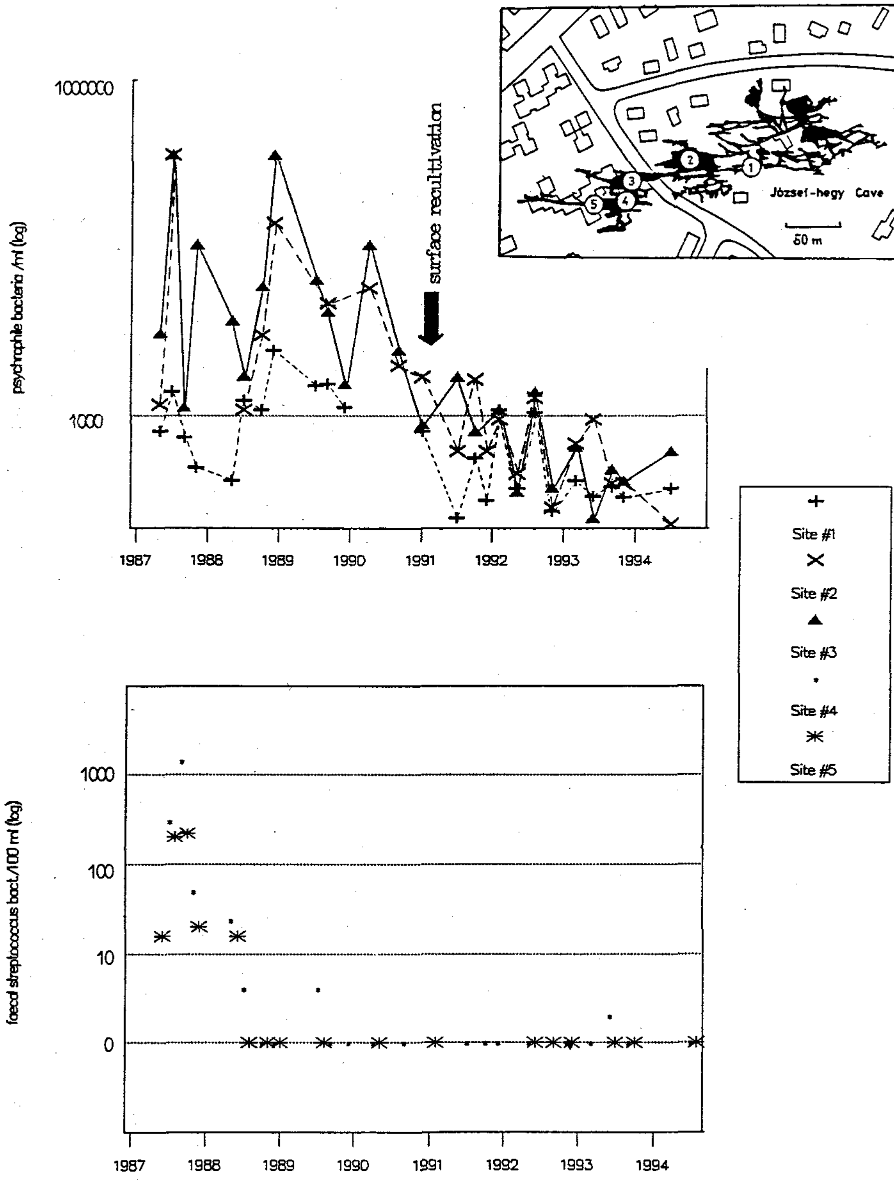

Fig. 5. Time distribution of faecal streptococcus and psychrophile bacteria contamination in dripping water samples of Jozsef-hegy Cave

midway between the surface and the modern springs - were started only ten years ago by at the iniciative of the National Authority for Environment Protection and Nature Conservation.

These studies proved that in the Rozsadomb area the most significant element endangering the caves, and through them the thermal springs, is the qualitative change of infiltrating waters. The maximum 800 m^3/day karstic infiltration of the area represents only about 2 % of the original discharge of the thermal springs. The effect of quantitative changes of this amount is negligable compared to those caused by the drilling of artificial thermal wells tapping the ascending branch of the flow in the northern part of Budapest and by preventive karst water pumping for coal-mine operations at Dorog area at a distance of some 50 kms, which has captured recharge areas from the system.

In 1987 the Institute for Speleology, co-operating with the Budapest Institute for Public Health and Epidemiology, started a comprehensive investigation to determine the extent, origins and areal distribution of contamination of infiltrating waters. This investigation involves seasonal chemical and bacteriological analyses on dripping water samples taken from 55 points of the 5 largest cave systems of the area. Sampling sites were chosen to represent drippings at different depths under surfaces of different rock types and utilisation. The qualification of the samples is based on 15 chemical and 10 bacteriological parameters and compared to the limit values of Hungarian drink water standard.

RESULTS AND CONCLUSIONS OF DRIPPING WATER ANALYSES

In possession of 28 series of analyses for all the permanent drippings and a little fewer for periodical ones, the most important results and recognitions are the following:

1. The different parameters show significant variations, not only with regard to the whole of the region, but also within short distances in the same cave *(Fig. 3.)*. At certain points chemical parameters are rather constant, but the bacteriological ones may vary even a thousand-fold within a short period. Consequently, controlling of dripping water quality requires regular monitoring.

2. All the sampled drippings more or less frequently show bacteriological contamination, and the majority of them chemical contamination too *(Fig. 4.)* regardless of their depth, surface rock and environment. There is no reason to presume that the infiltrating waters of the whole area are of better quality.

3. Chemical contamination of the samples does not always correlate with bacteriological contamination. There are samples with frequent bacteriological contamination that are of drinking water quality from chemical point of view. The explanation is the different sensitiveness of the methods: sewage contami-

nation can be detected by chemical methods up to a dilution of a thousand-fold, while by bacteriological ones up to a million-fold. But, on the other hand, there are samples with stable nitrate contamination (generally considered to reflect sewage impacts) but only rarely with bacteriological contamination; which indicates other possible sources of nitrate. Consequently, neither chemical nor bacteriological analyses alone are suitable for detecting environmental impact.

4. Comparing the results to those of the first two years *(T. BOLNER, TARDY and NÉMEDI, 1989)*, there are no clear trends in changes. Certain parameters at certain points show more favourable values, other parameters or other points less favourable ones. The general condition of infiltrating waters seems to be constant during the past 7 years.

5. Chemical contaminations prove to be rather stable if they occur. Sudden and permanent changes in chemical parameters were usually accompanied by similar changes in intensity of the drippings, which could be interpreted as caused by pipeline damages or repairing of the damage. With respect to chemical parameters, a ten-fold excess over the limiting drinking water standard occurred at three sites and for chloride only. Bacteriological contaminations proved to be more occasional, but more serious also: a 100-fold excess of the limit occurred at 14 sites altogether and for 5 parameters. The endangering effect of relatively low but stable chemical charge, and that of occasional but intense bacteriological charge can be evaluated as equal in the area.

6. Contamination of chloride, that occured with simoultaneously increase of Na-content, and with 10-fold values (up to 3197 mg/l) under roads only, reflects the effect of deicing the roads during winter. As within the past 7 years most of the winters have been mild in Hungary, and no significant salting was needed, the stability of contamination in the drippings drew attention to a considerable deposition of salt in surface sediments. The stable nitrate contamination (up to 265 mg/l) without any significant bacteriological contaminations might be evaluated as the effect of fertilization and other chemical treatment of gardens; while sulphate contamination (up to 925 mg/l) may also be of natural origin, due to weathering of pyrite in the marl-layers covering the limestone bedrock of the caves.

7. Fairly stable bacteriological contamination was found only with respect to *psychrophile* bacteria (up to 600,000/ml) and the ENDO numbers (up to 80,000), which are interpreted as signs of stagnant waters and, a general anthropogenous effect respectively. Direct sewage water infiltration, represented by joint appearence of coliform (up to 8000/100 ml), faecal streptococcus (up to 2000/100 ml) and *clostridium* bacteria (up to 13/40 ml), has been detected at 20 sites, but in 12.1 % of the samples only that refer mostly to casual contaminations. Independent appearence of faecal streptococcus bacteria (up to 1400/100 ml) indicate old faeces effects due to fertilization or leaking

of old septic tanks, that had been constructed before main drainage of the area started.

8. The water quality of drippings in Matyas-hegy cave proves that protective measures on the direct surface of the caves are not enough to avoid contamination. Most of the surface above this cave is a forest belonging to Buda Landscape Protection Area for decades; thus the stable chemical contamination there can originate from outside only, and might be caused by an apparently dry valley being inhabited in its upper section.

9. Time distribution of bacteriological contamination of Jozsef-hegy cave *(Fig. 5.)* is an example of the dangers of disturbing large surfaces by construction work. The two years of stable faecal *streptococcus* contamination in the western part of the cave correlate with the re-gardening of a housing estate built in 1985; while the high level of *psychrophile* bacteria that decreased to quite normal after the re-cultivation of the surface disturbed by foundation pits above the eastern part of the cave, supports the stagnant water origin of this kind of contamination.

All the above features show that current protection involving mostly administrative measures are not sufficient to preserve the sensible equilibrium of the Rozsadomb thermal karst system. The problems identified reflect on the necessary technical-economic steps, the realisation of which might also be promoted by preliminary candidation of the area to the World Heritage in 1993.

REFERENCES

T. BOLNER, K. - TARDY, J. (1988): Bacteriological and chemical investigations of dripping waters in the caves of Budapest. Comm. of Int. Symp. on Phys., Chem., and Hydr. Research od Karst, Kosice, p. 102-108.

T. BOLNER, K. - TARDY, J. - NÉMEDI, L. (1989): Evaluation of the environmental impacts in Budapest's caves on the basis of the study of the quality of dripping waters. Proc. of 10th Int. Congr. of Spel., Budapest, v. 2. p. 34-639.

TEŽAVE Z VAROVANJEM KRAŠKE VODE, KOT KAŽEJO ANALIZE PRENIKAJOČE VODE V TERMALNEM KRASU V BUDI

Povzetek

Med antropogenimi površinami madžarske prestolnice in sedanjimi termalnimi izviri je 29 km dolg splet fosilnih termalnih jam. V okviru preučevanja odnosov med urbanim okoljem in podzemeljskim naravnim bogastvom Speleološki inštitut v sodelovanju z budimpeštanskim Inštitutom za javno zdravje in epidemiologijo že od l. 1987 preučuje kvaliteto prenikajoče jamske vode. Redne kemijske in bakteriološke analize vzorcev prenikajoče vode, zajemanih na petih mestih v vsaki izmed petih večjih jam, kažejo pomembne razlike v kvaliteti; toda vsi izmed opazovanih curkov so se pokazali za bolj ali manj pogosto onesnažene glede na kemijske in/ali bakteriološke parametre, ne glede na njihovo globino (10 - 90 m), kamnino na površju (apnenec, lapor, glinasti lapor) ali na okolje (vrt, park, gradbišče, cesta, itd.).

Izmed 25 vzorčevalnih mest jih 23 izkazuje stalno kemijsko onesnaženost, vendar relativno nizkih vrednosti: desetkratni presežek dovoljene količine po standardih za pitno vodo se je pojavil le na 3 mestih, in sicer so presegali dovoljene meje le kloridi (do 3197 mg/l), čemur je vzrok zimsko soljenje cest. Onesnaženje z nitrati (do 265 mg/l) kaže na poškodovano ali pomanjkljivo kanalizacijo ali, kadar ni sočasne bakteriološke kontaminacije, na uporabo kemikalij v vrtovih. Visoka vsebnost sulfatov v nekaterih curkih (do 925 mg/l) je lahko naravnega izvora - razpadanje pirita v laporju nad matično kamnino. Bakteriološke kontaminacije so bolj občasne, a tudi resnejše: stokratno preseganje dovoljene meje se je vsega skupaj pojavilo na 14 mestih pri šestih parametrih. V 12,1 % primerov je bila zasledena neposredna infiltracija odpadnih voda (skupen pojav koliformnih bakterij, fekalnih streptokokov in bakterije *clostridium*). Bolj pogost je bil pojav povečanega števila bakterije *psychrophile* (do 600 000/l), kar odraža stoječe površinske vode; visoko ENDO število kaže splošni antropogeni vpliv, samostojen pojav fekalnih streptokokov (do 1400/100 ml) pa razlagamo z gnojenjem ali puščanjem greznic.

VERTICAL POTHOLES ON KARST

O KRAŠKIH BREZNIH

IOSIF VIEHMANN

Izvleček UDK 551.442(498)

Iosif Viehmann: O kraških breznih

Poleg bibliografskega pregleda najpomembnejše literature o kraških breznih in njihovi klasifikaciji, vsebuje prispevek rezultate avtorjevega preučevanja teh oblik v Romuniji in tudi nekaj zaključkov o njihovi morfogenezi. Avtor podpira misel, da so brezna rezultat neposrednega odtoka vode s površja v podzemlje.

Ključne besede: krasoslovje, morfologija krasa, morfogeneza, brezno, Romunija

Abstract UDC 551.442(498)

Iosif Viehmann: Vertical potholes on karst

After reviewing several bibliographical issues concerning the potholes and their classification the article presents the karst forms studied by the author in Romania and also some conclusions regarding the morphogenesis of potholes. The author insists on the idea that the potholes develop by direct passage of water from the surface into the underground.

Key words: karstology, karst morphology, pothole, Romania

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România

INTRODUCTION

La forme karstique la plus représentative pour les cavités verticales est l'aven. Le terme est résérvé pour désigner les cavités ouvertes à la surface, car, dans l'endokarst les avens sont appelés puits, par opposition aux cheminées (MAIRE, 1980) qui selon LEHMANN (cité par TRIMMEL, 1968) representent des secteurs de voûte à évolution ascendente. Un aven qui continue à sa base avec une grotte est nommé par le même auteur "Schachthöhle, c'est-à-dire aven-grotte.

Jusqu'à l'apparition du travail de MARTEL (1921), on croyait que les avens sont d'anciens point d'echappement des eaux minérales. Il decrit dans le cas du Gouffre de Padirac (France) le premier aven d'éffondrement. GÈZE (1953) ajoute les avens d'érosion régresive remontante. Parmi les plus rares formes on connait les avens émissifs, qui sont en fait des résurgences "per ascensum" (par exemple, La Luire, Vercors - France). L'aven Hennemorte (Haute Garonne - France) est en même temps un aven absorbant et une chéminée d'equilibre. La classification la plus usuelle des avens reflète la vision de GÈZE (1953): Les avens d'éffondrement, tectoniques, absorbants, émissifs et les chéminées d'equilibre. On doit aussi mentionner la classification morphologique de BÖGLI (1978) comprenant les avens purement verticaux, les avens en marche et les avens en cloche. MÜLLER et SARVARY (1971) ont decrits l'aven d'érosion pure qui s'ouvre d'habitude au fond d'une doline. La base plus large de ces avens s'explique souvent par le processus de "corrosion de mélange". Il y aussi le phénomène inverse, qui met le fond de l'aven hors des conséquences de la corrosion: c'est l'érosion remontante ou "antigravitationelle" (PASSINI, 1967), qui se produit lorsque la sédimentation des alluvions oblige les eaux à couler aux niveaux des plus en plus élevés.

Parmi les avens considérés comme "sismiques", (BAURES, 1958) nous mentionnons: de Sauve (Gard) et Tindoul de la Vaissière (Aveyron), France, ainsi que les "sluggas" d'Irlande. De tels exemples rappellent la théorie de Buffon, selon laquelle les avens sont des ouvertures sismiques.

Les avens considérés d'être d'effondrement se sont formés (GILLI, 1989) souvent à l'aide des eaux résultées de la fonte des glaciers. Même l'aven Padirac considéré comme un exemple de "verticale d'éffondrement" se trouve dans la bordure d'une valée séche. Les traces de l'activité de cette vallée peut être observé à l'entrée, etant marquées par la présence des depôts de tuf calcaire. NOVAK (1963) a étudié le cavernement vertical connu dans les Alpes sous le nom de "vodnjak". Bien qu'à present ils se trouvent au niveau des intersections téctoniques, ils sont à l'origine des pertes de rivière formées par les eaux de fonte des glaciers.

