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KRASOSLOVNI ZBORNIK
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ACTA CARSOLOGICA

KRASOSLOVNI ZBORNIK

XXIII
1994

PROCEEDINGS
OF
1ST INTERNATIONAL KARSTOLOGICAL SCHOOL
"CLASSICAL KARST"
Lipica, September 20 - 23, 1993

AND

LA TABLE RONDE INTERNATIONALE
"E. A. MARTEL ET LE KARST SLOVENE (1893-1993)"
Postojna, 12 - 13 Novembre, 1993

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1994

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ČLANKI
PAPERS

PREDGOVOR

V letu 1993 je Inštitut za raziskovanje krasa ZRC SAZU priredil troje pomembnejših mednarodnih strokovnih srečanj: na pobudo Slovenske nacionalne komisije za UNESCO 1. Mednarodno krasoslovno šolo "Klasični kras" septembra v Lipici, konec istega meseca mednarodni simpozij, posvečen 70-letnici akademika I. Gamsa, "Man on karst" v Postojni, novembra pa mednarodno okroglo mizo "E A. Martel et le karst Slovène". Prvotno smo načrtovali objaviti gradivo vseh treh srečanj v XXIII. številki Acta carsologica. Ker pa se je nabralo precej več gradiva, kot smo pričakovali, posebej še več tehtnih prispevkov o slovenskem krasu in krasoslovju izven programa teh srečanj, smo morali gradivo razdeliti na dva dela.

Tako je v pričujoči številki objavljeno gradivo 1. Mednarodne krasoslovne šole "Klasični kras" in mednarodne okrogle mize "E A. Martel et le karst Slovène" ter seveda članki, ki jih je uredništvo sprejelo v objavo izven teh prireditev. Precej prispevkov, ki so bili predstavljeni na omenjenih mednarodnih srečanjih, povsem ne ustreza kriterijem za "izvirne znanstvene razprave", kar pa je seveda razumljivo, saj so kriteriji in omejitve, predvsem prostorska oziroma časovna omejitev, za take prispevke drugačni. To pa ne pomeni, da bi bili zato manj vredni ali manj strokovni. Gradivo simpozija "Man on karst" pa bo objavljeno v naslednji, XXIV. številki Acta carsologica.

Posebej bi želel opozoriti na prispevke o slovenskem krasu, ki so jih napisali avtorji, ki niso člani Inštituta za raziskovanje krasa, bodisi da gre za upokojenega univerzitetnega profesorja, za raziskovalca z univerzitetnega inštituta ali za Angleža, v vsakem primeru to potrjuje, da Acta carsologica ni le inštitutsko glasilo in upam, da bo revija še dalje uspešno težila v smeri proti resnični "osrednji krasoslovni reviji".

Urednik

INTRODUCTION

In 1993 the Karst Research Institute ZRC SAZU has organized three important international professional meetings: by the initiative of the Slovenian National Commission for UNESCO the First International Karstological School "Classical Karst" in September at Lipica, at the end of the same month the international symposium, dedicated to the 70th anniversary of the academician I. Gams "Man on Karst" at Postojna, in November the international round-table "E.A. Martel et le Karst Slovène". At first we planned to publish the material of all the three meetings in the 23rd volume of Acta carsologica but there was much more material than we expected, in particular much more substantial contributions regarding the slovene karst and karstology and thus we were forced to divide the material into two parts.

In the present volume we publish the papers presented at the First International Karstological School "Classical Karst" and at the international round-table "E.A. Martel et le Karst Slovène" and the articles, received by the editorial board to be published out of these two meetings. There are several papers, presented at the above mentioned international meetings, that do not correspond entirely to the criteria of "the original scientific treatise" but it is self-understanding as the criteria and the limitations, in particular the time limitation, adopted for such papers are entirely different. But it does not diminish their value and it does not mean that they are less professional. The material concerning the symposium "Man on Karst" will be published in the next, 24th volume of Acta carsologica.

In particular I should like to draw your attention to the communications about the slovene karst written by the authors who are not the members of the Karst Research Institute, f.e. retired professor of the University, researcher of the University Institute or an Englisman, all confirming, that Acta carsologica is not the Institute's internal bulletin but that this publication is successfully aimed towards virtual "central karstological review".

The Editor

PAPERS PRESENTED AT
1ST INTERNATIONAL KARSTOLOGICAL SCHOOL
"CLASSICAL KARST",
LIPICA, SEPTEMBER 20TH - 23RD 1993

PRISPEVKI PREDSTAVLJENI NA
1. MEDNARODNI KRASOSLOVNI ŠOLI
"KLASIČNI KRAS",
LIPICA, 20. - 23. SEPTEMBRA 1993

UNESCO BIOSPHERE RESERVE: NOTRANJSKI KRAS AS A STRATEGY FOR CONSERVATION AND DEVELOPMENT

UNESCO BIOSFERNO OBMOČJE: NOTRANJSKI KRAS KOT STRATEGIJA ZA SOČASNO VARSTVO IN RAZVOJ

BRANKA BERCE-BRATKO

Izvleček UDK 504.7(497.12-13)

Branka Berce-Bratko: UNESCO biosferno območje: Notranjski kras kot strategija za sočasno varstvo in razvoj

UNESCO MAB Biosferno območje Notranjski Kras predlagamo kot strategijo, ki sočasno omogoča varstvo in razvoj območja. Osrednji del je Notranjski park, ki sodi v kategorijo regionalnih parkov. Le ta predstavlja osrednjo in varovalno cono MAB - Biosfernega območja, prehodno cono MAB območja pa ozemlje vseh štiri občin: Logatec, Postojna, Cerknica in Ilirska Bistrica. Poleg prednosti in slabosti UNESCO kategorije "Biosferno območje" je predstavljen tudi eko-turizem kot oblika primernega razvoja ter možne oblike upravljanja Notranjskega parka glede na dejstvo, da je pretežna večina zemljišč v zasebni lasti.

Ključne besede: Biosferno območje, človek in kras, varstvo, razvoj, trajnostni-sonaravni razvoj, biološka raznovrstnost, kulturna raznovrstnost, sprejemljivost oz. obremenitvena zmogljivost, sonaravni turizem, eco-turizem, upravljanje, sistemi upravljanja, ureditveni in upravljalski plani.

Abstract UDC 504.7(497.12-13)

Branka Berce-Bratko: UNESCO Biosphere Reserve: Notranjski kras as a Strategy for Conservation and Development

UNESCO-MAB Biosphere Reserve is proposed as contemporaneous conservation and development strategy based on Notranjski Park in a category of Regional park. The Core and Buffer zones of the MAB Reserve are within the Park's terrioty, and the Transitional zone is within the boundary of the four Municipalities: Logatec, Postojna, Cerknica and Ilirska Bistrica. Beside advantages and deficiencies of the MAB Reserve eco-tourism is discussed as one of the suitable development strategies and different management plans for the Notranjski park are discussed in a view of predominantly private ownership of the land.