Les puits ont été classifiés par MAIRE (1980) selon deux points de vue:

a. hydrologique: actif, semi-actif, noyés et semi-noyés et
b. morphologique: tubulaires, en cloche, en entonnoir, hélicoidaux, étranglés, en marche, de type faille et puits-salle.

TROMBE (1956) a observé que les diaclases élargies (générant des avens) se trouvent d'habitude au sommet d'un anticlinale, dont le plissement a comme conséquence justement l'ouverture des diaclases. Le relief et les mouvements orogénétiques préexistentes du phénomène karstique étudié doivent être identifiés et pris aussi en considérations. Ainsi YVES-BIGOT (1989) dans une étude sur les grottes des Picos (Espagne), constate à présent le rôle hidrologique de "the thrust fault". Un relief évidente d'éffondrement est la doline-aven nommé "kukave". Celle-ci se trouve au-dessus des grandes salles écroulés (HABIČ, 1963) et peut être observée dans la zone des polies Planinsko, Cerkniško. SERONIE - VIVIEN (1961) a mis en evidence le fait que les joints de stratification ont également le rôle de regrouper les eaux entrées à un certain niveau. L'écoulement vertical peut atteindre souvent le niveau de base (POHL, 1955). Les diaclases approfondissent le niveau d'un plan de stratification, élevant le niveau des voûtes et favorisant l'élargissement des salles par éffondrement. Pour ce motif, les avens à section circulaire sont rares, la plupart ayant des sections ellipsoidales dont le grand axe coïncide avec la direction de la diaclase.

Enfin, dans des zones climatiques différents, tel qu'Ofra (Israel) on trouve des avens formés à l'aide des courrants d'eau qui ont corrodé leur chemin de pénétration sous la terre (FRUMKIN, 1986).

L'ANALYSE DES CERTAINES VERTICALES DANS LE KARST DE LA ROUMANIE

- L'entrée de la Grotte de Pojarul Politei (Monts Bihor, Transylvanie) est représentée par une verticale de 35 m. Sa présence est due au fait que le versant gauche de la vallée de Gârda Seacă (dans lequel se trouve la grotte) a été érodé jusqu'à l'apparition d'une ouverture dans la voûte d'une salle souterraine. Cette salle est aujourd'hui l'entrée de la grotte. RUSU et al. (1970) n'ont pas pris en considération ce mécanisme de genèse de cette "fenêtre" ouverte parmi draperies et stalagmites, tout en supposant que l'actuelle entrée a été une ancienne résurgence de la grotte! Mais "l'aven" de Pojarul Politei est donc une pseudoaven.
- Les puits de la Grotte "Peştera Fagului" (Monts Bihor, Transylvanie). Cette grotte est une ancienne géode karstique (VIEHMANN, 1975) découverte il

y a dix années à la suite d'une prospection géologique. Le réseau souterrain comprends trois puits de 6 m, 15 m et 25 m de profondeur, dont les deux premiers se sont formés par l'éffondrement, tandis que le dernier représente une diaclase classique.

- ◆ Les avens de la Grotte à glace "Gheţarul de la Scărişoara" (Monts Bihor, Transylvanie). Les deux avens, avec une verticale de 50 m, par lesquels cette grotte s'ouvre à la surface, distancés de seulement 30 m, peuvent être considérés comme formés soit par éffondrement, soit par absorbtion. L'aven principal, dont le diamètre est en moyenne de 40 m est aménagé et permet l'accès des touristes dans la grotte. Le second, impracticable, est prévu avec deux ouvertures jumélées. Entre les deux avens il y a une galerie de communication horizontale, avec un diamètre moyen de 3 m. Nous avons étudié et topographié cette galerie. En consequence nous sommes d'avis que cette galerie n'a pu pas se former par éffondrement. RACOVITZA (1927) considérait l' aven de la Grotte de Scărişoara comme une perte d'eau qui captait jadis la vallée d'à côté. La même explication est donnée ensuite par ŞERBAN et al.(1957). L'origine de l'aven est repris plus tard par RUSU et coll. (1970) qui n'acceptent pas le caractère absorbant de celui-ci, en affirmant que l'aven a été formée par éffondrement. La galerie de communication qui relie les deux avens présente des traces évidentes d'évorsion, avec le tourbillon orienté vers le grand aven. Fait qui nous donne le droit de considéré les avens de la Grotte a glace "Gheţarul de la Scărişoara" comme des anciens passages directes de l'eau en souterrain. Pour expliquer des telles confluences souterraines on peut utilisée le modèle hidrologique (BLEAHU, 1985) nommé "antecedent confluence due to headward erosion".
- ◆ L'aven de Stanu Foncii (Monts de Pădurea Craiului, Transylvanie) s'ouvre à une altitude de 660 m. Sa côte minime est de -325 m. Il est formé par huit puits, dont la profondeur varie entre 8 m et 60 m. Les premiers quatre sont compris dans le même plan vertical, tandis que les autres forment un second alignement déplacé de 96 m vers le sud-ouest. L'ensemble de l'aven se différencie au point de vue tectonique en trois zones:

- la première inclue les puits I-IV, creusés dans de calcaires norienne. Les diaclases et les fissures verticales sont orientées N 45^0 O, N 40^0 E et N 50^0 V.
- la seconde zone est représentée par la galerie de liaison entre la première et le seconde groupement de puits, développée le long des joints de stratifications.
- la troisième zone comprend les puits V-VIII, dont le dernier qui abouti à la rivière souterraine, est "en cloche", comme suit à la "corrosion de mélange". Le cours d'eau collécté sur un relief aujourd'hui inexistant a pénétré sous terre dans la période d'une platforme d'erosion pléistocène inférieur. En dépit de la localisation "suspendue" au sommet d'un plateau

karstique, cette aven a été aussi une perte de rivière.

- La Grotte d'Izvorul Albastru al Izei (Monts de Rodna, Transylvanie) a eté prise en considération en premièrement pour le fait qu'elle se développe au contact entre les calcaires et les schistes sérito-chloriteux. Malgré la profondeur de 170 m, la grotte ne présente aucun puit, à cause de la composition de la roche dominante dans laquelle se développent les schistes. Les puits sont donc des formes du relief endokarstique spécifiques au calcaires.

CONCLUSIONS

Le cavernement vertical a comme objet principal l'aven. Dans la plupart des cas celle-ci doit être étudié en liaison avec le paleokarst, la paleohydrographie et avec le relief préexistent.

L'age des avens et leurs origine doit être cherché dans la période antequaternaire . . . jusqu'au l'idée de karst syngénétique.

En resumant les observations, nous considérons qu'il est difficile de définir et de classifier rigoreusement les types d'avens. QUINLAN et al. (cités par MITROFAN, 1981) admettent que les avens sont le résultat du passage direct de l'eau de la surface vers le souterrain. Cette énonciation peut être considéré comme un résumé du schéma de la genèse des avens.

BIBLIOGRAPHIE

BAURES J., 1958: L'aventure souterraine.- Edit A. Michel, Paris.

BLEAHU M., 1985: Subterranean confluences.- "Cave geology", I, 10, Nat. speleo. soc. Gleen Road, p. 408.

BLEAHU M., DECU V., NEGREA ST., PLESA C., POVARA I., et I. VIEHMANN, 1976: Peşteri din România.- Ed. ştiinţşi enciclop., Bucareşti, pp.

BÖGLI A., 1964: The role of corrosion by mixed water in cave forming.- Proc. Internat. Speleo. Conf. Brno.

BÖGLI A., 1978: Karsthydrographie und physische Speläologie.- Springer Verlag, Berlin, pp.

FRUMKIN A., 1986: Spelogenesis of vertical shafts in a Mediterranean environement.- Proc. IX. Congr. Internat. Speleol., Barcelona, I, pp.

GAMS I., 1959: O legi in nastanku najdaljših jam na Slovenskem.- Naše jame I, pp.

GÈZE B., 1953: La génèse des gouffres.- I Congr. Internat. Speleol., T. II, Paris.

GILLI E., 1989: Recherches sur le creusement et la stabilité des grands volumes karstiques.- Bul. "Speleologia", 147, Nice, pp.

HABIČ P., 1963: Udorne vrtače koliševke in podzemski tokovi.- Congr. Yugosl. Speleol., ses. III, Sarajevo, pp.
MAIRE R., 1980: Eléménts de karstologie physique.- Spelunca, 1, suppl. 3, Paris, pp.
MARTEL E. A., 1921: Nouveau traité des eaux souterraines.- Ed., pp., Paris.
MIOTKE F. D. et PALMER A. N., 1972: Genetic relations between caves and Landformes.- Univ. Hannover, pp.
MITROFAN H., 1981: Concepţii curente asupra genezei avenelor.- Bul. spéol. F. R. T. A., 5, Bucureşti, pp.
MÜLLER P., et SARVARY I., 1971: Pure corrosive model of the developement of vertical karst-shafts.- Internat. geogr. union europ. conf. Symp. karst morphol.
NOVAK D., 1963: "Vodnjak" značilna oblika visokogorskega krasa.- Congr. Yugosl. Speleol., ses. III, Sarajevo.
PASINI G., 1967: Nota preliminare sul ruolo speleogenetico dell'erosione "antigravitativa".- Grotte d'Italia, ser. 4, 1, Castellana Grotte, Bari.
POHL E. R., 1955: Vertical shafts in limestone cave.- N. S. S., 2, Trenton.
RACOVITZA E., 1927: Observations sur la glacière naturelle dite "Ghèţarul de la Scărişoara".- Bul. Soc. °t. Cluj, 3.
RUSU T., RACOVITA Gh., et D. COMAN, 1970: Contributions à l'étude du Complexe karstique de Scărişoara.- Ann. Spéléol., 25, 2, Moulis.
RUSU T., et RACOVITA Gh., 1971: Le complex karstique de Damiş-Ponoraş (Pădurea Craiului).- Trav. Inst. Speol. "E. Racovitza",X, Bucureşti.
ŠERBAN M., COMAN D., et I. VIEHMANN, 1957: Recherches spéléologiques dans les Monts Apuseni (Roumanie).- Cekoslov. Kras, 10, 1, Praha.
SERONIE VIVIEN M. R., 1961: Les diaclases, leur rôle dans la spéléogènese.- Ann. Spéléol. XVI, 1, Moulis.
TRIMMEL H., 1968: Höhlenkunde.- Braunschweig.
TROMBE F., 1956: Traité de spéléologie.- Paris.
VIEHMANN I., RACOVITA Gh. et M. ŞERBAN, 1963: Gheţarul de la Scărişoara.- Ed. Meridiane, Bucureşti.
VIEHMANN I., 1975: Quelques considérations sur l'aragonite des grottes.- Trav. Inst. Spéol. "E. Racovitza", XIV, Bucureşti.
YVES-BIGOT J., 1989: Trave system: third deepest cave in the world.- Caves and caving, 46.

O KRAŠKIH BREZNIH

Povzetek

Najpomembnejši objekt vertikalnega izvotljevanja je brezno. V večini primerov mora biti brezno preučevano v zvezi z paleokrasom, paleohidrografijo in s paleoreliefom. Starost in izvor brezen moramo iskati pred kvartarjem ... prav do zamisli o singenetskem krasu.

Če strnemo opazovanja ugotovimo, da je težko strogo klasificirati brezna na tipe. Quinlan et al. (citirano v Mitrofan, 1981) dodaja, da so brezna rezultat neposrednega odtoka vode s površja v podzemlje. To ugotovitev lahko štejemo kot povzetek sheme nastanka brezen.

DISCUSSION

ČLANEK

EARLIER KNOWLEDGE OF THE AMERICAN CAVES REPORTED IN VALVASOR'S "DIE EHRE DESS HERZOGTHUMS CRAIN" (1689) - FROM 1513

ZGODNJE POZNAVANJE AMERIŠKIH JAM (OD 1513 DALJE) O KATERIH POROČA VALVASOR V "DIE EHRE DESS HERZOGTHUMS CRAIN" (1689)

TREVOR R. SHAW

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Izvleček UDK 551.442(7)(091)

Trevor R. Shaw: Zgodnje poznavanje ameriških jam (od 1513 dalje) o katerih poroča Valvasor v "Die Ehre Dess Herzogthums Crain" (1689)
Pri iskanju podatkov o štirih ameriških jamah, ki jih opisuje Valvasorjev soavtor Francisci v *Die Ehre dess Herzogthums Crain* (1689), so bili ugotovljeni opisi treh zgodnjih obiskov jam - v Gvatemali pred 1625, v Mehiki med 1612 in 1621 in na Hispanioli okoli 1513. Četrta jama, v Andih, je nedoločljiva in verjetno plod domišljije. Za opis jame na Hispanioli, izšel 1516, kaže, da je najstarejša omemba kake ameriške jame sploh.

Ključne besede: speleologija, zgodovina speleologije, Valvasor, Amerika, Gvatemala, Mehika, Zahodna Indija

Abstract UDC 551.442(7)(091)

Trevor R. Shaw: Earlier knowledge of the American caves reported in Valvasor's "Die Ehre dess Herzogthums Crain" *(1689)* - *from* 1513
In tracing the information provided on four American caves by Valvasor's co-author Francisci in *Die Ehre dess Herzogthums Crain* (1689), three early cave visits are described - in Guatemala before 1625, in Mexico between 1612 and 1621, and in Hispaniola about 1513. The fourth cave, in the Andes, is unidentifiable and probably imaginary. The description of the Hispaniola cave, published in 1516, seems to be the earliest account known of any American cave.

Key words: speleology, history of speleology, Valvasor, America, Guatemala, Mexico, West Indies

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INTRODUCTION

One of the reasons why Valvasor's descriptions of Slovenia in his *Die Ehre dess Herzogthums Crain* (1689) are so accurate and dependable is that they are written from his own direct knowledge and based on his own travels and researches. It is therefore worth examining some of those other parts of the book that were written by his collaborator Erasmus Francisci, because they are usually derived from earlier writings and so are liable to retain any errors that these might have contained.

The investigation has uncovered some interestingly early records of caves being visited in America, in the 16th and 17th centuries.

Francisci was responsible for those parts of *Die Ehre* ... that deal with the early history of Slovenia, and also those additions which serve to provide wider context for Valvasor's descriptions, such as accounts of similar places in other lands. It is usually clear from this which sections were written by him, and Baraga (1990) has given guidance on which ones he wrote.

Not only were his sources various, and therefore of different intrinsic reliability, but the information in them was often taken at second- or even third-hand from earlier books, thus introducing greater possibilities of error. This is not to say that he was a poor scholar - probably Valvasor would not have made him his collaborator if he had been - but the greater opportunities for error in the information Francisci provided necessarily makes it less dependable.

For this reason the present paper investigates the sources of the statements made in *Die Ehre ...* about caves in Central and South America and in islands of the Caribbean. At the very least this will date the information more exactly. In addition it may give more facts about the caves concerned; and it may also uncover errors or anomalies that might throw doubt on its truth.

A very brief preliminary note on these American sources has already been published (Shaw 1993), and a detailed analysis of the origins of the *Die Ehre* ... statement on the Bonewell karst spring in England (Shaw 1994) showed that it derived ultimately from a book published in 1607, some 80 years earlier.

The caves considered here were all introduced by Francisci to provide a world-wide background for Valvasor's own descriptions of karst phenomena in Slovenia. He describes two caves in Central America, one in a Caribbean island and one in South America (Fig. 1). Other foreign caves mentioned by him, but not of concern here, include ones in Austria, France, Germany, Greece and Switzerland (Kranjc 1989).

It will be shown that Francisci's accounts of the four American caves in *Die Ehre* ... can be traced back to earlier ones dating variously between 1513 and 1665.

These dates should be seen in the context of European discovery of the region and the other early descriptions of caves there. It was in 1492 that Columbus first saw land in the western hemisphere at what is now San Salvador island in the Bahamas. His first voyage, in 1492 and 1493, saw the discovery of many of the Caribbean islands. In his second voyage (1493-1496) he discovered many more, and set up the first European colony that survived, in Hispaniola. The first landing on the mainland, on the north coast of what is now Venezuela, took place in 1498; Honduras and other parts of Central America were reached in 1502 (Morison 1974).

Caves in America were, of course, known to man long before the

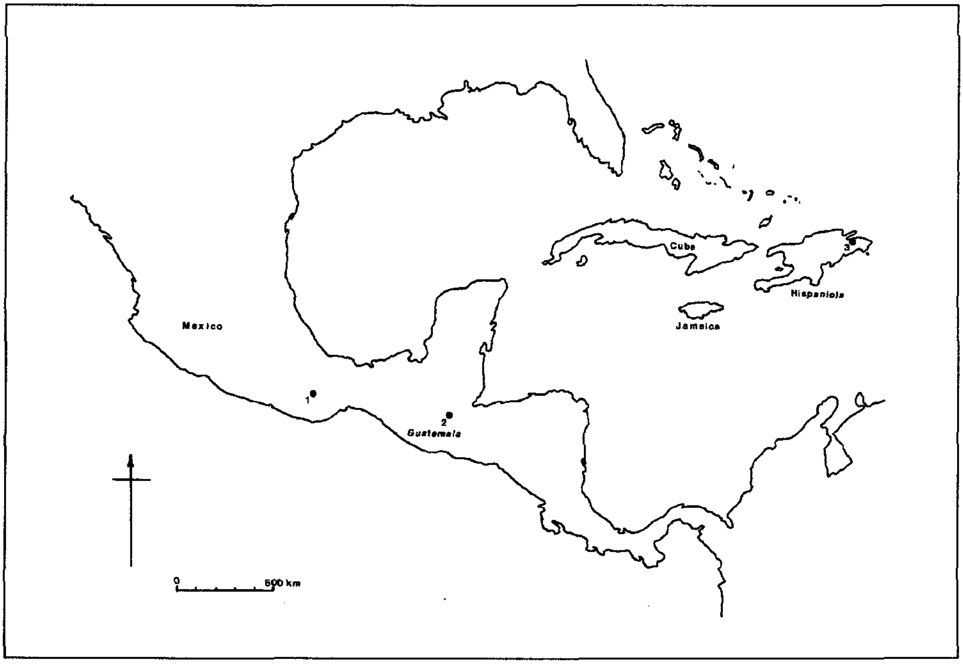


Fig. 1. American caves referred to in Die Ehre . . .
1. cave near Oaxaca in Mexico.
2. Gruta Lanquin, Guatemala.
3. Cueva Infierno, on the island of Hispaniola. The cave in the Andes is unidentifiable.

Europeans landed there. In the dry region of Yucatan in Mexico they were the sole permanent sources of water and so were of great importance to the Maya people living in the area. Remains of pottery as early as 200 A D have been found in the caves there (Brainerd 1953). In the Nan Tunch cave in Guatemala, a group of Mayan calendar glyphs or symbols painted on the wall is interpreted to mean 18 December 738 A D (Stuart 1981), and pottery from around 850 or 900 A D has been found in Gruta Seamay, also in Guatemala (Gould 1968).

Of the European accounts of American caves, the earliest now appear to be those of Peter Martyr, published in 1516, on caves in Hispaniola. One of these is the ultimate source of Francisci's information, and is considered in detail later.

It was in 1548 that Diego Ruíz de Vallejo went into a cave near Escuque in Venezuela, and in 1579 a cave near the city of Trujillo was mentioned by Alonso Pacheco (Urbani 1993). The first record of the well-known Cueva del Guacharo in Venezuela appears to be in a letter of 21 July 1660 by Agustín de Frias, a Capuchin priest, and the first published mention of it was in a book by José de Carabantes printed in 1666 (Urbani 1989).

Caves and karst springs in Yucatan were referred to in a manuscript of 1566 by the Spanish priest Diego de Landa (1941) who travelled extensively in several parts of Mexico.

Vázquez de Espinosa (1942, 1948) visited caves in Mexico between 1612 and 1621. Besides his description of one near Oaxaca, from which Francisci derived his account, he reported others in the Chiapas district of Mexico and (between 1617 and 1619) in Peru.

ERASMUS FRANCISCI

So as to understand Francisci's contribution to *Die Ehre* ... it is necessary to know a little about the man himself and the extent of his scholarship. In view of his importance, both in this paper and as the associate of Valvasor, two engravings of him are reproduced here (Figs. 2 and 3).

He was born at Lübeck on 19 November 1627 and died in Nürnberg on 20 December 1694 (i. e. 1 January 1695 according to the new style Gregorian calendar used in Catholic countries) (Baraga 1990). He lived in Nürnberg, the city in which *Die Ehre* ... was published.

Francisci wrote or edited more than 53 books on a very wide range of subjects, including biographies, histories, religious books and compilations of travel writings. As Baraga has pointed out, the range of subjects that he wrote about makes him one of the first professional generalist German writers. Many of his works are compilations. He never went to Carniola but the nature of his contribution to *Die Ehre* ... is such that this is not a disadvantage.

Fig. 2. Erasmus Francisci, from an engraving printed after his death in 1694, in the Department of Prints and Drawings of the British Museum. Height of original portrait 130 mm. Reproduced by courtesy of the Trustees of the British Museum

ERASMI FRANCISCI
Ost- und West-Indischer wie auch Sinesischer
Lust- und Stats-Garten /
Mit einem
Vorgespräch
Von mancherley lustigen Discursen;
In Drey Haupt-Theile unterschieden.
Der Erste Theil
Begreifft in sich die edelsten Blumen / Kräuter / Bäume / Oel-Wasser-Wein-Artzney- und Gifft-gebende Wurtzeln / Früchte / Gewürtze / und Speceryen / in Ost-Indien / Sina und America:
Der Ander Theil
Das Temperament der Lufft und Landschafften daselbst; die Beschaffenheit der Felder / Wälder / Wüstenungen; die berühmten natür- und künstliche Berge / Thäler / Hölen; ingleichen die innerlichen Schätze der Erden und Gewässer; als Mineralien / Bergwercke / Metallen / Edelgesteine / Perlen und Perl-Fischereyen;
Der Dritte Theil
Das Stats-Wesen / Policey-Ordnungen / Hoffstäte / Paläste / denckwürdige Kriege / Belägerungen / Feldschlachten / fröliche und klägliche Fälle / Geist- und Weltliche Ceremonien / merckwürdige Thaten und Reden der Könige und Republicken daselbst.
Nürnberg /
In Verlegung Johann Andreæ Endters / und Wolfgang deß Jüngern Sel. Erben.
ANNO M. DC. LXVIII.

Fig. 4. The title page of Francisci's book of 1668, reproduced by permission of the British Library (shelfmark 572. i. 19). Height of original 310 mm.

Fig. 3. Erasmus Francisci, from an undated engraving in the library of the Theological Seminary in Ljubljana, reproduced with permission. Copy made by Carmen Narobe of SAZU. Height of original portrait (within oval) 87 mm.

Not surprisingly, when he needed to insert information on American caves in *Die Ehre ...*, Francisci made use of his own previous book on the region, *Ost- und West-Indischer wie auch Sinesischer Lust und Stats-Garten ... die berühmten natür- und künstiche Berge, Thäler, Hölen ...* (Francisci 1668); the full title can be seen in Fig. 4. The fact that this book was compiled from already existing information was quite usual at this time. It was like a textbook, drawing on other relevant publications. This is not to minimise its value either to his contemporaries or to historians, since the 17th century and earlier sources that he used were not all readily available even then. The very fact that such compilations existed in relatively large numbers shows that they fulfilled a purpose. Dapper's regional descriptions, one of which plays a significant part in this study, were also compilations.

Although much of the content of such books came from earlier sources, this did not make them out of date. Often the information used was all that was available, and this is particularly true where explorations of the New World were concerned. People did not waste time rediscovering and describing the same places. Thus such 17th century compilations were different in nature and purpose to those popular ones of the 19th century with titles such as *The Wonders of Nature and Art* (Smith 1803-04) or *Facts from the World of Nature* (Loudon 1848), which were produced for popular reading or to instruct children.

A CAVE IN GUATEMALA

The cave near Verapaz in Guatemala described by Francisci in *Die Ehre* ... (1689, *1*: 487) is undoubtedly Gruta Lanquin (2298 m long) close to the town of the same name in Alta Verapaz, at 15⁰ 35' N, 90⁰ 03' W. There are modern descriptions of the cave by Gurnee (1962) and Courbon et al. (1989). The 1689 description is almost identical to that of Dapper, first published in 1670, but Francisci's own earlier account had a little more information in it. In its turn, this was derived from that of Laet in 1625.

The *Die Ehre* ... account is as follows:

> In der Guatemalischen Gegend Vera paz, hart am Flecken S. Augustin findt sich zwischen zween Bergen eine steinerne Höle mit einem weiten Munde: in derselben trifft man einen grossen geraumen Platz an mit vielen Winckeln. Durch den Felsen tröpffelt eine versteinernde Feuchtigkeit hinem: die in selbiger Hölen viel Bildnissen mancherley Gestalten figurirt derer schöner Glantz mit dem weissesten Alabaster um dem Preis ringet. Man vernimt aber auch daselbst ein furchtsames Geräusch so von einem Wasser sich erregt und von allen Ecken zivo Picquen hoch hinunter fällt in einen Wasser-Pfuhl: welcher eine unergründliche Tieffe hat hohe Wellen wirfft und einen mächtigen Strom von sich heraus schiesst.

Rather than translate the German text of *Die Ehre* ... into English at this point, it is compared with an earlier text, also in German, from which it is derived.

The immediate predecessor of the *Die Ehre* ... account, though not necessarily its source, is by Olfert Dapper. A copy of the 1673 German edition of Dapper's book survives in Valvasor's own library in Zagreb, and it is included (without date) in the list of sources printed at the beginning of *Die_Ehre* ... Further confirmation that this was the edition used is that it is cited by page number for the Mexican cave description discussed later.

The equivalent description of the Guatemalan cave in this 1673 edition is:

> Dichte bey dem Flecken des heiligen Augustiens lieget zwischen zween Bergen eine steinerne Höhle mit einem weiten Munde und in derselben eine grosse Fläche vol Winckel. Aus dem stähtigen durchtrüpfelen entstehen vielerhand Wunderliche Bilder weiche vor keinen weissen Albaster weichen. Man höret ein erschröckliches rauschen des Wassers welches an allen enden zwo Pieken hoch niederfället in ein Meer darinnen der unmäslichen tieffe wegen grosse Wasserwogen sich erhöben. Aus diesen Meere komt ein grosser Strohm geschossen.
>
> (Dapper 1673: 305)

The same facts and comments appear in the same sequence as in *Die Ehre* ... and with many of the same words and similar phrases presented in the same order, though the 1689 account is a little longer. A contemporary

English translation (Ogilby 1671: 228) renders Dapper's text as:

> ... St. Augustines; near unto which there is said to be a Cave and Fountain within Ground, which converts the Water that falleth into it out of several lesser Springs, into a kind of Alabaster or Stone, perfectly white, and fashions it likewise into Pillars, Statues, and other artificial Forms of very curious Workmanship, as Laet reporteth.

We shall come to Laet's description in due course.

Because Dapper's writing was so similar to that in *Die Ehre ...* on three of the four caves considered in this paper, and evidently was its direct source in at least one of these cases, the somewhat complex matter of the publication and disputed authorship of his book is summarised here.

Olfert Dapper was born at Amsterdam in 1636 and died in December 1689 (Brugmans 1927). He was a medical doctor but was particularly interested in geography and history (Hoefer 1855). From 1670 to 1688 he published a 12-volume collection of voyages and descriptions of foreign countries in Dutch. In this collection, the volume on America was attributed on the title page to Arnoldus Montanus (1671) and the description of the Guatemala cave is found on page 271. An English version of this was printed in 1670 as though the author was John Ogilby, and reissued in 1671. The German edition of 1673, already mentioned, was translated by J. C. Beers from the Dutch but Dapper is named on the title page as the author. This information is summarised by Sabin (1873, 1880) in his bibliography of books on America, where he calls Ogilby's and Dapper's books "impudent plagiarism" of Montanus's work. The actual authorship is still disputed (see Schuller 1907). For simplicity I have followed the practice of *Die Ehre ...* and of the British Museum library catalogue, and referred to the 1673 edition as by Dapper; the others are cited under the author's name given on the title page.

Whoever the author was, the books are regarded as "careful compilation(s) by a scholar ... including ... material from unpublished manuscripts which have since been lost" although he never visited the places described (Tye and Jones 1993).

It is clear too that the German edition cited in *Die Ehre ...*, and even the first printing in 1670, appeared after the publication of Francisci's 1668 book. Furthermore, Francisci (1688: 1091) includes some information not present in Dapper's account - a remark on extreme cold in the cave - which shows that he could not have borrowed from a draft of Dapper's book before its publication, but must have used the much earlier description by Laet (see later).

Nevertheless it remains that the *Die Ehre ...* text, although supplied by Francisci, is so similar to Dapper's that in 1689 Francisci must have used that rather than his own previous account.

Tantalisingly, Francisci (1668) refers to "Franciscus de Ulloa, in seiner Schiffabriss Verzeichniss bezeugt" ("in his ship's log book") as if as a source for the cave description. Ulloa, with three ships, was exploring on the west coast of Central America in 1539 and 1540, so this suggests an early origin for the information. However, all the published versions of his account traced (Ulloa 1556; 1809; Wagner 1929) and other references to his travels (e. g. Morison 1974) describe only coastal explorations, with no journeys far inland and no reports of caves. So, either a now lost Ulloa manuscript was seen by Francisci (as will be seen later, Francisci's knowledge of a cave in Mexico was derived from a manuscript which was not published until 1942) or the citation arose from a copying error.

Whichever was the case, Francisci's own source was clearly one of the editions of Johannes de Laet's "The New World and a Description of the West Indies". The content and sequence of the description are very similar in both books. Laet writes:

> Near the town on S. Augustin and between two mountains, there can be seen a cave in the rock which can contain many men. Inside its large entrance it is low and dark, like several others close by, and a certain liquor drips continually, turning into a white stone like alabaster and forming many columns and statues by an unusual process of nature: inside, there is a cold so gripping & acute that it is said to get into the bones: also one can hear there a confused murmuring of running water which comes from various streams, falling first of all into a pool in a deep pit where they combine and then flow off as a river which is large enough to carry boats, once it has left the cave.

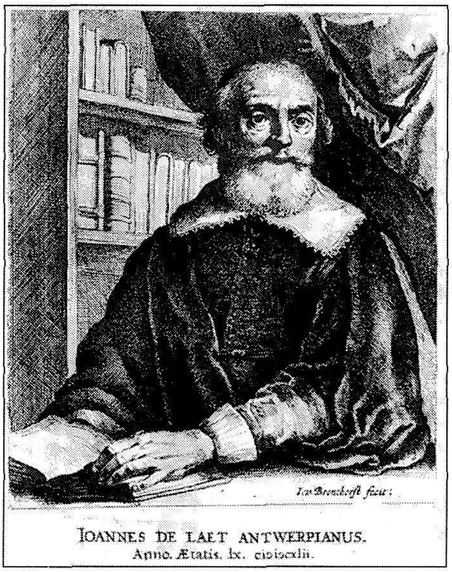


Fig. 5. Johannes de Laet at the age of 60 in 1642. An engraving by I. van Brouckhorst. Height of original portrait 211 mm. Reproduced by courtesy of the Trustees of the British Museum.

This translation has been made from the French edition of 1640 (p. 247). The book was published first in Dutch in 1625, with a second edition in 1630; a Latin version appeared in 1633 followed by the French one in 1640. So it was a popular book and one that was easily accessible in the 17th century. In a copy of Kircher's (1665) *Mundus Subterraneus* a contemporary owner has inserted a marginal note in ink about Laet's mention of this cave.