Key words: Biosphere reserve, man and Karst, conservation, development, sustainable development, biodiversity, cultural diversity, carrying capacity, sustainable tourism, eco-tourism, management plans, system plans.

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INTRODUCTION

The group Notranjski Park in AREA Cerknica has achieved to propose the area of the four Municipalities: Logatec, Postojna, Cerknica and Ilirska Bistrica to UNESCO as Man and Biosphere Reserve (MAB-Reserve) called Notranjski kras. The idea was to establish Notranjski Park as first international recognition as MAB Reserve and the strategy was devised to achieve it.

For cooperation with inhabitants, employees of AREA and local politicians, including promotion of the eco-tourism Liliana Mahne was responsible, for legal status of the park Matjaž Mlinar and the theoretical part and international connections were the responsibility of Branka Berce-Bratko. This paper is a joint venture of the group which collaborated in research project: Man and Karst. In this paper strategies of UNESCO for MAB reserves will be discussed in perspective of the regional park of Notranjski park, eco-tourism and management strategies for the Park in a view of participation in management as the majority of the land is owned privately.

WHAT IS UNESCO MAB RESERVE

The MAB Programme is a nationally based, international programme of research, training, demonstration and information diffusion aimed at providing the scientific basis and the trained personnel needed to deal with problems relative to rational utilisation and conservation of resources and resource systems and, to human settlements.

The MAB Programme emphasizes research for solving problems: it thus involves research by multi-disciplinary teams on the interactions between ecological and social systems; field training; and the application of a systems approach to understanding the relationships between the natural and human components of development and environmental management (Practical Guide to MAB, 1987).

MAIN CONCERNS OF MAB

There were three main concerns present in the biosphere reserve concept from the beginning, and these are:

1. the need to reinforce the conservation of genetic resources and ecosystems and the maintenance of biological diversity (conservation concern);
2. the need to set up a well-identified international network of areas directly related to MAB field research and monitoring activities, including the accompanying training and information exchange (logistic concern);
3. the need to associate concretely environmental protection and land resources development as a governing principle for research and education activities of the MAB programme (development concern).

It is the combination - and harmonization - of these three concerns which characterize the Biosphere Reserve.

SPATIAL DISTRIBUTION OF MAB

The biosphere reserve should normally consist of the three following types of areas:

1. Core area or areas

Each biosphere reserve includes one or several core areas which are strictly protected according to well defined conservation objectives and consist of typical samples of natural or minimally disturbed ecosystems. Collectively these core areas should be large enough to be effective as in situ conservation units and, whenever possible, have value as benchmarks for measurements of long term changes in the ecosystems they represent and in the biosphere. The size and the shape of the core area(s) depend on the type of landscape or aquatic environment in which they are located and on the conservation objectives they are intended to meet. They can obviously be much larger in regions of low human population density than in regions with heavier human pressure and less available land. Core areas are usually delineated, but may remain undelineated in certain cases within a delineated buffer zone.

2. Buffer zone

The core areas are normally surrounded by a buffer zone which must be strictly delineated and very often corresponds, together with the core areas, to a single and autonomous administrative unit (e.g: national park). This buffer zone must have a clearly established legal or administrative status even when several administrative authorities are involved in its management. Only activities compatible with the protection of the core areas may take place. This includes, in particular, research, environmental education and training, as well as tourism and recreation or other uses carried out in accordance with the management requirements. Besides its other functions, the buffer zone often serves to protect areas of land that could be used to meet future needs for experimental research.

3. Transition area

The core area(s) and the buffer zone are surrounded by a transition area which promotes several characteristic functions of the biosphere reserve, particularly its development function. It may include experimental research areas, traditional use areas or rehabilitation areas. Usually, the transition area as a whole is not strictly delineated and corresponds more to biogeographic than to administrative limits. It normally extends the above- mentioned areas into a larger and open area where efforts are made to develop cooperative activities between researchers, managers and the local population, with a view to ensuring appropriate planning and sustainable resource development in the region while maintaining the greatest possible harmony with the purposes of the biosphere reserve. The management of the transition area is usually the responsibility of a variety of authorities and therefore requires appropriate coordination arrangements.

MAB networks

MAB supports international cooperation in research through its international networks where the sharing of information and resources is mutually beneficial to the cooperating countries. These networks are all informally constituted and there is no "official" MAB elaboration procedure. They differ greatly in character and in objective, as well as in their regional or international extent and degree of development. Some are based on geographical proximity, such as the countries of the southern cone of South America, and others on common linguistic or socio- cultural background, such as Francophone African countries. Wider in scope are the MAB Pilot Project Networks and the Biosphere Reserve Network, where common research frameworks and well- developed scientific exchange are encouraged.

MAB Networks, whether regional or international are linked through:

- voluntary cooperation;
- information exchange;
- exchange of scientists and researchers through consultant missions, study tours, field visits, training courses, etc.;
- joint meetings, seminars, workshops.

In addition, some Networks are linked through:

- comparability of research design and data collection;
- joint training programmes;
- formal information systems;
- network newsletters.

PROPOSAL FOR BIOSPHERE RESERVE: NOTRANJSKI KRAS

The proposed area is a part of karst area placed in Slovenia, a newly established European state. The boundary of this area is formed by four local communities: Logatec, Cerknica, Postojna and Ilirska Bistrica.

Biosphere area:	1672 km^2
Number of inhabitants:	59904
Number of settlements:	279
Number of Local Communities	52
Number of Municipalities	4

The proposed conservation area or core zones are protected areas which are a part of proposed Regional park - Notranjski Park. The Buffer zone is estimated on 570 km^2. To this area additional 200 or 400 km^2, might be added as a part of scenic areas of karst geology in Slovenia serving as buffer and transitional zones. The natural landscape area is designated as Nature reserves with exceptional values according to IUCN categorisation:

a) IUCN Category I:	2 000 ha
b) IUCN Category III:	14 000 ha
c) IUCNCategoryIV and V:	41 000 ha

These are:
a) Parts of Snežnik massif and some caves,
b) Snežnik and Javornik massif, and some periodical lakes (2), parts of Cerknica lake (3) and karst caves (10),
c) various unique habitats: proteus, brown bear, lynx, wolf, different endemic birds, and Protected Cultural Landscapes.

These areas of karst geology are of outstanding value in terms of world's natural heritage as:
- karst eco-systems,
- preserved biological resources in terms of genetic resources, and caves as heritage of karst geomorphology,
- preserved traditional ways of farming, land use and landscape management,
- drinking water resource reserve,
- scientifically very important area for the research of cohabitation between natural systems and man's impacts on karst nature.

The Cerkniško polje (Cerkniško plain) and its intermittent lake are proposed as Natural Heritage to be declared by Regional Government and is proposed to RAMSAR international convention. Cerknica lake is the the first drying up karst lake to be explored, and Valvasor became a Member of Royal Society in 1664 because of his description of that lake. Cerkniško jezero is internationally recognised as IBA, there are breeding about 90 species of birds. In IUCN Red List of Threatened Animals are 9 species of birds in category (E), 19 are in category V, and 6 are in category R (Gregory, Matvejev 1992).

The karst area is particularly valuable for the biological diversity of its underground habitat, with 30 endemic species in Notranjski Karst recorded in the IUCN Red List of Threatened Animals. Significant is the karst system of river Ljubljanica with unique karst fields (polje), sink wholes and caves (e.g. Križna, Postojnska and Planinska jama) on the North West border of Dinaric mountains. On pure limestone area the river has found her underground way, but on impermeable areas is still running on the surface, and always with different name. It sinks eight times, and so the same river has 7 different names. there are some smaller periodical lakes like, collapsed dolina Rakov Škocjan. The only tectonically undisturbed transact through Mesozoic of South Eastern Europe from Borovnica to Kališe, the system of river Ljubljanica has the biggest known number of hypogean Taxons in the world. Many of them are endemic, even narrow endemic.

The area has also the largest uninterrupted, natural and intact woodland area on the border between Dinaric and Alpine mountain chain. It is also known as Western most habitat of the brown bear in Europe with wolfs and lynx.

The area is also a European foot-path between Baltic and Adriatic sea, and a nature reserve for endangered species of birds and plants. Visually the area changes every day, when the water is at its peak it is the greatest karst lake surface with the biggest island in Slovenia. The area offers a great landscape variety within a small area.

Beside the core zones as strictly protected areas, there are cluster buffer zones as a part of protection policies concerning UNESCO -World Natural Heritage - Škocjanske jame. The Notranjska river is a wider buffer zone to Škocjanske caves. The smaller part of the South West buffer zone is a part of future Kras Regional Park and is proposed on behalf of local inhabitants. The area proposed to MAB as Notranjski Karst is a part of the Kras Region in Slovenia. Long term we expect this area to be proposed as an extension of the proposed MAB Reserve. The proposal for an extension is viable after local people agree to it, like in the case of Notranjski Karst.

The decision to make the border of the proposed MAB reserve was the convinience of four Municipalities which agreed to nomination of this area to UNESCO.

Figure No.1. is showing the MAB area with zonation, Park area and neighbouring protected landcsapes (Fig.1).

In Notranjski Kras efforts are made to preserve the regional spatial, social and cultural identity. In that context originality and independence of inhabitants are their advantage, and the awareness of landscape values, such as:

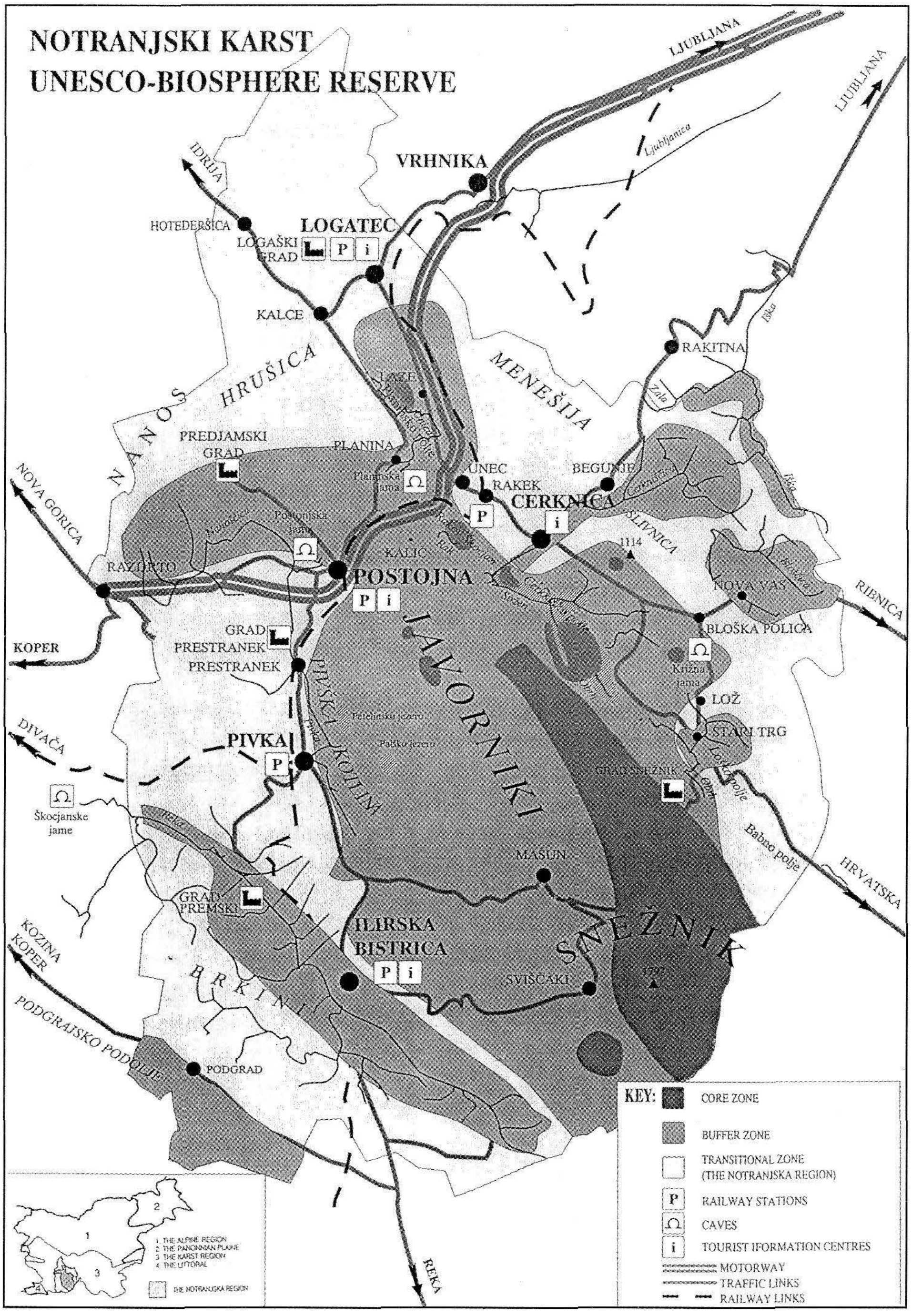
-identity of cultural landscape, natural and cultural heritage
-variety enabling choice, and the choice means freedom
-comprehension that man is an integral part of nature
-ecological value of drinking water and conservation value.