Johannes de Laet (Fig. 5) was born at Antwerp in 1581 and died at Leiden in 1649 (Bekkers 1970). Other sources (Brugmans 1930; Elaut 1962) give different years for his birth but Bekkers argues convincingly that it must have been towards the end of 1581. Laet studied philosophy and theology at Leiden, but after being appointed one of the 19 directors of the Dutch West India Company in 1621 his chief interests were in geography, history and languages. He was a prolific writer and his best-known book is the one quoted here.

In the same way that Laet's description was repeated and recycled in the 17th century, it was again summarised a hundred years later by Rosenmüller and Tillesius (1799: 69-70), and as late as 1887 Schwalbe in turn cited their publication in referring to the extreme cold in the inner part of the cave.

A CAVE NEAR OAXACA IN MEXICO

The cave close to Cuertlavaca near Oaxaca in Mexico, described in *Die Ehre ...*, has not been identified as there are many caves in that area. Perhaps the present publication will stimulate investigation locally.

Tracing the source of the 1689 information here is less complex than it was for the Lanquin cave in Guatemala. The cave is not mentioned at all in Francisci's earlier book and the 1689 text is taken almost verbatim from Dapper's 1673 edition. The information contained there came, via Laet's 1625 book, from Vázquez de Espinosa's then unpublished manuscript of about ten years earlier.

The *Die Ehre ...* text reads:

> Lust Beschaffenheit der Mexicanischen Höle Kuertlavaka
>
> Keines mittelmässigen Lobs mag auch berechtigt seyn die Höle bey dem Mexicanischen Flecken Kuertlavaka, an einem hohen Berge in Neu Spannien (oder Mexico) Sie hat einen gar engen Eintritt: der sich aber bald nachdem man ein wenig hineingekommen zu einem viereckten funfftzig-schuhigem Platz erweitert: An dessen Ende eine Brunn-Grube mit hohen Treppen (oder Stafeln) gefunden wird: woselbst ein krummer und insamer Weg angeht und eine gantze Meile weit lausst; aber fast auf Art der Irrgarten gerichtet ist. Nachmals trifft man noch einen andren grossen Platz an welchen ein Spring-Brunn frisches Wassers belustiget und nicht weniger ein nechst dabey rinnender lieblich-schöner Bach recommendirt. Wie aber die übrige Theile dieser Hölen gestaltet

senn mögen weiss bisshero die Verborgenheit für sich allein nur: weil noch zur Zeit sich Niemand hat weiter hinein erkühnt.[b]

[b] Sihe das 2 Buch Americae c. 15. p. 287

(Valvasor 1689, *1* : 490)

Again, the *Die Ehre* ... text is left untranslated here, the better to compare it with the description it acknowledges as its source (Dapper 1673: 287):

> Bey den Flecken Kuertlavaka lieget ein hoher Berg darinnen eine wunderseltsame Höhle zu finden. Der Eingang dieser Höhle ist sehr änge. Wan man ein wenig hineingelanget ist siehet man einen viereckichten Platz von fünfzig Fützen. Am ende desselben stehen Brunnen oder Gruben mit hohen Treppen; bey denen ein krummer Weg der auf die weise der Irrgarten sich eine Meile lang erstreket beginnet. Hierauf folget noch ein ander grosser Platz mit einem Springbrunnen vol guhten Wassers versehen; bey welchem einer schöne Bach fliesset. Weil aber niemand sich weiter in gemeldte Höhle hinein begeben so ist das übrige bis nochzu verborgen geblieben.

The same description appears in the Dutch version (Montanus 1671: 254), and the English translation (Ogilby 1671: 269) reads:

> Not far from the Village Cuertlavaca, lies a high Mountain, remarkable for a strange Cave, whose Entrance is very narrow, at the end whereof appears a square Place of fifty Foot; upon one side whereof stand Pits with Steps; near which begins a crooked Way of a League long; at the end of which is a spacious Place with a Fountain of good Water; from the Foot of which flows a small Brook: But because none have made any farther discovery of this Cave, the other parts of it remain yet unknown.

In turn, this Dapper/Montanus/Ogilby description is clearly taken from de Laet's account first published in Dutch (1625: 164), and repeated in the subsequent Latin and French editions:

> On the borders of the villages of Cuertlavaca and Tequicistepeque there is a wonderful place under a high mountain which was entered in the past by a Jacobin monk with some natives; the descent into it is so narrow that they could only go in one at a time, inside there is a place 50 feet square, where there are some pits with steps; from thence one goes by a route with many bends, and with twists like a labyrinth, to a large space in the middle of which a spring wells up and forms a stream on one side: having walked there for an hour, as they could find no end, they came back by following a thread which they had fixed at the cave mouth.
>
> (translated from Laet 1640: 175)

Laet's description of 1625 was the earliest one to be printed but he must have obtained his information, perhaps in his capacity as a director of the Dutch West India Company, from the Spanish traveller Antonio Vázquez de

Espinosa, whose own nearly identical account was written about the same time but not published until the 20th century:

> In the villages of Cuertlavaca and Tequixtepec there is a very high sierra, and on its slopes there is another cave with a mouth so narrow that a man can hardly get through it; immediately one enters a square room over 50 feet high, and beyond this reception chamber there are flights of steps; next there is a passage with many turns like a labyrinth, through which one walks following a cord which serves as a guide to keep one from getting lost and which is fastened at the entrance. Beyond this labyrinth there is a large plaza and in the midst of it a spring of excellent water; the heathen did not venture to drink it, for they considered that it was sacred and that those who drank of it, would die; at one side of this spring runs a little stream. The cave goes much farther; they have never found the end of it; the heathen considered it a holy place.
>
> (Vázquez de Espinosa 1942:182)

Vázquez de Espinosa was a Carmelite friar and Spanish writer born in Jerez de la Frontera in the last third of the 16th century and who died in Seville in 1630. He travelled in America from 1612 or before until about 1622 when he returned to Spain. He was certainly in Mexico in 1612; from 1614 to 1619 he is known to have been in Ecuador and Peru for at least part of the time; and in 1620 and 1621 he was in Guatemala. His information on the cave, which seems to be based on a visit to it, therefore dates probably from 1612 or 1613 and this is supported by the position of the description in his manuscript.

The lengthy manuscript account of his travels, now in the Barberini Collection in the Vatican Library (Barb. Lat. 3584), is known to have been written in 1628 and corrected in 1629. It is likely that earlier drafts or at least notes existed and Laet must have obtained his information from these. Vázquez de Espinosa had begun printing his manuscript before he died in 1630, and some of the sheets already printed evidently got into circulation for they are referred to in the 1738 edition of a library catalogue (Leon Pinelo 1737-38). Whether the passage quoted here was in those printed pages is not known. Certainly it was not included in the book he published in 1623. For complete publication in the original Spanish the manuscript had to wait until 1948, but an English translation appeared six years earlier, with an introduction by C. U. Clark from which most of the above information has been obtained.

As was the case with the Guatemala cave, the same information continued to be printed, sometimes without acknowledgement, in the 18th century. Thus Schwabe (1755) used it in his 21-volume description of the world, and it appeared again in Rosenmüller and Tillesius (1799: 70).

A CAVE IN HISPANIOLA

The origin of the information given in *Die Ehre* ... on a cave in Hispaniola has been traced back to 1513. The identity of the cave is discussed later after the full description contained in the source document has been presented.

The 1689 text is short:

> Petrus Martyr zeuget in der Americanischen Insel Hispaniola, (S. Domingo, oder Dominici) sey gleichfalls eine Höle oder holer Erd-Schlund dabey immerfort ein solches Krachen und Stürmen wütet dass biss auf 5 (welsche) Meilen niemand hinzu treten darff soferrn er nicht sterben oder auss weningste um sein Gehor kommen will.
>
> (Valvasor, *1*:142)
>
> Peter Martyr testifies also to a cave or chasm in the American island of Hispaniola (S. Domingo or Dominica) round which there are always such storms and gales that no-one can come within 5 (foreign) miles of it lest he die or at least become deaf.)

The derivation of this passage is complex, and part of it obscure.

Dapper (1673: 185) does describe a deafening cave in Hispaniola. But his text does not resemble that of *Die Ehre* ... The contemporary translation (Ogilby 1671: 322) reads:

> In the said Province of Caizimu is a very remarkable Rock, or vast Stone to be seen, at the Foot of a high Mountain; and underneath the said Stone is a great Cave, into which they go through a large Passage, not unlike a Temple Door; near which conjoyn many deep Rivers, with such a Noise and Foam, that they lose both their Sight and Hearing, whoever approach the same.

In 1668 Francisci gave quite a lengthy account (Fig. 6) of what must be the same cave, but it is very different to his insertion in *Die Ehre* ... As in Dapper's paragraph, there is no mention in the 1668 book of the five-mile radius within which people are injured or killed by the noise; and *Die Ehre* ... says nothing of the sea being nearby, as the 1668 account does. So the precise source of the wording used in *Die Ehre ...*, and in particular of the "five-mile" phrase, is not known. That five-mile statement was perpetuated after Valvasor's time, however, for it is repeated by Derham (1713 and later editions), in a further modified form.

There is no doubt, however, where the 1668 text comes from; it is taken direct from the account by Peter Martyr (1457-1526), being an almost exact translation of the original Latin. Peter Martyr's text is printed here in the English translation of 1555, with spelling updated to 1612. To make it easier to read, the modern letter "v" has also been inserted in place of the original "u".

Wasser-Höle in der Insul Hispaniola.

Petrus Martyr erzählet/in Beschrei-
bung der grossen Americanischen Insul
Hispaniolæ, daß in einer Provintz da-
selbst/ Namens Caizimu, eine sehr grosse

(a) Aus der Japanischen Relation Francois Caron, Directorn der Niederländischen Compagnie auf Japan.

(b) Libro 6. Navigation. c.4.

Spelunck/ unten am Fusse eines treffli[ch]
hohen Berges/ in einem hohlen Fels[en]
sey/ ungefehr zwey Stadien/ oder zwey
Achttheil einer welschen Meilen/ vom
Meer gelegen: welcher Hölen Eingang
den Pforten oder Thüren eines grossen
Tempels ähnlich/ und Bogenweise for-
mirt. In solche Höle hat sich/ auf Befehl
deß Hispanischen Gouverneurs, ein
Schiffer/ mit einigen Schifflein/ hinein
begeben/ um dieselbe durchzuforschen;
und die Nachricht gebracht; daß daselbst
viel Flüsse/ durch verborgene Canäle/ zu-
sammen liessen/ als wie in einen Pfuhl/
oder in eine Pumpe. Auf solches/ hat
man fallen lassen die Verwunderung und
Befremdung/ wohin doch immermehr
so viel hinlangs fliessende Ströme gera-
then möchten/ welche von 90. Meilen weit
herab strömeten/ aber im Lauffen endlich
verschlungen/ und weiter nicht gesehen
würden: sintemal man geschlossen/ daß
sie/ von dieses Stein-Felsens Abgründen
und Pfülen eingeschluckt/ nach besagter
Hölen zu ihren Lauff nehmen müsten.
Der Schiffmann/ so/ verstandener mas-
sen/ sich hinein ins Loch gewagt/ wäre
schier nicht wieder kommen/ sondern bey
nahe in dem Wasser-Schlunde begraben
worden: angesehen/ sehr viel Stru-
deln und Wasser-Würbel darinnen zu-
sammen stiessen und rungen. Es stun-
den ihm alle Haar gen Berge (oder/ recht
eigentlich zu sagen/ unter dem Berge und
halb im Bauche deß Grabs) als er hörte
und sahe/ mit was vor schrecklichem Ge-
brüll solche Schlund-Tieffen gegenein-
ander brauseten: und noch vielmehr/ da
sie sein Schiff zu sich rissen; welches bald
der Würbel hieher/ bald der Strudel
dorthin/ warff/ und damit gleichsam den
Ballen schlug: also gar/ daß er anfieng zu
wünschen/ er wäre nie hinein gekommen.
So wuste er auch/ welches das aller-
forchtsamste und übelste war/ keinen Aus-
gang wieder zu treffen: muste/ nebenst et-
lichen seiner Schiffgefährten/ nur also/ im
Tunckeln/ schweben/ und wallen; so wol
wegen der Finsterniß selbsten/ welche in
selbiger Klufft sich gar weit erstreckt; als
wegen der Nebeln/ welche aus den feuch-
ten Dünsten der stets miteinander strei-
tenden Wässern entstehen. Sie funden
in dieser brausenden Wasser-Klufft/ ein
gleiches Geräusche/ und krachendes Wel-
len-Getöß/ als wie der Nilstrom macht/
wenn er von den Morenländischen Ge-
birgen herab stürtzet: ertaubten auch
darüber dermassen/ daß keiner den an-
dren hören/ vielweniger verstehen
kunte/ wie laut und starck man auch
[sch]rie.

Endlich ist er dennoch/ weiß nicht
[w]ie/ aus solcher Klufft/ wiewol schier
[ha]lb tod von Angst und Schrecken/ wie-
[d]er entkommen; und solche Entwischung
[i]hm nicht anders fürgekommen/ als ob
man ihn/ aus dem Schlunde der Höl-
len/ hätte wieder heraus ans Liecht ge-
führt. (a)

Fig. 6. *Francisci's account of the cave in Hispaniola, from pp. 1092-1093 of his 1668 book (reduced in size).*

> In the province of Caizcimu, within the great gulfe of the beginning, there is a great cave in a hollow rocke under the root of a high mountaine, about two furlonges from the sea, the entry of this cave is not much unlyke the doores of a great temple, being very large, and turnyng many wayes. Andreas Moralis the shypmaister, at the commandement of the governour, attempted to search the cave with the smallest vessels. He sayth that by certayne privie wayes many ryvers have concourse to this cave, as it were a synke or chanel. After the experience hereof, they ceased to marvaile whither other ryvers ranne, which comming fourscore & ten myles were swalowed up, so that they appeared no more, nor yet fel into the sea by any knowne wayes. Nowe therefore they suppose that ryvers swalowed up by the hollow places of that stony mountayne, fall into this cave. As the shypmaister entred into the cave, his shippe was almost swalowed. For he sayth, that there are many whirlepooles and rysinges or boylinges of the water, which make a violent conflict and horrible roryng, one encounteryng the other: also many huge holes and hollow places, so that what on the one side with whirlpooles, and on the other side with the boyling of the water, his shyppe was long in manner tossed up and downe like a ball. It greatly repented him that he had entred, yet knew he no way how to come forth. He now wandred in darknesse aswell for the obscurenesse of the cave into the which hee was farre entred, as also that in it were thick clouds, engendred of the moist vapours proceeding of the conflict of the waters, which continually fall with great violence into the cave on every side. Hee compareth the noyse of these waters, to the fal of the famous ryver Nilus from the mountains of Ethiope, they were also deafe, that one could not heare what another saide. But at the length with great daunger and feare, he came foorth of the cave, as it had been out of hell.
>
> (Martyr 1612, f. 135)

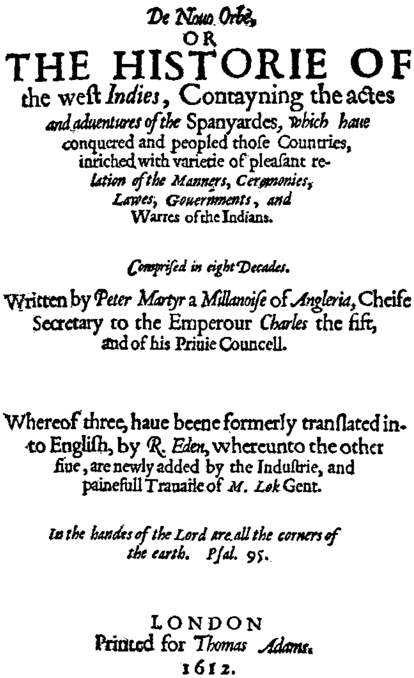
The identity of the cave and the probable date of the visit are discussed later. At this point, however, it is necessary to explain or comment on a few points in the text:

- The province of Caizcimu is "the most eastern district of the island", according to Martyr.
- A distance of "two furlonges from the sea" (stadia in the original Latin) was equivalent to between 400 and 440 m.
- "Andreas Moralis the shypmaister" is not named in the Latin original but is implied because it was he who supplied the information to Martyr. More about him later in this paper.
- "the commandement of the governour". This is the governor of Hispaniola, Nicolas Ovando (or Obando), who had appointed Moralis (usually called Morales) to explore the island.
- "search the cave with the smallest vessels". The Latin text just has "navigiis antrum" ("sail into the cave") with no mention of what he should

sail in. The ship's boats would have been used, as they were for coastal exploration in the other islands.