PROPOSAL FOR REGIONAL PARK: NOTRANJSKI PARK

The buffer zone of the MAB Reserve is Notranjski Park shown on Figure No.1.

Regional park is defined according to International Union for Conservation of Nature and Nature Resources- IUCN (1975) as:

a relatively large area where one or several ecosystems are not materially altered by human exploatation and occupation, where plant anbd animal species, geomorphological


NOTRANJSKI KARST
UNESCO-BIOSPHERE RESERVE
LJUBLJANA
LJUBLJANA
IDRIJA
VRHNIKA
Ljubljanica
HOTEDERŠICA
LOGATEC
LOGAŠKI GRAD
KALCE
RAKITNA
MENEŠIJA
NANOS
HRUŠICA
PREDJAMSKI GRAD
PLANINA
LAZE
Planinsko polje
Planinska jama
UNEC
RAKEK
BEGUNJE
CERKNICA
SLIVNICA
1114
NOVA GORICA
Postojnska jama
RAZDRTO
KALIČ
Rak
POSTOJNA
Cerkniško polje
Stržen
NOVA VAS
RIBNICA
BLOŠKA POLICA
KOPER
GRAD PRESTRANEK
PRESTRANEK
JAVORNIKI
Križna jama
LOŽ
STARI TRG
DIVAČA
PIVKA
PIVŠKA KOTLINA
Petelinsko jezero
Palško jezero
GRAD SNEŽNIK
Loško polje
Škocjanske jame
Reka
Babno polje
HRVATSKA
MAŠUN
GRAD PREMSKI
ILIRSKA BISTRICA
SNEŽNIK
KOZINA KOPER
BRKINI
SVIŠČAKI
1797
PODGRAJSKO PODOLJE
PODGRAD
REKA
KEY:
CORE ZONE
BUFFER ZONE
TRANSITIONAL ZONE (THE NOTRANJSKA REGION)
RAILWAY STATIONS
CAVES
TOURIST IFORMATION CENTRES
MOTORWAY
TRAFFIC LINKS
RAILWAY LINKS
1 THE ALPINE REGION
2 THE PANONNIAN PLAINE
3 THE KARST REGION
4 THE LITTORAL
THE NOTRANJSKA REGION

sites and habitats are of specific scientific, educative and recreative interst or which contain a natural landscape of great beauty.

The proposed conservation area of Notranjski Regional Park is estimated on 400 km^2. To this area additional 200 or 400 km^2, might be added as a part of scenec areas of Carst geology in Slovenia. The natural landscape area is designated as Regional Park and the cultural landscape area as the Country Park.

A) Regional Park includes Cerknica and Planina plaine, Pivka and Javor massive, Postojna and Križna caves.

B) Country Park includes Snežnik and Javor massive.

These areas of karst geology are of outstanding value in terms of world's natural heritage, such as carst caves, drying up or sesonal carst lakes. Cerknica lake is the biggest drying up carst lake in the world, and the largest continous (uninterrupted) natural or intact woodland area , and as Western most habitat of the brown bear in Europe. The area is European foot-path between Baltic and Adriatic sea , and a nature reserve(ation) for endengered specioius of birds and plants. Visually the area changes every day, when the water level is at its peak it is the greatest carst lake surface with the biggest island in Slovenia. The area offers a great landscape variety within a small area.

Beside natural qualities there are some small scattered settlements, approximately 20 hamlets with not more than 3000 inhabitants.

Strategies and measures to achieve conservation and development:

To promote both in the karst area which is known as one of the most sensitive eco systems, it is needed:

- information and education of local people and visitors in ecological terms and sustainable development options
- raising awareness of the uniquness of the karst systems
- democratic approach with widespread public involvements to achieve ecologically sound development
- participation and collaboration of local people in all matters of conservation and development
- monitoring and research of the area utilising the special knowledge and expertise of scientists, both those who live locally and experts from sarthir afieled
- action plan to prepare Management Plan
- preparation of Management plan in consultation with inhabitants.

To elaborate this proposal eco-turism is discussed in more detail.

ECO-TOURISM AS STRATEGY FOR DEVELOPMENT AND CONSERVATION

The Biosphere reserve offers unique opportunity to maintain the natural and cultural heritage enhanced with human activities appropriate to the formal status of the area.

Tourism can be beneficial to local residents in economic and social terms, but can cause problems in terms of conservation of the area. There are conflicts between conservation and development, local identity in economic terms has to be enhanced by initiating locals to be entrepreneurs in tourism, for the purpose of conservation some strategies has to be devised.

CONFLICT BETWEEN CONSERVATION AND DEVELOPMENT

The concept of sustainable development is a relatively recent one, resulting from concern that the needs and ways of life of an ever growing world population are outstripping our planet's capacity to support us. "Caring for the Earth" a report produced in 1991 by the World Conservation Union (IUCN), World Wildlife Fund (WWF) and the United Nations Environment Program (UNEP), sets out a strategy for sustainable living. The strategy defines sustainable development to mean: "improving the quality of human life while living within the carrying capacity of supporting ecosystems" (Loving them to death, p.36).

According to IUCN, there are categories as follows:

I - Scientific reserve/strict nature reserve with exceptional visits allowed.
II - National Park, primarily serves the function of conservation.
III - Natural monument, strictly protected.
IV - Managed nature reserve or wildlife sanctuary with limited visits.
V - Protected landscape which enable visiting under certain rules of sustainability and equals regional designation (Notranjski park) and English National Parks. These landscapes are less protected and allow visitors to enjoy and explore the area.
VI - Resource reserve has different uses which are ecologically viable.
VII - Natural biotic area or anthropological reserve important on local and regional level.
VIII - Multiple use management area/manager resource has different uses which has to be in terms of sustainable development.
IX - Biosphere reserve which has three zones : core-zone which equals to nature reserve and is strictly protected, buffer-zone equals to IUCN category V, and those two zones are either natural original territories, transitional-zone where more or less scarcely populated areas around the park are joined together into MAB-reserve.
X - World Heritage Site is outstanding site of international importance in rarity, scientific importance and beauty.

Conservation is of particular concern, but some of the growing demand for leisure-tourism or special interest-tourism has to be met within such areas because it is believed that it can generate local economy in a sustainable way.

The IUCN recommendations:

1. Additional legislation is needed at European and national levels to ensure that effective national systems for protected areas are established in all european courtiers. This legislation should include controls over tourist activities and tourism developments. Sufficient resources must be provided to manage protected areas adequately;

2. Tourism development should only take place in and around protected areas if it is sustainable in the long term;
3. National sustainable tourism strategies and policies must be developed which set protected areas and their immediate surroundings in a wider context;
4. Improved information and trends on tourism related to protected areas is needed at European, national and local levels. Better information systems are needed to use this data and these should be compatible between different parks;
5. The tourism sector must adopt policies for sustainable operation for tourism associated with protected areas and adapt their practices so its to be sustainable;
6. Protected - area managers and the tourism sector must work more closely together to develop sustainable forms of tourism for protected areas and in order to pool resources and skills;
7. Standards and safeguards are needed for sustainable tourism operations related to protected areas. A European Charter for Sustainable Tourism for Protected Areas needs to be agreed by protected - area managers and the tourism sector and adopted for use throughout Europe.

Inhabitants and tourism Looking to this problems it is important to establish the potential market and organise locally based initiative in enterpreneurship in tourism "industry" developing soft tourism with local inhabitants where tourism is a part of their income generated in the park area.

MODERN TOURIST TRENDS AND MARKET GROUPS

Initial characteristics of contemporary tourist trends in the world:

- gradual increase of numbers of tourists,
- aging of the tourist population in general,
- general increase of tourist flexibility in terms of time and space concerning the spatial distances,
- in general search for a higher quality in every aspect of tourist service,
- aspirations for contents of vacations enriching personal development,
- the importance of activities on vacations has gradually increased, -general increase in ecological consciousness of tourists.

For the analysis of tourist trends in Slovenia the data from the research of Ingrid Petrovič and Petra Kalan for the year 1991 can be used. According to authors mentioned in Slovenia there were 32% tourists of domestic origin. The same data can be traced in Studio Marketing research stating that Slovenians are the most important tourist guests to Slovenia as they represent 33% of all official overnight lodgings.

The age structure varies considerably, but the majority represent guests of middle age group. The vast majority are traveling with their families, 57 percent; with friends 22 percent, with partners 18 and alone 3. The surveyed tourists mainly stay in one place, 1/5 is traveling and taking a vacation together, while 1/5 is only traveling. The highest percentage takes vacations only once a year at the coast. 25 percent are taking holidays in the spring and autumn. Beside the coast the most popular vacation is to the mountains. For Slovenia it is characteristic that 7 percent of domestic tourists are taking their vacation in the countryside. Their intents are:

- rest 20 percent
- the discovery of new places and people 29 percent
- recreation 18 percent

The destination is decided mainly according to the recommendation of friends. The primary transport is by car, but it is encouraging that 3 percent are cycling and 4 percent are on foot.

It is characteristic, that 41 percent of the surveyed tourists has at least 10 one-day-trips a year.

The potential markets were distinguished into: home, neighbouring and distant markets.

STRATEGIES TO ACHIEVE CONSERVATION IN AREAS OPENED TO TOURISM

To achieve conservation it is necessary to establish carrying capacity for different areas and to zonate areas accordingly. As a pilot example the Cerkniško jezero is proposed for zonation.

In the case of Notranjski park most of the IUCN recommendations are acceptable and are enhanced with UNESCO - MAB programme guidelines.

One of the important development tasks is the tourist-product of the Notranjski regional park.

NOTRANJSKI PARK ZONATION

From the international data of (Boo,WWF 1988) it is evident that country's natural areas were the main criterion in selecting destination (56%), very important (28%) for visitors. Similar results were obtained in our own Survey (Bratko et al., 1992). Therefor it is of prime importance to preserve the most valuable areas from destruction. From the experience abroad and in our country it appears that zonation is the most appropriate strategy. In the central zone of Notranjski park only scientific visitors are allowed in buffer zone guided visit and free access to visitors is enabled. The proposed zonation corresponds to UNESCO-MAB recommendations.

ZONES FOR RECREATION AND TOURISM IN AND AROUND PROTECTED AREAS

1. A sanctuary zone which is strictly protected from any form of tourism development.
2. A quiet zone where access is limited to small, mainly guided groups and few faccilites are provided.
3. A zone for compatible forms of tourism without additional development where activities and facilities compatible with the type of protected area continue but without further development of facilities.
4. A zone for development of sustainable forms of tourism where activities and developments, compatible with the type of protected area concerned, are developed. Tourism should be based around nature, cultural and educational activities. Developments should be small-scale and in keeping with the local culture and building styles.

   The zonation of the Cerkniško jezero is presented in Figure no.2

   After looking to the the conservation and development aspects the aims for the project were decided as follows:

   a. The continuance of relationship between man end environment on this territory in such a way, that the natural environment is preserved also för next generations;

   b. employment opportunities of local people;

   c. making the conditions for promotion, visiting and researching of this territory;

   d. making a collective product of Notranjska territory and indirectly creating the Notranjska identity as the today's and world's principles demand in tourist market.

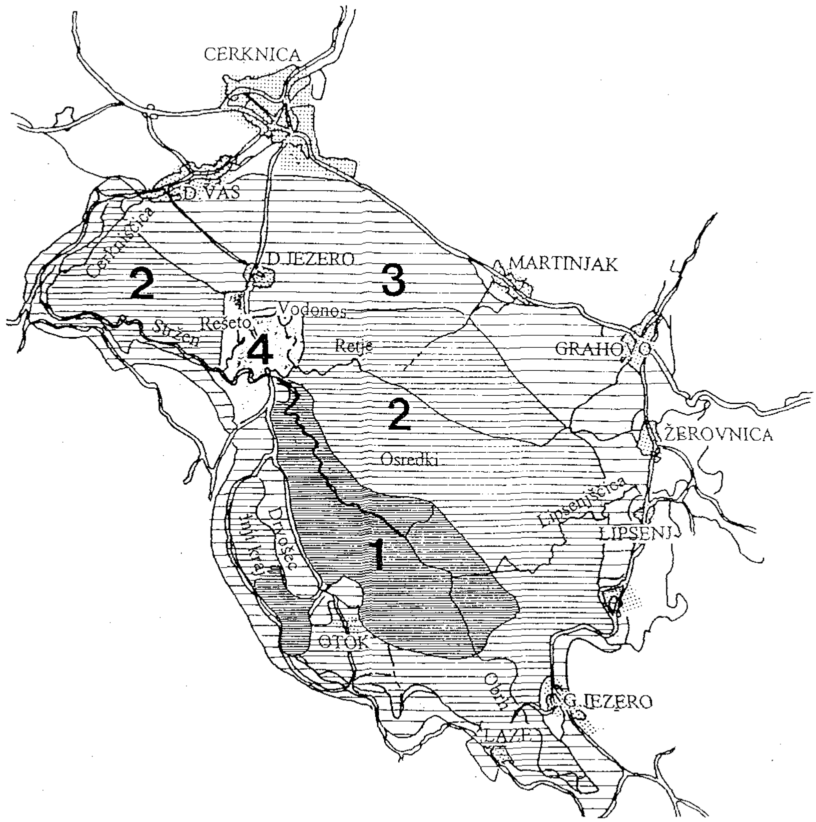
ACTIONS

The first steap in developing sustainable tourism was to hold seminar involving researches, local administrations, managers of protected areas and tourism developers. The action plan for sustainable tourism in Notranjski park will be an integral part of the national plan for tourism. It includes the following aspects:

1. The control of tourism in the reserve: the issue of regulations and the training and testing of guides.
2. The diverzification of tourism: including rest cures and recreation such as sport fishing, canoeing, flying, cycling, caving, rural and scientific tourism.
3. Zoning in time and territory: tourism activity will be spread across the buffer and transitional zones according to thein carrying capacity. This will enable the carst and the forest areas to b more fully used throughout the year.
4. A system of information: is needed for both: tourists and local people and includes: the publication of information, the marking of strictly protected areas, camping, fishing zones, cavex, the organization of guided traveling.....

In order to attain these goals which are in accordance with UNESCO - MAB programe listed strategies were defined:

THE NOTRANJSKI PARK ZONATION



PROPOSED DIVISION OF THE PROTECTED AREA:

1,2 - OSREDNJI PREDEL — CENTRAL ZONE
3 - BLAŽILNI PREDEL — BUFFER ZONE
4 - TURISTIČNI PREDEL — TOURIST ZONE

a. arrangements that are necessary for protection, conservation and sustainable development;
b. a consistent protection of natural and cultural environment;
c. research of needs for the protectoin and conservation and establishment of conditions for advancing the co-natural model of development;
e. establishment of international connections;
f. promotion and information;
g. permenent education of inhabitants and visitors.

MANAGEMENT AND FINANCIAL ORGANISATION OF NOTRANJSKI PARK

To discuss this matter it is of prime importance to look for legislative background to be able to find proper management and financial organisation.

LEGISLATIVE BACKGROUND

Important existing legislation where the Bill on Notranjski Park can endorse acts and paragraphs with comments are:

- Bill on Natural and Cultural Heritage,1981

On the basis of this particular legislation the Triglav National Park had been established, at the very moment the only park of "national - state " importance which represents 4% of the national territory. According to the last Strategy of Nature Protection there is the intention to designate for protection approximately 20% of the total territory of the State of Slovenia.

The major shortcomings of the Bill Of Natural and Cultural Heritage is that it regimes of protection are based on prohibitions, and there is not specified what is permitted and under what conditions. There is no guidance given in what way it would be permissible to develop this area, so also no directions are available on competence of administration and control of protection (guardianship) and the same applies to the problem of development.

The most important regulations are:

- competence,
- authority(authorization),
- finance,
- relations towards other users,
- relations towards local government,
- relations towards inhabitants, and
- relations towards associations.

If all these regulations are not determined there are major problems which are evident not only in financial side but could eventually lead towards the closure of the Park.

Because of these shortcomings only Bill on Natural and Cultural Heritage is not suitable as the basis to designate and establish the parks.

- The Bill on Environmental Potection, 1992

The Bill is widely based as the Bill on Natural and Cultural Heritage as it also deals with problems of environmental protection, pollution, quality of life. This Bill is of prime importance because it allows direct designation in a package in connection with spatial planning legislation.

The main problem is that spatial planning legislation is only being prepared.

Management concerns are based on the fact that Regional park is dependent on many development sectors, not only nature nonservation. Therefor the proposal is put forward for the management system which is called GOVERNMENT AGENCY and its main task is to be integral to overcome problems seen by one sector only.

The concessions for:

- scientific research,
- promotion and information,
- coordination of conservation and protection,
- coordination of development.

Beside concessions there is a need to provide the genuine democracy in establishment of park by naming the COUNCIL of the park which consists of political bodies and local people, especially professionals of nature conservation and different nature conservation and ecological associations. This Agency should establish legal body to enable the financial construction for the establishment of the Notranjski Regional Park.

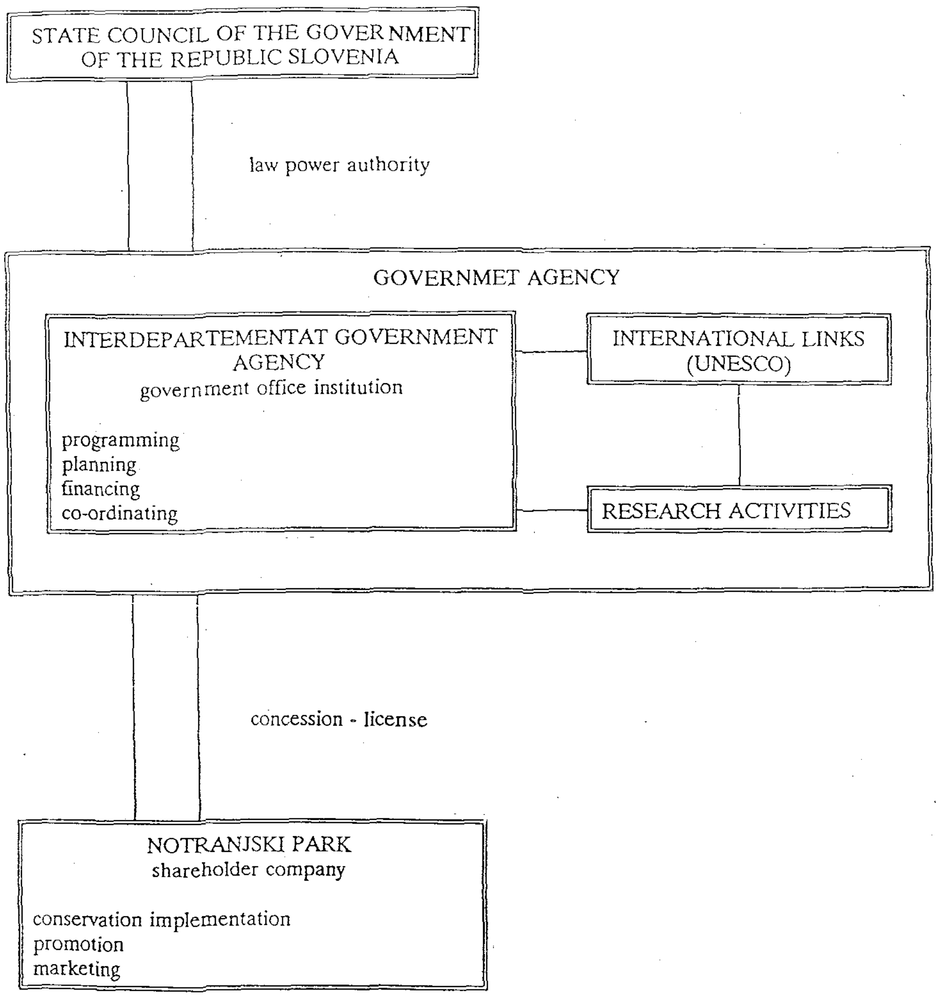
The actual political position is that Government Agency should be in place for the Notranjski Park funded either from National or Regional budget. The proposal presented in figure No. 3. is an alternative where there is Public Agency funded nationally and has the responsibility of programming park activities, planning responsibilities, the overall co-ordination of conservation and development with mainly budgetary funding for conservation and responsibility for financing the operation of the park required as their statutory duty. Beside already described responsibilities they are responsible for concessions and licensing for conservation and development purposes. The new idea is that inhabitants will be participants in shareholder company called Notranjski Park responsible for actual conservation implementation on their properties, promotion and marketing of the park. The idea behind it is that marketing part is located in a separate company which operates as shareholder company where profits are used privately.