Because of the somewhat complex way in which Martyr's book was written and published, some attention needs to be given to its structure. It was divided into eight parts ('Decades'), and each of these into long sections or Libri (Books) - rather equivalent to the Buch and Cap subdivision of *Die Ehre* ... Just when each part was originally written is not known.

Decades I to III were first published in Latin in 1516 and translated into English in 1555. The passage quoted above is in Decade III. The complete work, including the Decade VII from which a short quotation is given below, appeared in 1530, also in Latin, and an English version of the whole was printed in 1612 (Fig. 7). A modern rather free English translation by MacNutt appeared in 1912; it is not very exact so it is not as suitable as the one of 1612 for seeing what Martyr really wrote about the cave.



De Nouo Orbe,
OR
THE HISTORIE OF
the west *Indies*, Contayning the actes
and aduentures of the Spanyardes, *which haue*
conquered and peopled those Countries,
inriched with varietie of pleasant re-
lation of the Manners, Ceremonies,
Lawes, Gouernments, and
Warres of the Indians.

Comprised in eight Decades.

Written by *Peter Martyr* a *Millanoise* of *Angleria*, Cheife
Secretary to the Emperour *Charles* the fift,
and of his Priuie Councell.

Whereof three, haue beene formerly translated in-
to English, by *R. Eden*, whereunto the other
fiue, are newly added by the Industrie, and
painefull Trauaile of *M. Lok* Gent.

In the handes of the Lord are all the corners of
the earth. Psal. 95.

LONDON
Printed for *Thomas Adams*.
1612.

Fig. 7. The title page of the first complete translation of Peter Martyr's De Orbe Novo, *published in 1612.*

To show conclusively that the extract printed above is the one referred to in *Die Ehre ...*, it was necessary to search the whole of Peter Martyr's book. Might there not be another cave description there that fits equally well or even better, mentioning the five-mile danger radiius? A very thorough examination of all eight decades established that there is no reference anywhere to such a cave.

The search did, however, throw up a rather puzzling cross-reference to the passage already quoted. In a part of the book written later and not published until 1530, Martyr refers to what is evidently the same cave, but here he places it in the western province of Guaccaiarima at the other end of the island. Thus, in Lib. 8 of Decade VII:

> In my first Decades I spoke of a vast maritime cavern in the province of Guaccaiarima in Hispaniola, which extends a distance of several stadia into the heart of the lofty mountains along the west coast. The interior of this cavern is navigable. In its gloomy depths, where the sun's rays hardly penetrate save for a moment at sunset, is heard such a roaring from a waterfall that those who enter shiver with horror.
> (Martyr 1912, v. 2: 298)

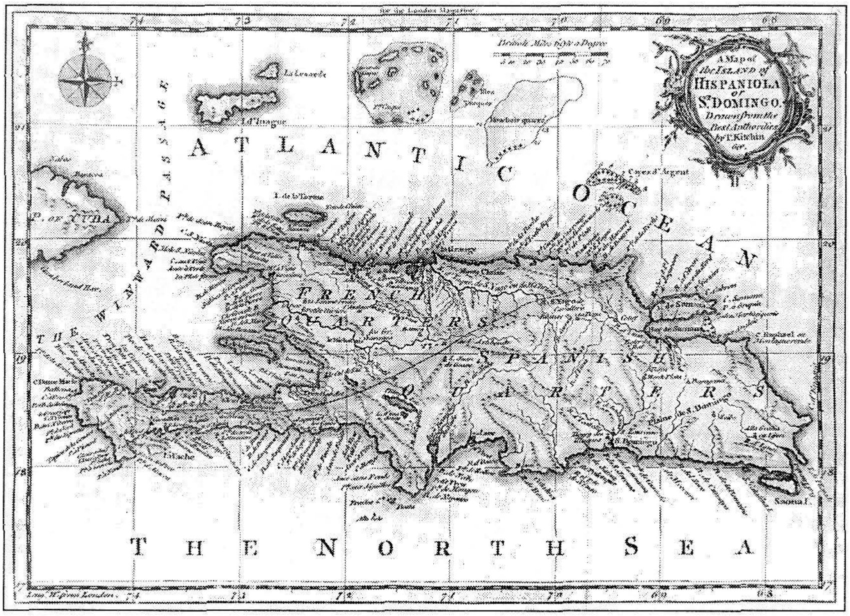


Fig. 8. A map of Hispaniola made by Thomas Kitchin and published in 1758 (reduced in size). Bahía de Samaná is on the north-east coast. Crosses in the sea denote the presence of rocks.

Apart from the east/west contradiction, the two extracts seem to refer to the same place. Moreover, nowhere in the "first Decades" is there a description of any other similar cave, nor of any navigable river cave at all in the Guaccaiarima province. A possible reason for Martyr's apparent error in the later quotation, confusing Caizcimu province (east) and Guaccaiarima province (west), may be that, two sentences before the Decade III description to which he is referring, there occurs a sentence beginning "In Guaccaiarima... ". Perhaps Martyr misread his earlier text when, in later years, he referred to it in Decade VII.

All this leads to a consideration of how accurate can Martyr be expected to be in matters of detail; how did he obtain his information and from whom?

Peter Martyr d'Anghera (or Anglerius) was born on 2 February 1457 at Arona on Lake Maggiore in Italy. 1455 and 1459 have also been quoted as the year of his birth but the 1457 date was carefully deduced from conflicting evidence by MacNutt (1912). He died in 1526 after 23 September, the date

Fig. 9. Location of Cueva Infierno at Bahía de Samaná.

on which his will was signed. An Italian, he rose to high ecclesiastical positions in Spain and became the friend of Columbus, Cortés and other explorers of the New World. From these personal contacts and his official position as a member of the Council for the Indies, which allowed him access to authentic documents, he was able to obtain much first-hand information concerning their discoveries. Concerning his Hispaniola report Martyr himself wrote "He (Morales) therefore resorted to me, as they are all accustomed to do which return from the Ocean." From October 1494 until his death in 1526 he made a manuscript record of voyages to the New World, though this was interrupted when he served in the Spanish army and when he was Spanish ambassador in Bohemia and in Egypt. Although he did not go to America himself, he was regarded as reliable in his own time when information was fresh in the memories of potential critics.

Surprisingly, there seem to be no portraits of Peter Martyr d'Anghera. Those purporting to be of him (in Halstead 1965; and in Giorgi de Pons 1930, reproduced by Stoppa 1992) are of his namesake Peter Martyr Vermigli (1500-1562). The text accompanying the first publication of the Halstead portrait (Verheiden 1603) makes this clear, and so does a biographical verse engraved with the second picture in 1697. The 1603 portrait was wrongly identified as of the earlier Peter Martyr in the Library of Congress portrait index (Lane and Browne 1906), though the British Museum catalogue (O'Donoghue 1914) was correct, and it may have been this that led Halstead into error.

There is reason to consider Martyr's writing to be as accurate as any record could be. That is to say, his record of what he read and was told was probably correct, but exaggeration could occur, then as now, between a particular event and its transmission to him. How accurate, though, were the facts he was given? Was Morales a reliable informant? Again using Martyr's words (1612, f. 130): "This man had diligently searched the tracte of the supposed continent, and especially the inner regions of the Ilande of Hispaniola ... so that with his own handes hee drewe fayre cardes (maps or plans) and tables (written records) of such regions as hee discovered. Wherein as he hath beene founde faithfull of such as have since had better triall hereof, so is he in most credite amongst the best sort." So there is every reason to think that his account is a correct record of how Morales had remembered the occasion, including the exaggeration resulting from his "feare".

Martyr's main description of the cave, the detailed one published in 1516, describes it as being in "vastum initii sinum" ("the first gulf found in the province of Caizcimu" of the 1912 translation) at the eastern end of the island. This can only be the Bahía de Samaná, some 1300 km^2 in area, on the north-east coast of the island (Fig. 8). This identification is accepted also by MacNutt (1912). Karst exists both to the north and the south of this long bay, with the higher hills (500 m to 1000 m) to the south; Martyr refers to "a high mountaine" near the cave. There are many large caves in the cliffs of the bay and karst springs exist on the coast near Sabana de la Mar on the south side (Palmer 1983). Also on the south coast of the bay and sufficiently prominent to be marked on the modern map (Hildebrand 1985) is Cueva Infierno (see Fig. 9), out of the large entrance of which flows the Rio Almirante (Muscio & Sello 1989). This is the entrance to a cave known also as Cueva Fun Fun, from the name of the nearby village, in which more than 7 km of cave passage have now been explored (Savoia 1986).

In the Cueva Infierno we do have a large resurgence cave in a place consistent with Martyr's description. The water noise which deafened the early explorers in the cave, and no doubt gave rise to the stories of deafness up to five miles away, can reasonably be attributed to flood water, as well as to unfamiliarity, fright and exaggeration. The presence of flood water may also have made a normally fairly small stream explorable by boat. To match the early description to the existing caves with certainty requires local investigation.

The date of Martyr's information about this cave is clearly of extreme interest being, it appears, the earliest description of any cave in the Western hemisphere.

The first Decade of his manuscript had been written out in 1500 and 1501 (Morison 1974: 140) so Decade III, containing the cave description, must have been written some time between then and its first publication in 1516. Nevertheless his notes had been started as early as 1494 so, if there had been no other evidence about the date, the cave information could have been recorded as early as that.

It was in December 1492 that Columbus discovered Hispaniola, in the course of his first voyage to America. His ships were at anchor in Bahía de Samaná, near which the cave is, from some time after 8 January 1493 until 18 January, when he sailed for Europe (Morison 1974: 82). It is tempting to think that Martyr's information might have dated from that time, but this is not so.

The man who entered the cave is named by Martyr as Andreas Moralis (Morales). He was a 'pilot', that is to say a navigator, and only the captain of his ship was senior to him. According to Martyr (1612, f. 130) he had often been to the newly discovered lands. He is known to have been a friend and companion of Juan de la Cosa (1449-1510), the map-maker who made six voyages to the Caribbean, and may have accompanied him on Columbus's second voyage (1493-1496). He was not present on the first voyage of 1492 to 1493, in which only three ships took part. It is known for certain that he was in the Caribbean from 1499 to 1500, but most if not all of that voyage was spent close to the mainland of South America.

Morales's visit to the cave must have been not earlier than 1502. According to Martyr (1612, f. 130), he was appointed to explore Hispaniola "by his brother Nicolaus Ovandus (the governour of the Ilande ...)." Now Nicolas Ovando was appointed governor of Hispaniola in September 1501 and left Spain to go there in February 1502, arriving presumably in March. When Morales died is not known, but the visit cannot have been later than 1515 for it to be recorded in Martyr's third Decade.

The date can be approximated more closely, however, for Martyr (1612, f. 130) says that Morales told him about it only just after "Petrus Arias the governor of the supposed continent" had sailed from Spain for Darien. This was Pedro Arias de Ávila, who arrived in the Caribbean on 29 June 1514 to replace Balboa as governor of Darien (Morison 1974: 203-4). Thus Martyr would have received his information from Morales early in June. Morales had only recently returned home, so the most probable year for the cave visit is 1513, though it could have been before if Morales's voyage had been a long one. The frightening noise of the water in the cave suggests that the exploration took place in the rainy season, which eliminates the winter months and makes the most probable time between May and November 1513. This was the same year in which Balboa crossed the isthmus of Panama and was the first European to see the Pacific Ocean.

If the cave was explored specifically "at the commandement of the governor", as implied by Martyr's text, then the entrance at least must have been known to Europeans before his exploration. Even if the "commandement" was just the general one to explore the island, it is still likely that such a prominent entrance would have been seen near to where Spanish ships used to anchor.

Although not directly relevant to the cave described by Martyr, it should be mentioned that as early as October 1495 Michele de Cuneo, sailing with Columbus, had referred to the existence of a cave in the small limestone island of Saona, close to the south-east corner of Hispaniola. He did not describe it and it is probable that only the entrance was seen (Chiappa 1986).

A CAVE IN THE ANDES

The cave described as being in the Andes mountains of South America is almost certainly an imaginary one. The account in *Die Ehre* ... is nearly identical to that in Francisci's earlier book (1668) and to that in Kircher's *Mundus Subterraneus* (1665) from which it was evidently taken. All three refer to a *story* of such a cave.

The essential part of the *Die Ehre* ... text is:

> Denn die West-Indische Historien berichten es gebe in selbigem Gebirge so erschrecklich-grosse Hölen die gantzen Ländern in der Weite nichts nachgeben ...
>
> (Valvasor 1689, v. 1: 489)

> (West Indian stories tell of such terrifyingly large caves in these mountains that they are second to none in the whole world)

In 1668 Francisci imparts the same information in the same sequence and using some of the same words. The equivalent passage in Kircher's book (1665), rendered into English, is:

> There is a wonderful American story about the Andes mountains, in the interior of which is said to be a cave, more frightening than can be described, of such a size that there is nothing to equal it in the whole of the earth's surface ...

And he goes on:

> For the reality of such wonders of the Andes - hidden places, rivers, waterfalls and other natural phenomena - the reader should consult the comprehensive and curious book of Father Alphonse d'Ovalle ...

thus distinguishing between the story he has repeated and what he believes to be accurate information. Ovalle (1646) does not give the Kircher story of an immense cave in the Andes. Rather, as Kircher points out, he describes individual streams (but no caves) as if from personal observation. Where Kircher obtained his "wonderful American story" is not known.

Once again, the presence of such a 'cave' description in respected early books tempted a later compiler to accept it. In this case it was the Russian vice-consul in New York (Cramer 1837) who referred to the "cave in the Andes".

CONCLUSION

The information contained in *Die Ehre* ... about the four American caves described there has been traced back, in the preceding sections, to sources dating respectively from 1625, between 1612 and 1621, about 1513, and 1665. Two of these dates, the first and last, are those of printed books in which the information appears apparently for the first time. The other dates are of visits to the caves.

The earliest source of all, first printed in 1516, was written a little before that by Peter Martyr, the contemporary and friend of Christopher Columbus, and is probably the earliest description of any cave in America.

In all these cases, the facts appearing in *Die Ehre* ... have been traced through several intermediate publications. Comparison of phrases used in successive texts have shown the route by which Valvasor's book acquired its facts about these caves. Although there was scope for errors to be introduced by this repeated copying, it has been shown, by printing the earliest statements in full as well as those published in 1689, that no essential changes occurred.

Thus the information in *Die Ehre dess Herzogthums Crain* is no less correct than that in its ultimate sources, which in some cases were almost contemporary with the explorations described. The probably accuracy of the original information can only be assessed for each cave individually.

The account of the Lanquin cave in Guatemala is fully consistent with modern explorations and plans. The visit to the Mexican cave near Oaxaca rings true but can only be confirmed when the cave described is identified. The fearful water cave at Samaná Bay in Hispaniola has been identified with reasonable certainty from the lengthy description by Peter Martyr early in the 16th century; the alarm felt by those present has, not surprisingly, resulted in exaggeration. The enormous cave in the Andes reported by Kircher from a local tale he had heard was suspected by him of being dubious; shorn of such qualification in *Die Ehre* ..., it was liable to be accepted later as true, as indeed it was in 1837.

REFERENCES

Baraga, F.,1990: Erazem Francisci - redaktor Valvasorjeve Slave.- Valvasorjev zbornik ob 300 letnici izida Slave vojvodine Kranjske, Referati s simpozija v Ljubljani 1989, 112-142.

Bekkers, J. A. F. (ed.), 1970: Correspondence of John Morris with Johannes de Laet (1634-1649).- Assen, Van Gorcum (pp. xv-xvii, 172).

Brainerd, G. W., 1953: Archeological findings.- Pp. 109-119 in Hatt, R. T. et al. Faunal and archeological researches in Yucatan caves. Cranbrook

Institute of Science Bull. 33.

Brugmans, H., 1927: Dapper (Olfert).- Cols. 354-356 in Molhuysen, P. C. et al. (eds.). Nieuw Nederlandsch Biografisch Woordenboek, v. 7.

Brugmans, H., 1930: Laet, Johannes de.- Cols. 991-992 in Molhuysen, P. C. et al. (eds.). Nieuw Nederlandsch Biografisch Woordenboek, v. 8.

Chiappa, B., 1986: Santo Domingo '86.- Mondo Sotteraneo, ser. 3, v. 10 (1-2), 3-16 (p. 7).

Courbon, P. & Chabert, C. & Bosted, P. & Lindsley, K., 1989: Atlas of the great caves of the world.- St. Louis, Cave Books (p. 59).

Cramer, C., 1837: Etwas über die Natur Wunder in Nord America.- St. Petersburg, Ministerium des Innern (p. 22).

D (apper), O., 1673: Die unbekante Neue Welt oder Beschreibung des Welt-teils Amerika, und des Sud-Landes.- (trans. by J. C. Beers). Amsterdam. J. von Meurs.

Derham, W., 1713: Physico-theology: or, a demonstration of the being and attributes of God, from his works of creation.- London, W. Innys (p. 131).

Elaut, L., 1962: Johan de Laet (1593-1649), kommentator van Anselmus de Boodt, bant de geneeskunde uit de mineralogie.- Biologisch Jaarboek Dodonaea, Antwerp 30, 474-482.

Francisci, E., 1668: Ost- und West-Indischer wie auch Sinesischer Lust- und Stats-Garten ...- Nürnberg, J. A. Endter.

Giorgi de Pons, R., 1930: I grandi navigatori italiani.- Firenze, Nuovissima Enciclopedia Monografica Italiana.

Gould, R., 1968: (Mayan cave discoveries -) archeology.- Explorers Journal, New York 46 (3) Sept., 164-167 (p. 164).

Gurnee, R. H., 1962: The caves of Guatemala.- Bull. National Speleol. Soc. 24 (1), 25-30.

Halstead, B. W., 1965: Poisonous and venomous marine animals of the world.- Washington, U. S. Government Printing Office (v. 1, p. 31).

Hildebrand, (1985): Hildebrand's travel map (of) Hispaniola ...- (scale) 1:816,000. Germany, Karto+Grafik.

Hoefer, (J. C. F.), 1855: Nouvelle biographie générale ...- Paris, Firmin Didot, v. 13, cols. 74-75.

Kircher, A., 1665: Mundus subterraneus ...- Amsterdam, Jansson & Weyerstrat (v. 1, p. 120)

Kranjc, A., 1989: O krasu izven Kranjske v Valvasorjevem delu slava vojvodine Kranjske.- Acta Carsologica 18, 103-112.

Laet, J. de, 1625: Nieuvve Wereldt ofte beschryjvinghe van West-Indien ...- Leiden, I. Elzevier (pp. 164, 229)

Laet, J. de, 1633: Novvs Orbis seu descriptionis Indiae Occidentalis.- Leiden, Elzevir (pp. 261, 328)

Laet, J. de, 1640: L'histoire dv Nouveau Monde ou description des Indes

Occidentales.- Leiden. B. & A. Elseuier (pp. 175, 247)
Landa, D. de, 1941: Relación de las Cosas de Yucatan, trans. and ed. by A. M. Tozzer.- Papers of the Peabody Museum of American Archaeology and Ethnology, Harvard University, 18 (pp.187-188).
Lane, W. C. & Browne, N. E., 1906: Library of Congress A. L. A. portrait index and index to portraits contained in printed books and periodicals ...- Washington, Government Printing Office (p. 40).
Leon Pinelo, A. de, 1737-38: Epitome de la bibliotheca oriental, y occidental, nautica, y geografica.- Madrid, F. Martinez Abad, 3 vols (v. 3, col.1330).
Loudon, (J.), 1848: Facts from the world of nature ...- London, Grant & Griffith.
MacNutt, F. A., 1912: Introduction (and) Bibliography.- Pp. 1-54 in Martyr 1912, v. 1.
Martyr, P., 1516: De rebus oceanis et Orbe Novo decades tres ...Alcala, A. de Nebrija.- (Not seen; cited by MacNutt 1912: 49-50) and in the National Union Catalogue, v. 17, 1969, p. 14)
Martyr, P., 1530: De Orbe Nouo decades.- Compluti, M. d'Egina.
Martyr, P., 1555: The decades of the Newe Worlde or west India ...- Trans. by R. Eden. London, G. Powell.
Martyr, P., 1612: De Nouo Orbe, or the historie of the West Indies ... comprised in eight decades.- London, T. Adams. (Decades I -III are in the Eden translation of 1555, with the spelling updated; Dec. IV - VIII were translated by M. Lok).
Martyr, P., 1912: De Orbe Novo the eight decades of Peter Martyr D'Anghera.- Trans. with notes and introduction by F. A. MacNutt. New York, G. P. Putnam, 2 vols.
Montanus, A., 1671: De Nieuwe en onbekende Weereld: of beschryving van America en 't Zuid-land.- Amsterdam, J. Meurs (a Dutch version of Dapper 1673).
Morison, S. E., 1974: The European discovery of America - the southern voyages A. D. 1492-1616.- New York, Oxford University Press.
Muscio, G. & Sello, U., 1989: Speleological research in the Dominican Republic.- National Speleol. Soc. News 47 (10), Oct., 242-248.
O'Donoghue, F., 1914: Catalogue of engraved British portraits preserved in the Department of Prints and Drawings in the British Museum.- London (v. 4, p. 341).
Ogilby, J., 1670: America: being an accurate description of the New World ...- London, J. Ogilby (an English version of Dapper 1673) (Not seen; cited by Sabin 1880, pp. 304-305, who locates a copy at Harvard).
Ogilby, J., 1671: America: being the latest, and most accurate description of the Nevv Vvorld ... collected from most authentick authors ...- London, J. Ogilby.
Ovalle, A. de, 1646: Historica relacion del reyno de Chile ...- Roma, F.

Cauallo (pp. 17-24, 28-30).
Palmer, R. (J.), 1983: The Dominican Republic a brief study of caving potential.- Caves & Caving (21) Aug., 25-27.
Rosenmüller, (J. C.) & Tillesius, (W. G.), 1799: Beschreibung merkwürdiger Höhlen. Ein Beitrag zur physikalischen Geschichte der Erde.- Leipzig, Breitkopf & Härtel.
Sabin, J., 1873, 1880: A dictionary of books relating to America from its discovery to the present time.- New York, J. Sabin (v.5, p. 213; v. 12, pp. 303-305).
Savoia, F., 1986: La Cueva Fun Fun.- Mondo Sotteraneo, ser. 3, v. 10 (1-2), 57-64.
Schuller, R. R., (1907): Novvs Orbis - de A. Montanus o de Dapper?- Santiago de Chile, Bibliotheque Nacionale.
Schwabe, J. J., 1755: Allgemeine Historie der Reisen zu Wasser und zu Lande;oder Sammlung aller Reisebeschreibungen ... in Europa, Asia, Africa und America.- Leipzig, Arkstree & Merkus, v. 13 (pp. 693-694).
Schwalbe, B., 1887: Uebersichtliche Zusammenstellung litterarischer Notizen über Eishöhlen und Eislöcher nebst einigen Zusätzen.- Mitt. der Section für Höhlenkunde des Oesterreichischen Touristen-Club, 6 (2 & 3), 13-39 (p. 37).
Shaw, T. R., 1993: The history of cave studies in Trinidad, Jamaica, the Bahamas and some other Caribbean islands.- Acta Carsologica, 22, 11-76 (p. 15).
Shaw, T. R., 1994: The Bonewell spring (England) in Valvasor's "Die Ehre dess Herzogthums Crain" (1689) - the author's sources.- Acta Carsologica, 23, 360-367.
Smith, T., 1803-04: The wonders of nature and art ...- London, J. Walker, 12 vols.
Stoppa, A. L., 1992: Del nome e del volto.- Pp. 20-22 in L'Umanista Aronese Pietro Martire d'Anghiiera prima storico del "Nuovo Mondo", Atti del Convegno Arona 28 ottobre 1990. Novara, Interlinea (Studi Novaresi 9).
Stuart, G. E., 1981: Maya art treasures discovered in cave.- National Geographic 160 (2), Aug., 220-235.
Tye, A. & Jones, A., 1993: Birds and birdwatchers in West Africa, 1590-1712.- Archives of Natural History 20 (2), 213-227 (p. 216).
Ulloa, F. de, 1556: Navigatione per discoprire le Isole delle Specierie ...- P. 339-354 in Ramusio, G. B. Navigationi et viaggi, v. 3.
Ulloa, F. de, 1809: A relation of the discovery, which ... the fleete of ... F. Cortez ... made.- Pp. 473-505 in Hakluyt, R. Collection of the early voyages ..., v. 3.
Urbani, F., 1989: Cuevas venezolanas conocidas en los siglos XV al XVIII.- Bol. Hist. Geociencias en Venezuela, Caracas, 37, 1-78 (pp. 16-17).

Urbani, F., 1993: Vida y obra de los iniciadores de la espeleología en Venezuela.- Parte 5: siglos XV y XVI. Bol. Soc. Venezolana de Espeleología (27), Dec., 7-13.
Valvasor, J. W., 1689: Die Ehre dess Herzogthums Crain ...- Laybach and Nürnberg, W. M. Endter, 4 vols.
Vázquez de Espinosa, A., 1623: Tratado verdadero del viage y nauegacion deste ano de seiscientos y veinte y dos, que hizo la flota de Nueua Espana y Honduras ...- Malaga, I. Regne.
Vázquez de Espinosa, A., 1942: Compendium and description of the West Indies.- Trans. and with an introduction by C. U. Clark. Smithsonian Misc. Coll., v. 102.
Vázquez de Espinosa, A., 1948: Compendio y descripción de las Indias Occidentales.- Smithsonian Misc. Coll., v. 108.
Verheiden, J., 1603: Af-beeldingen van sommighe in Godts-Woort ervarene mannen ...- s'Gravenhaghe, Nieulandt (f. 108) (O'Donoghue, 1914, cites a Latin edn. of 1602).
Wagner, H. R., 1929: Spanish voyages to the northwest coast of America in the sixteenth century.- San Francisco, California Historical Society Special Publication 4 (pp. 15-50, 293-312).

ZGODNJE POZNAVANJE AMERIšKIH JAM (OD 1513 DALJE) O KATERIH POROČA VALVASOR V "DIE EHRE DEß HERZOGTHUMS CRAIN" (1689)

Povzetek

Tiste dele "Die Ehre deß Herzogthums Crain" (1689), ki dajejo širšo vsebino Valvasorjevim lastnim opisom Kranjske, kot npr. poročila o podobnih krajih v drugih deželah, je napisal Erazem Francisci. On sam se je moral opirati na objavljene ali neobjavljene informacije. Zaradi tega je v teh delih lahko prišlo do napak in glavni namen tega članka je izslediti vire, ki jih je imel na razpolago Francisci o ameriških jamah in oceniti njihovo verodostojnost. Pri tem pa je avtor odkril nekaj do sedaj slabo poznanih zgodnjih obiskov jam v Srednji Ameriki in na Karibih, v letih 1625, med 1612 - 1621 in okoli 1513.

Pri teh letnicah moramo seveda upoštevati, kdaj je Evropa odkrila ta ozemlja, kajti Kolumb je šele 1492 kot prvi zagledal neko deželo zahodne poloble. Do sedaj znani zgodnji opisi ameriških jam so iz 1548, 1556 in 1579, tako da je eden izmed opisov, o katerih je govora v tem prispevku, najstarejši opis neke ameriške jame, 35 let starejši od do sedaj najstarejšega. Valvasorjev sodelavec Francisci je bil ploden pisatelj, ki je že sam 1668 objavil knjigo o

Zahodni Indiji. V nekatereih primerih je uporabljal to delo neposredno za opise v Die Ehre ...,

v drugih primerih pa je to, o čemer je že pisal, spremenil ali pa tega sploh ni upošteval. To njegovo delo je kompilacija starejših virov, kot nastane npr. učbenik iz objav drugih avtorjev v znanstvenih revijah.

V Valvasorjevi Die Ehre ... je Francisci opisal jame iz Gvatemale, Mehike in z otoka Hispaniole. Ponavlja tudi trditev o gotovo izmišljeni jami v Andih.

Jama pri Verapazu v Gvatemali je Gruta Lanquin. Opis v Slavi se tesno naslanja na Dapper-jevo (1673) knjigo, ki pa vsebuje manj podatkov, kot Franciscijeva lastna, prej omenjena knjiga. Oba, Francisci in Dapper, sta črpala iz knjige Johannesa de Laet, prvič objavljene 1625.

Jame blizu Cuertlavace pri Oaxaci v Mehiki ni bilo mogoče določiti, saj je na tem področju mnogo jam. Jama ni omenjena v Franciscijevi prejšnji knjigi in besedilo iz 1689 je skoraj dobesedni prepis iz Dapperja (1673). Dapper je črpal iz Laeta (1625), ta pa je dobil podatke iz okoli deset let starejšega neobjavljenega rokopisa avtorja Vázquez de Espinosa.

Za jamo na Hispanioli je avtor določil jamo Cueva Infierno, iz katere teče reka v morje. Franciscijev opis iz 1668 je razmeroma dolg, vendar zelo različen od njegovega vključka v Slavi (1689). Njegovo besedilo iz 1668 je skoraj dobesedni prevod latinskega originala avtorja Petra Martyra (1516). Martyr je živel v Španiji in je dobro poznal Kolumba, Corteza in druge raziskovalce Novega Sveta. Novice o jami je dobil neposredno od Andreasa Moralesa, morjeplovca in zemljemerca, ki je sam raziskal jamo. Ob upoštevanju datumov potovanj španskih uradnikov na Karibe, omenjanih v besedilu, in ob upoštevanju deževne dobe, je mogoče zaključiti, da so jamo obiskali med majem in novembom 1513 - daleč najstarejši zapis obiska kakega Evropejca v ameriški jami.

Zgodba o ogromni jami v andskem gorovju je preko Franciscija (1668) prevzeta iz Kircherja (1665).

S tem, da so objavljene najstarejše omembe o vsaki izmed jam, ta članek potrjuje, da ni bistvenih razlik med njimi in med objavo iz 1689. Za vsako jamo je še posebej ocenjena zanesljivost izvirnega opisa.

Lanquinov opis jame v Gvatemali se popolnoma sklada s sodobnimi raziskavami in načrti. Obisk mehiške jame pri Oaxaci je videti resničen, vendar ga bo mogoče potrditi šele, ko bo jama identificirana. Vodna jama na Hispanioli je določena s precej zanesljivosti; vznemirjenost, ki so jo čutili obiskovalci, lahko pripišemo pretiravanju. Že Kircher je dvomil, če je opis jame v Andih resničen, vendar je v objavi iz 1689 njegov dvom izpuščen.