CONCLUSIONS

In the case of Notranjski park most of the IUCN recommendations are acceptable and are enhanced with UNESCO - MAB programme guidelines.

The aim of the project is to establish MAB Reserve Notranjski Kras and Regional Park. Eco-torism and maqnagement possibilities were discussed in order to show possibilities and the variety of approaches. Major activities are:

- conservation,
- appropriate development,


STATE COUNCIL OF THE GOVERNMENT OF THE REPUBLIC SLOVENIA
law power authority
GOVERNMET AGENCY
INTERDEPARTEMENTAT GOVERNMENT AGENCY
government office institution
programming
planning
financing
co-ordinating
INTERNATIONAL LINKS (UNESCO)
RESEARCH ACTIVITIES
concession - license
NOTRANJSKI PARK
shareholder company
conservation implementation
promotion
marketing

- research - logistics,
- international co-operation,
- legal status - managerial and financial,
- promotion and information.

In order to attain these goals which are in accordance with UNESCO - MAB programme listed strategies were defined and arrangements that are necessary for protection, conservation and sustainable development like:

- consistent protection of natural and cultural environment by helping with proper legislation and implementation,
- research of needs for the protection and conservation,
- establishment of conditions for advancing the co-natural model of development,
- establishment of international connections,
- promotion and information,
- permanent education of inhabitants and visitors,

are the first priority and are being inplemented in the proposed area of the MAB Reserve and Notranjski Park in striving for balanced approach to conservation and development.

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UNESCO BIOSFERNI REZERVAT - OBMOČJE: NOTRANJSKI KRAS KOT STRATEGIJA ZA VAROVANJE IN SOČASNI RAZVOJ OBMOČJA

Povzetek

Biosferni rezervati, ki smo jih v Sloveniji poimenovali Biosferna območja, ponujajo enkratno priložnost, da združimo ohranitev, zaščito in razvoj na osnovah trajnega razvoja. Strategija obravnava človeka kot del narave in pravilnega fizičnega, socialnega (ekonomskega) in kulturnega okolja. Razvoj je osnova za zaščito. Poleg ohranitve biološke raznovrstnosti je cilj ohranitev in ojačanje kulture v najširšem pomenu besede. Pomembno je, da je tako območje razdeljeno na več con treh kategorij, kar omogoča, da so obrobna območja vključena brez omejitev razen služiti kot ekonomski faktorji skupaj z naravno zavarovanimi območji, kot npr. v Notranjskem parku. Torej je meja biosfernega rezervata - MAB-a na območju štirih občin: Cerknica, Postojna, Logatec in Ilirska Bistrica. Najpomembnejši je obstoj človeka na Krasu s tremi glavnimi nalogami:

- ohranitev narave,
- razvoj,
- logistika.

Da bi te tri naloge izpeljali je bistveno, da se:

- zviša zavest med prebivalci in obiskovalci krasa, da je to območje enkratno in unikatno,
- doseže ekološko zdrav razvoj z demokratičnim pristopom in visoko udeležbo prebivalstva,
- doseže sodelovanje lokalnega prebivalstva pri vseh poskusih ohranitve in razvoja,
- opazuje in preučuje območje s pomočjo izkušenj znanstvenikov iz tega področja in od drugod,
- gleda na relacijo človek - narava oz. človek - kras kot na osnovo za kulturno krajinski in ekološko prijazen razvoj.

Del razvoja je v skladu z ekoturizmom, ki je mehke narave in se z njim ukvarjajo lokalni

kmetovalci kot s postransko zaposlitvijo ter lokalni podjetniki, ki delujejo na osnovi koncesij, ki jih podeljuje Uprava parka.

Glavno vprašanje ostaja: Kako upravljati regionalni park, za katerega država pričakuje, da se bo financiral sam. Bodisi kot delniška družba, kjer bi imela večino delnic v rokah država, druge pa bi pripadale prebivalcem bodisi kot družba, ki je bolj odprta tudi tujim investitorjem, kot pa samo domačim oziroma lokalnim prebivalcem. Zadnja alternativa je, da bi park prešel v državno last, čeprav je že doslej več ko 80 % zemljišč v zasebni lasti prebivalcev. Trenutno bi bila taka odločitev proti ustavi, je pa v skladu z obstoječim zakonom o naravni in kulturni dediščini. Ta zakon je iz leta 1984 in se trenutno pripravlja njegova revizija, zato je primeren čas, za izražanje dilem in predlogov za vnos sprememb.

GEOLOGICAL BASIS OF ANCIENT GREEK COLONIZATION

GEOLOŠKE OSNOVE STAROGRŠKE KOLONIZACIJE

DORA P. CROUCH

Izvleček UDK 711.4(37/38):550.8

Crouch, Dora P.: Geološke osnove starogrške kolonizacije

Prispevek je predhodno poročilo o interdisciplinarnem preučevanju pomena fizične osnove urbanizacije v antičnem svetu. Z vidika geologije so medsebojno primerjana grško-rimska mesta. Ali fizične poteze kažejo na medsebojni vpliv med geološkimi procesi in človekovimi gradbenimi izražanji? Kakšne geološke spremembe so se dogodile v tem času? Počasne geološke procese je težko datirati, toda plazove, poplave in zamuljevanja je lahko določiti in primerjati s podatki o človekovih zgradbah. Geološka informacija lahko pomaga k podrobnejši opredelitvi mestne zasnove, zgodovine in arheologije posameznega mesta.