REPORTS

POROČILA

THE THIRD INTERNATIONAL KARSTOLOGICAL SCHOOL AT POSTOJNA

The Karst Research Institute ZRC SAZU together with the Speleological Association of Slovenia, organised the Third International Karstological School Classical Karst from June 27 to 30, 1995. The first such school was held two years earlier. The aim of these karstological schools is to discuss a selected topics related to karst, either karst forms and processes or human impact. Anthropogenic interventions influence the karst surface and indirectly the karst underground, in particular with respect to water quality. The presentations record previous knowledge about the selected topic and show the existing gaps to be solved in the future. We must be aware that human activities must adapt to the karst properties in order to ensure enough pure water for our children. At each Karstological School the spoken papers are complemented by extensive field work, visit to characteristic karst features, presentation of problems and work methodology; all this permits a better understanding of the problems and establishes contacts among the researchers of similar problems all over the world; it provides an exchange of experiences, methods and solutions.

The First International Karstological School was held in autumn 1993 at Lipica; it was followed by the second one between June 27 and July 1, 1994 at Postojna. The main topics were karst poljes, especially karst hydrology, the connection of man and karst, ecology and karst environment safeguarding. 44 participants from 6 countries have taken part and 24 papers were presented.

The Third International Karstological School took place at Postojna again, from June 27 to 30, 1995. It was dedicated to karst dolines. As in previous years the School was supported by the Slovene National Commission at UNESCO, the Ministry of Science and Technology, the Ministry of Environment and Physical Planning, the Ministry of Education and Sport, the Postojna Commune and Postojnska Jama.

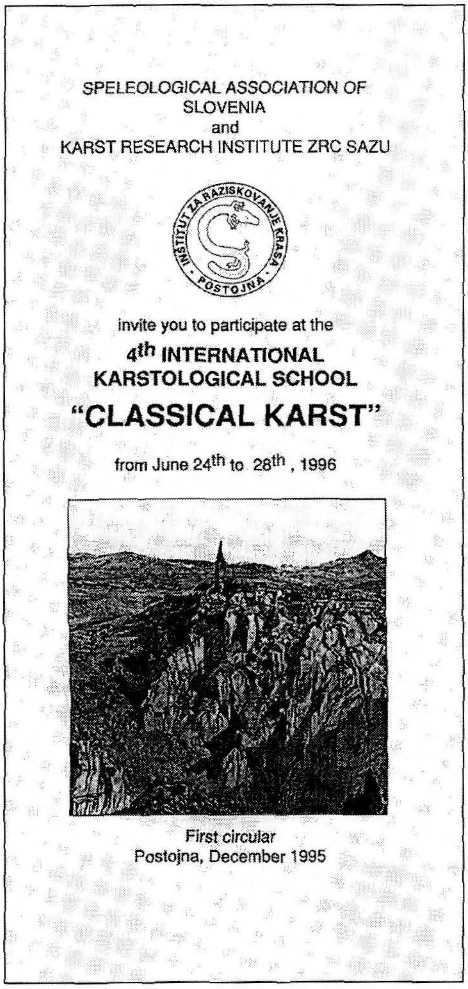
45 participants from 9 countries took part; 15 were from abroad. The range of participants was similar to that at previous Schools. Distinguished experts on karst were present, for example Academician Prof. I. Gams, Prof. Ugo Sauro, Prof. F. Šušteršič, Prof. J. Čar, Prof. J. Kunaver, Dr. P. Habič and others. Numerous researchers represented the results of their work, and a number of students and other persons interested were present, for example the representatives of the Urbanistic Institute and DARS, Sector of Technology and Development.

In the mornings 20 papers were presented, 13 of them dealing with dolines. Šušteršič spoke about classification of dolines with respect to their genesis; Moreno (Spain) reported on doline formation due to karstification in Spain; Čar reviewed the mapping of dolines in limestone; Kogovšek reported about rainfall percolation through dolines; Šušteršič reported about the development of collapse dolines; Šebela presented the dolines above the collapse chamber of Postojnska Jama; Mišič and Šušteršič reported on the clay sediments of some dolines of Notranjska, Zupan Hajna and Mihevc about the clastic sediments of dolines and caves on the new motorway near Divača. Sauro (Italy) presented some aspects of doline morphology; Tyc (Poland) spoke about collapse on paleokarst of Poland due to human impact; Kunaver presented snow dolines as a high-mountain version of dolines. The participants got a wide insight into the previous knowledge about dolines and at the same time it was made clear, which are the themes that must still be studied and researched in the future; such is the intention of karstological schools.

At field work on the first afternoon Šebela acquainted us with the dolines above Postojnska Jama, and Kogovšek with the results of the study of rainfall and waste water from the toilets of Pivka Jama campsite percolation through a doline above Pivka Jama and with the results of water tracing test from the same doline. For a demonstration, a water tracing test was carried out and the first results were read on the spot. Next day the field work extended to the Classical Karst and karst phenomena on the new motorway; the third day was dedicated to Hrušica and Trnovski Gozd where the results of achieved water tracings from a doline near Zavrhovec, 550 m above Hubelj resurgence were presented; Mala Lazna, Paradana and Smrekova Draga were also visited. The Karstological School ended on the fourth day by whole-day excursion to dolines of the Slovene Karst; we travelled from Postojna over Snežnik to Kočevska Reka and the Kolpa river.

During the excursions we sought a topic for the next Karstological School. It seems that logical continuation leads from dolines to shafts; so, next year we shall learn what is known and researched in this area.

Janja Kogovšek



SPELEOLOGICAL ASSOCIATION OF SLOVENIA
and
KARST RESEARCH INSTITUTE ZRC SAZU

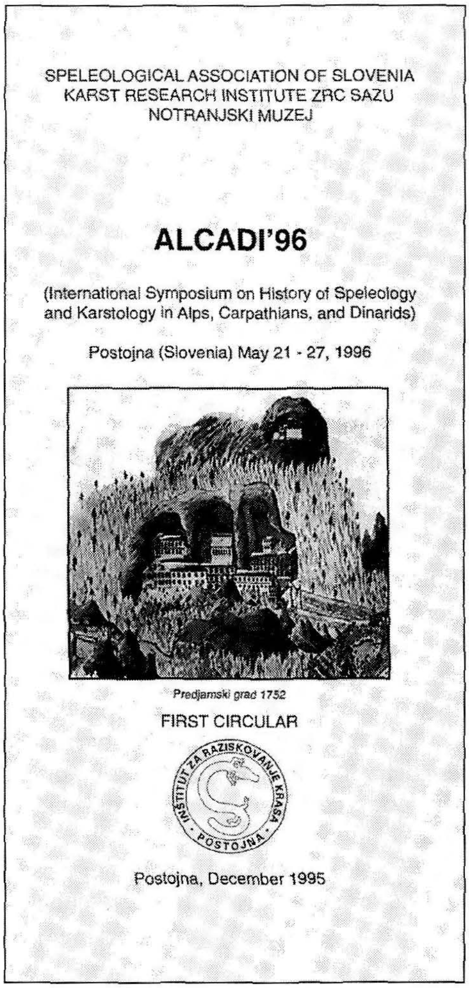
invite you to participate at the

4th INTERNATIONAL KARSTOLOGICAL SCHOOL

"CLASSICAL KARST"

from June 24th to 28th, 1996

First circular
Postojna, December 1995



SPELEOLOGICAL ASSOCIATION OF SLOVENIA
KARST RESEARCH INSTITUTE ZRC SAZU
NOTRANJSKI MUZEJ

ALCADI'96

(International Symposium on History of Speleology and Karstology in Alps, Carpathians, and Dinarids)

Postojna (Slovenia) May 21 - 27, 1996

Predjamski grad 1752

FIRST CIRCULAR

Postojna, December 1995

Every year the circulars invite to various events organized by the Karst Research Institute.

THE FIRST CROATIAN GEOLOGICAL CONGRESS (OPATIJA, CROATIA)

The First Croatian Geological Congress was held at Opatija between October 18 and 21, 1995. This congress was undoubtedly one of the more important parts of the celebration of both the 120th anniversary of geological studies at Zagreb University and the 85th anniversary of the Croatian Geological Society.

The Congress organizers wished to gather the highest possible number of scientists and experts in geology and associated fields from Croatia and abroad, at their first congress in the Republic of Croatia. They succeeded, as in the Adriatic Hotel, where the participants stayed, more than 250 people gathered. The Karst Research Institute ZRC SAZU, Postojna contributed two active representatives. Most of the participants came from Croatia; some from Albania, Bosnia and Hercegovina, Slovenia, Hungary, Austria, Germany and Poland.

Many well known geologists payed a part in creating this Congress, from M. Herak, to cite only one of the Honorary Committee, to D. Benček and M. Šparica, members of the Organizing Committee, and B. Biondić of the Scientific Committee.

The fact that geological scientific knowledge represents the foundation for the entire life system within a certain area was one of the main Congress's lines. Further on it was emphasised that, without detailed knowledge of geological relations, nature protection, water safeguarding, and mineral resources exploitation are practically impossible. This is why it was suggested to the participants that they demonstrate by their contributions the results of and the need for further development of the geological science.

The program of the Congress included invited lectures, lectures by the participants, and exhibition of posters. Four excursions were organized during the congress; also several exhibitions, and various meetings, and round tables. The Congress itself was divided into four sections:

1. stratigraphy, paleontology, sedimentology and tectonics;
2. mineralogy, petrology, geochemistry, and mineral resources;
3. hydrogeology, engineering geology, and informatics in geology;
4. geology of hydrocarbons, and geophysical researches.

The organizers arranged four excursions for the end of the Congress, all of them to Istria, from Rijeka in the east to Buzet in the north and Pula in the south.

A stratigraphic excursion, led by I. Velić and colleagues was in western Istria between Rovinj and Kanfanar. Participants visited the carbonate layers of shallow-sea platforms from Upper Dogger to Medium Cretaceous. Within this period span, geologists distinguish three mega-sequences separated by two distinctive emmersions (land phases).

The sedimentological excursion was organized by I. Tišljar and colleagues; it went to south-western Istria between Pazin, Rovinj and Banjole. The first part of the field visit was dedicated to cyclic shallow-sea carbonate sediments of Upper Titonian, Beriassian and Lower Aptian lagoon limestones and Albian trangressive carbonates. The second part of the visit took place on the rocks of Upper Albian and Lower Cenomanian.

A. Gabrić and colleagues presented in the next excursion the mineral resources of Istria. Stopping points were at the bauxite deposits, in the quarries of decorative stone and quarzite sands.

The hydrogeological, engineering-geological and speleological excursion was prepared by B. Biondić and many research associates. It took place between Rijeka and Pazin. Participants met the problems related to water supply of Rijeka, to land-slides and to the road-tunnel under Učka. The final part was at the well-known cave Pazinska jama.

Beside several co-organizers, the main organizers of the Congress were the Croatian Geological Society and the Institute of Geology from Zagreb; it was sponsored by the Ministry of Science and Technology of the Republic of Croatia.

The lectures, abstracts of papers and the texts to posters, as well as the guide-book for all four excursions, were already published in special volumes before the Congress. The publications are very well edited and well produced which, without doubt, contributed to a successful congress.

It was very pleasant to spend four days with the geologists of Croatia in an autumn Opatija and I support their wish that the Congress becomes traditional.

Martin Knez

THE REPORT ON THE FIFTH MULTIDISCIPLINARY CONFERENCE ON SINKHOLES AND THE ENGINEERING AND ENVIRONMENTAL IMPACTS OF KARST (GATLINBURG/TENNESSEE, 2-5 APRIL, 1995)

Between March 31 and April 17, 1995 I took part in the International Conference on Sinkholes and the Engineering and Environmental Impacts of Karst in USA. The main organizer of the meeting was B.F. Beck, sponsored by P.E. LaMoreaux & Associates, Inc. (P.E.L.A.).

This symposium was the fifth in a series which has been organized at intervals since 1984. The papers presented at the Conference were published at the same time. This year's publication is entitled Karst Geohazards (Beck 1995), 66 papers are presented in 581 pages. Like all the previous volumes, it was published by Dutch Publishing House A.A. Balkema.

The Conference was held in a tourist town Gatlinburg, south of Knoxville which was celebrating its 50th anniversary. This is a typical American tourist place with a large catering industry, and selling a lot of souvenirs. The town developed at the northern foot of the Great Smoky Mountains National Park.

The official opening of the Conference was on Sunday, April 2, 1995.

The first day excursion showed some examples of sudden sinkholes and water hazards near Knoxville. At first we stopped a little out of Pigeon Forge in the Vulcan Materials Quarry (Sevierville Quarry) of Lower Ordovician dolomites, and Middle Ordovician limestones. At the bottom of the quarry is a permanent lake caused by collapse and later filled by water. The water does not come from the nearby river Little Pigeon Forge but from other sources, including groundwater; this is proved by the differences in temperature, conductivity and other parameters. In two years the water level has not changed, so that this collapse must contain a spring to compensate for evaporation.

In Kodak Community we visited by bus sinkholes and collapse dolines that are typical of this country and which frequently present a hazard by sudden subsidence even close to houses.

Nearby the motorway at Knoxville we visited a sinkhole that opened above a cave.

We also visited Cherokee Cavern. Recently a caver has become involved and slowly he is making the pathways and he displays the cave to tourists. The cave is electrically illuminated and it was a show cave already in the past. It developed in Upper Cambrian Copper Ridge dolomite with layers of cherts along the fissures. Three levels may be distinguished in the cave. The passages are 230 m in length but, they suppose that they may be connected with other caves, 16 km away.

In September 1994, 6.829 caves were already registered in Tennessee; their average length is 222 m, 161 caves are longer than 1,6 km, and 25 caves are entered by a shaft of more than 100 m (Moore 1995).

West from Knoxville we stopped at Tuckaleechee Cove; this is a geological window where limestones (Cambrian - Ordovician) are exposed. These limestones are very karstified and there are a lot of caves in them (30 caves are known). The most famous are Tuckaleechee Caverns developed in Paleozoic limestones (Cambrian - Mississippian). The tourists may visit 800 m. The largest chamber is 30 x 48 m, and 20 m in height.

We also visited the outcrop of Pre-Ordovician shales (at Road 321 near Great Smoky Mountains) that are folded in smaller (about 2 m wide) synclines and anticlines. This is a nappe (about 300 m of overthrust) on younger Middle Ordovician limestones.

On Monday, April 3 the three days of Symposium papers started. The introductory lectures were given by the organizer, B.F. Beck and by P.E.L.A. director P. LaMoreaux. The first paper, Geotechnical Aspects of the Design and Construction of Dams and Pressure Tunnels in Soluble Rocks was presented by A.H. Merritt. Out of about 200 participants, a little more than 50 presented papers orally or by the 16 posters.

The morning lectures were related to the topic Karst Geology - Surficial Processes and Sinkholes and the afternoon ones to Karst Hydrology. It was a great honour for me to be co-chair of the afternoon lectures together with Dr. W.B. White. The lectures ended at 5 p.m.

On Tuesday, April 4 we continued with lectures. The morning topic was Karst Geohazard - Stormwater Drainage and Flooding Problems and Transport of Groundwater Contamination in a Karst Aquifer. After lunch the lectures related to the topic Foundation Considerations and Improvements in Karst, and Investigating Karst with Geophysics followed.

In the evening, about 7.30 p.m. a social meeting was guided by A.H. Merritt. The young Ernst H. Kass Kastning III got a silver medal for Boy Scouts in conservation. Then we looked at some cave slides commented on by A.H. Merritt.

On the last day of the Conference, Wednesday April 5, 1995 the lecture topics in the morning were Government Regulations for Karst Areas, Karst Geohazards - Groundwater Contamination Through Sinkholes and the Karst Surface, and in the afternoon Karst Geohazards - Case Studies on Engineering Sinkholes in Planning and Investigation for Engineering in Karst. In the last section I presented my paper The Problems of Constructions on Karst: the Examples from Slovenia with co-author Andrej Mihevc. It deals with karst phenomena discovered during the motorway construction over the Classical Karst in the years 1994 and 1995. The vertical shafts and horizontal caves discovered during the motorway preparation are an obstacle that needs reliable sanitation.

Only two papers from Europe were presented at the Conference, one from Belgium and ours from Slovenia. Our country received special attention and interest as the country of the Classical Karst. I met many American karstologists, as Dr. Quinlan, Dr. Beck, Dr. White and his wife Elisabeth, Dr. Mylroie. It was pleasant to see that they know Slovene karst as almost all of them have visited the more characteristic caves and terrains years ago.

The International Conference was attended by numerous representatives of American private firms dealing with hydrogeological and geophysical problems of karst terranes. By such a way they got acquainted with concrete solutions of the enginnering problems; some of them accomplished by sponsorship.

After the Conference I remained for another 10 days in the United States and, guided by people I had met, I visited karst regions and the most important caves of Tennessee, Kentucky (Stephen Capps, Chris Groves) and West Virginia (Roy Jameson).

My participation at the Conference was made possible by the Karst Research Institute ZRC SAZU, Ministry of Science and Technology of the Republic of Slovenia, and Open Society Fund. Without their help my active participation at this important Conference would not have been possible.

Stanka Šebela

REGIONAL CONFERENCE OF LATIN AMERICAN AND CARIBBEAN COUNTRIES; LATIN AMERICA IN THE WORLD: ENVIRONMENT, SOCIETY AND DEVELOPMENT (HABANA, CUBA, JULY 29 TO AUGUST 12, 1995)

In Habana (Cuba) a regional geographic conference of Latin American and Carribean countries has taken place between July 31 and August 5; I participated on behalf of the Karst Research Institute ZRC SAZU with the financial support of Ministry of Science and Technology RS.

The Conference has taken place in spacious and well-preserved, and well equipped congress center in Habana (Palacio de las Convenciones). The program included the plenary sessions, postconference field-work, symposium and free topics.

Among the the scientific issues let me enumerate the following: Natural processes and geodynamics, Space and region serving to people, Environment: problems and new alternatives (within this issue the topic for karstology appeared under the title PROBLEMATIC ENVIRONMENTS: KARST REGIONS, guided by Dr. Javier Rodrigez Rubio, Cuba), New methods and technologies, Geographical mind and education, Latin America: conflicts and directions.

The main topics of the "karstological issue" of the Conference were: Relations between Eastern and Central Cuba tropical karst, Hydrology and dynamics of karst proceses, Test karst terrain, Human impact on karst environment, Exploitation, use and safeguarding of karst regions and Methodology issued from the theoretical researches applied on karst.

The lectures went on the whole day, in the morning from 8 a.m. to noon and in the afternoon from 2 p.m. to 6 p.m. Apart from frantic introduction and fare-well parties of South American type, several facultative activities were organized. The Conference's official languages were English and French although great majority of participants were Spanish spoken.

As a co-author of Andrej Kranjc I presented the paper entitled Highways across Karst - Environmental Risk with Special Regard to World Natural Heritage. I tried to present and emphasise the problems of motorway constructions over the karst terrains and to stress the problem of the karst underground safeguarding in respect to UNESCO's World Heritage (Škocjanske jame).

The Conference was attended, according to estimation by more than 1000 people from 45 different countries and from almost all the continents. The president of the Organization Committee was well known Antonio Nunez Jimenez, the President of the Cuban IGU National Committee.

The Conference was organised by a joint cooperation of Cuban National

Committee of Geography, Academy of Sciences of Cuba, University, Habana, Pedagogical Institute "Enrique Jose Varona, Cuban Geographical Association and International Geographical Union (IGU).

Within the field work on the tropical karst we visited a karst doline, near capital Viñales, in the province Pinar del Rio, some 200 km W of Habana. The karstic landscape with famous carbonate mogotes in the middle of more or less flat country is supposed to be, besides China, Puerto Rico, and Vietnam, the unique in the world.

We visited not only the superficial karst features but also the longest Cuban cave Gran Caverna de Santo Tomas (45 km in length), and the cave Majaguas-Cantera Cavern System (37 km in length). On our return we visited some shorter show-caves (Great Cavern, Dos Anas) in the Ancon valley.

The participation in the Conference and the visit to tropical karst near Habana were, without doubt, extremely interesting, instructive, and advantageous. I formed connections with the colleagues (Cuban and others) dealing with the karst researches, on behalf of the Karst Research Institute ZRC SAZU and on my own behalf; consequently I think that the voyage to Cuba achieved its purpose.

Martin Knez

IN MEMORIAM
MARJORIE M. SWEETING (1920-1994)

The karstologists of all over the world were struck by news that on the New Years Eve 1994, died of severe illness one of the greatest modern karstological personalities, Reader in Geography at the University of Oxford, Dr. Marjorie M. Sweeting. The Slovene karstologists remember her sympathy with the Slovene and Dinaric karst, reflected in her basic works on karst, in her frequent visits to Slovenia and in her help to educate the researchers from the Dinaric karst. The beginning of her interest into Slovene and nearby Dinaric karst go back to the period soon after the War. From Diary of Pavel Kunaver we learn that she visited Slovenia in 1951 for ten days and they together visited all the tourist and karst places of importance in Slovenia; from Bohinj and Savica, over Bled to Cerknica Lake, Rakov Škocjan, Planinsko Polje with Vranja Jama, to Postojnska jama, Predjama, Škocjanske jame and the whole Istria. Even better she got acquainted with the Slovene and the rest of Dinaric karst during the Fourth International Congress of Speleology in 1965; she took part in the Pre-Congress excursion to high-mountainous karst of Triglav and into Valley of Seven Lakes and in the Post-Congress excursion along the Adriatic Coast. Also later she visited Slovenia to take part at various meetings (1978, Symposium on Intensity of Karstification; 1987, Human Impact on Karst); in the latter case the Geographical Association of Slovenia awarded her a special decoration in recognition of her merits at invigorating the professional contacts between the British and Slovene geography and karstology (the meeting of Executive Committee of the Geographical Association of Slovenia, September 17, 1987). In her major work Karst Landforms (1972) a deep impression left by her stay in Slovenia and in the rest of Dinaric karst may be felt. Several times she guided the Oxford students of geography at karstological field trips through our places.

Dr. Marjorie Sweeting, born in 28 February, 1920 in a family of pianist and university professor of geology, got the knowledge and interest for natural sciences since her birth. From her mother she inherited the love for music, opera in particular, but she never realized her wish to visit the Opera House in Bayreuth. Her career started by studies at Cambridge where she obtained a First Class and in 1948 she was awarded the doctorate for her thesis on "The Landforms of the Carboniferous Limestone of the Ingleborough District, N.W. Yorshire." Because of her thesis this landscape became famous as one of the typical karst areas in the world. In 1951 Marjorie Sweeting began missionary work in Oxford and was appointed Lecturer and Director of Studies in Geography at St. Hugh's College. This is a college with which she has been associated ever since, occupying many posts including Dean and Senior Tutor and in 1977 she was awarded the distinction of being given a personal readership, from where she retired in 1987. During this time she was even appointed Acting Head of the School, which under English, in particular Oxford circumstances hardly ever happens to a lady. She lived 33 years in Oxford. A major feature of her career is the influence that she has exercised on generations of British karstologists and geographers, later leading karst geomorphologists in various parts of the world. Her name is respected in all Anglo-American geographical, and in particular geomorphological circles and not the less elsewhere in the world.

It would be interesting to know why she decided to study karst in Great Britain; however, one may suppose that in her youth she started with geomorphologically less known and thus for basic studies more convenient area. The caves in Yorkshire karst were known previously, in particular was famous Gaping Ghyll, but before Marjorie Sweeting started her researches the area was the domain of geologists mostly. M. Sweeting researched the micro-morphology of the karst surface and related superficial morphology and underground cave levels. Her speleological knowledge was of great help. The Karst of Yorkshire and its successful presentation was a spring-board for wider world that offered to the young English lady, after tradition, numerous opportunities for voyage and research. At first she visited the karst in Malaysia, followed by Jamaica and Fitz-Roy Mt., Australia. Inbetween she travelled a lot over Europe and systematically recognized the most important karst areas. After she educated a series of karstologists she, in her mature age, set out on longer voyages to some important karst regions. In the seventies and eighties she almost exclusively published researches in Sarawak and south China karst. Thus she contributed an important share to international treasury of knowledge of various global karst types and regions, in particular tropical karst of Southern China and the Guilin province became her promised land to which she dedicated her book about the China Karst.

All of us, that today with respect and gratitude remember Prof. Sweeting, know her rich work within the sphere of karst denudation to which she consacrated a great part of her research efforts. She was one of the initiators of dynamical approach to karst development and thus the first who theoretically discussed the corrosion intensity in karst and its measurements. She headed the commission on Karst Denudation of the International Speleological Union. Very important is her study of limestone petrology impact on karst processes and morphology.

Marjorie Sweeting took part at numerous international karstological and speleological meetings, she was appointed as a visiting professor at numerous American, Australian, South African and Chinese Universities and everywhere she was the central figure in the exchange of karst knowledge. She received national and international honours, she was "persona grata" in France where she was in particular respected due to her ability for international scientific communications regardless the differences in language or method.

By the departure of Miss Sweeting probably ends an important period of karstology development in the second half of this century where she left deep traces. Many of us have the privilege to profit from her profound knowledge and her commitment to international fieldwork, collaboration and exchange of ideas. She was always willing to share all her knowledge and cognition. All her life Miss Sweeting lived for her students and for karst and such life was worth living. And therefore all of us that have the privilege to meet the deceased remember her as a gentle and kind person who knew how to give to the students and how to extract the misteries of karst.

Jurij Kunaver

12th INTERNATIONAL CONGRESS OF SPELEOLOGY 1997 • UIS

LA CHAUX-DE-FONDS SWITZERLAND

1st CALL FOR PARTICIPATION

12th International Congress of Speleology and "6e Colloque d'hydrologie en pays calcaire et en milieu fissuré"

(6th Conference on Limestone Hydrology and Fissured Aquifers).

La Chaux-de-Fonds (Neuchâtel, Switzerland)

August 10 – 17, 1997

Organization

- Swiss Speleological Society
- Swiss Academy of Sciences, Speleology Commission
- Center of Hydrogeology, University of Neuchâtel, Switzerland
- Geology laboratory, University of Franche-Comté, Besançon, France
- Prehistory Seminar, University of Neuchâtel
- The Town of La Chaux-de-Fonds

Which Congress ?

The 12th International Congress of Speleology will take place in La Chaux-de-Fonds (canton of Neuchâtel, Switzerland), heartland of the watchmaking industry, a town of 40,000 inhabitants located in the karst of the Jura *mountains.*

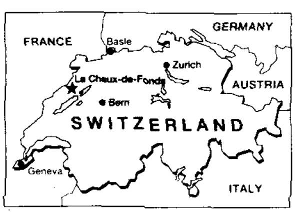
■ *The main guidelines in the preparation of this* congress are:

- to bring together cave explorers and scientists.
- to organize a regional attraction for the general public.
- to do everything possible to turn the International *Congress back into the four yearly speleological get* together event it should *be.*

The congress itself, the associated general meetings, and UIS commissions, will be held in the city college building or within 2 miles of that central location. Most of the lodging and camping will also be located in that area. *Access by train, road or even by special flights from Geneva* or Zurich airport will be arranged depending on the needs.

Scientific Program

The congress backbone will consist of a rich program covering all the aspects of speleology and karst study. Every one is called to present his / her discoveries in caves, carst, or other related fields of study in form of an oral or a poster presentation. Workshops and public round tables will be organized to allow everyone to share his / her experiences. Oral presentations, posters, workshops and round tables will be grouped in sessions for which themes will be defined in order to facilitate discussions and exchanges. Some of the themes defined in the various fields linked to speleology can already be named: in the geomorphology session: "Karstic Fill and Paleoclimates", "Speleogenesis *of the Large Alpine Systems"; in the exploration speleology* session, "Exploration in Tropical Areas", "Alpine Speleology"; in the topography and techniques session: "Underground Topography: What's new ?", "Cave Diving Techniques"; in the archeology session: "Man and Caves: 200,000 years of Dialogue", etc. ... The biospeology session will emphasize bat studies.



All the "Hydrogeology" part of the Congress will be integrated into the traditional "6e Colloque d'Hydrologie en pays calcaire et en milieu fissuré" organized for the 6th time by the Universities of Neuchâtel and Besançon. A couple of themes have already been defined: "Hydrogeological Behavior of Karst Aquifers" and "Use of Speleological Observations and Measurements to the Karstic Hydrogeology".

A more regional symposia will treat, through conferences, expositions and excursions, the various aspects of the karst and speleology in the Jura mountain, the area in which the Congress will take place.

Excursions and Camps

One day dedicated to field trips will be included in the Congress in order to allow the participants to leave the conference rooms.

Before the Congress (from July 27) and after (until August 30) scientific excursions and camps will be organized in Switzerland and across the border: Sieben Hengste, *Hölloch, Jean-Bernard, Parmelan, Dent de Crolles,* Franche-Comté, Slovenian Karst and many other systems and well known regions will be waiting for you...

During the Congress, tired participants and companions will have the opportunity to take underground breaks during the day (or the night).

Attractions

- ■ *Opening gala and closing banquet for everyone.*
- ■ Multi-media festival August 7 - 9 as an introduction to the congress.
- ■ Howdy party in a pure Swiss style (food and attractions) for everyone to get to know other cavers.
- ■ Diverse program for participants and companions featuring touristic excursions, competitions and exhibitions, meeting places with live music, etc.
- ■ In addition to the usual gear and book selling booths on the congress site, specific exhibitions will be featured throughout the town:
  - Speleology and biospeology at the Natural History Museum;
  - Cave paintings and engravings at the Museum of Fine Arts;
  - Cave books and documents at the Documentation Center of the U.I.S-S.S.S located in the town's library.
- ■ *Pass to the regional museums: The International* Clockwork Museum in La Chaux-de-Fonds, Archeology and Ethnography Museum in Neuchâtel, Underground Water Mills in Le Locle.

Food, Lodging and Transportation

- Lodging is planned to accommodate all participants (approximate fees per person and per night in Swiss Francs): Camping, dormitory (10 to 25), Guest room (25 to 50), hotel room (single 60 to 140, double 40 to 110).
- *Food service is planned for the lunches at the congress* site for 7 to 10 SFR. Other meal arrangements will be available in the 89 restaurants in town. It will also be possible to cook (barbecue) your own meals at the campground.
- A pass to the town's public transportation services will be available during the Congress.
- A children's day care service is also planned.

Registration

The registration fees for participants will be about 120 SFR.

- *Prices for the extras will be announced in the second* call for the Congress.
- Only those who will have returned the pre-registration form below, will receive the second call brochure *in early 1996, which will allow their firm booking.*
- Congress address: SubLime, P.O. Box 4093, CH-2304 La Chaux-de-Fonds, Switzerland
- Pre-registration is possible through the Internet to: http://www.unine.ch/UIS97/
- E-mail: congress.uis97@chyn.unine.ch

Calendar

- Pre-registration as soon as possible in order to receive the second call for participation with the congress program (by returning the form below)
- Second call brochure for the Congress with complete information and firm registration form will be available March 1996
- Deadline for abstracts of the announced presentations: June 30, 1996.

Pre-Registration form to return as soon as possible to:
SubLime, P.O. Box 4093,
CH-2304 La Chaux-de-Fonds, Switzerland

LAST NAME: ____________

First name: ____________

Address: ____________

Speleological Affiliation: ____________

Institution: ____________

I intend to submit a presentation: ❑ YES ❑ NO

Theme: ____________

Other contributions (slide show, film, exhibition, etc.): ____________

Personal suggestions: ____________

7th INTERNATIONAL SYMPOSIUM ON WATER TRACING

(7th SWT)
Portorož - Portorose
May 26-31, 1997
SLOVENIA

FIRST CIRCULAR

Organized by
International Association of Tracer Hydrology (ATH)
and
Karst Research Institute ZRC SAZU, Postojna

INSTITUT ZA RAZISKOVANJE KRASA • POSTOJNA •