Ključne besede: interdisciplinarnost, inženirska geologija, grško-rimski čas, hidrogeologija, hidravlika, vpliv, morfologija, strukturna geologija, mestna zasnova, urbanizacija.

Abstract UDC 711.4(37/38):550.8

Crouch, Dora P.: Geological basis of ancient Greek colonization

This is a preliminary report on a new collaborative study about the importance of the physical base for the process of urbanization in the ancient world. Greco-Roman cities are compared in terms of their geology. How do physical features show evidence of interaction between geological processes and human construction efforts? What geological changes took place during the period? Slow geological processess are difficult to date, but avalanches, floods and silting up can be bracketed and compared with the dates of human structures. Geological information can make more specific the urban design, history, and archaeology of each site.

Key words: collaborative, engineering geology, Greco-Roman, hydrogeology, hydraulic engineering, intervention, morphology, structural geology, urban design, urbanization

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INTRODUCTION

This is a preliminary report of a new study relating the geological base to the history of urbanization in the ancient Greco-Roman world. The study is based on preliminary work done by each of the investigators, such as Water Management in Ancient Greek Cities by Dora Crouch, leader of the team. She is an urban and architectural historian. Other team captains are Prof. Dr. Paul G. Marinos, an engineering geologist at the Technical University in Athens; Prof. Dr. Ünal Özis, an hydraulic engineer at Dokuz Eylül University in Izmir; Dr. Laura Ercoli, a structural geologist at the University of Palermo; and Dr. Giovanni Bruno, an applied geologist at the Technical University in Bari. Our junior collegues are hydraulic engineers, geologists, and speleologists, and we also have the cooperation of Italian, German and French archaeologists who have been working on our selected sites.

This pioneering study will be the first to compare groups of cities in terms of their geology. Of course, there are existing studies of groups of cities, such as Rorig's of German trading cities of the Hanseatic league (Medieval Towns), Andrews' of the urban design history of Maya Cities, and Hohenberg and Lee's of the economic history of European cities (The Making of Urban Europe, 1000-1950)[1].Yet to compare cities in terms of their geological base, analyzing both form and function in terms of that base, has not been done.

In the Mediterranean region, karst is the major type of geology, and is related strongly to urban location and form, as I know from my preliminary study. Indeed, Vit Klemes (then president of the International Association of Hydrological Sciences) told me that there was no Greek city that was not built on or next to karst terrane, citing as proof the Greek cities of Asia Minor. From the twenty-five Greco-Roman sites studied in my first volume, we have selected eleven which exemplify differing geological situations for further study:

in Sicily: Agrigento, Morgantina, Selinus, Syracuse
in Greece: Argos, Corinth, Delphi, Delos
in Turkey: Miletus, Perge, Priene.

The chosen sites will be analyzed in terms of their structural geology, hydrogeology, morphology, and engineering geology. We are particularly interested in how their physical features were ammenable to hydraulic engineering and urban design. For instance, we will examine the relationships between siting and foundations, consider building materials in

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[1] Rorig Medieval Towns. G. F. Andrews Maya Cities. 1975. University of Oklahoma Press. P. M. Hohenberg and L. H. Lee, The Making of Urban Europe, 1000-1950. 1985. Harvard University Press.

terms of what was available on or next to the site and what the aesthetic characteristics of such materials were, and analyze the utilization of water for baths, public fountains, drainage channels, etc.

QUESTIONS

In studying the ecology of human settlement as set of practical constraints on human needs, desires, imagination - not as a set of theories - we will be asking the following questions:

1. What is the underlying geology and hydrogeology of the site?

As an illustration our integrative work, the person who did a recent dissertation on the morphology of Argos will restudy that site with us, integrating new hydrogeological and archaeological information into her previous understanding of the site and giving us the benefit of her morphological understanding. Maps of hydrogeological and geological features will be made if they do not already exist, and correlated with archaeological maps.

2. What geological changes took place at the site during the period studied? How much and what kind of correlation can be determined with datable changes in urban form during the same period?

Slow geological processess are difficult to date, but rapid events such as avalanches, floods and silting up, can be bracketed and compared with the dates of human structuress and pottery, to some extent. I will supply historical dates known from previous studies, and the geologists will ascertain the probable chronology of the geological events. It is likely that the Turkish sites will be most amenable to our attempts at dating, as the geological processes along the Ionian and Aegean coasts have been very rapid during the last 2500 years, and are not too difficult to correlate with human constructions in the area.

3. How does the local geology provide construction materials, water, and building sites? How was water managed at the site?

Construction materials and building sites can be determined by surface reconaisance by a historian/archaeologist plus reference to the archaeological literature, but investigation of water supply will take the collaboration of geologist, hydraulic engineer, and urban historian. It is likely that our Morgantina and Perge studies will be the most fully developed for the question of water supply, as we have hydraulic engineers working specifically on these sites. Without the input of geologists, however, many of the nuances of of the sites hydrogeology would be overlooked.

4. How does this geology affect agriculture or port facilities here?

In the period studied, the choice between farming and herding was largely determined by geology, in the sense of suitable land for the activity adjacent to the settlement. At Selinus and Agrigento, settlements were sited to dominate the rich agricultural land which was the basis of the wealth of each city. We are already speculating that the silting up of the rivers at Selinus with concommitant scourge of malaria was a geological change that caused the abandonment of the settlement in the second century BC. Soil types and conditions further determined what crops could be grown. In addition to having a food-producing hinterland, five of the cities to be studied were ports, for which we hope to determine the interaction of geological base and human construction. Syracuse is perhaps the most noted port, but we will also examine Miletus and Priene in terms of the silting up of their ports.

5. Which features of the urban form were determined by specific geological materials, factors, and events?

At Priene, for example, the Stadium Bath was located in order to utilize a karst spring, recently cleared but not reported in the literature. This spring is now dry, but when when the dewatering occurred is an interesting question for urban form. Was the later Roman bath near the theater built merely for the convenience of the population, or was its new location necessary because the lower spring had gone dry?

6. How do visual features of the city acknowledge the geological base?

The grottoes above the theater at Syracuse, serving as fountains and reservoirs, were visible evidence of the termination of natural and man-made water lines. Their location in such a public place not only provided an amenity but also drew attention to the cooperation of nature and government in supplying water to the people. More abstractly, we may ask how are sight lines organized, such as the gap between the Erechtheum and the Parthenon as seen from the Propylaea, at Athens - a gap that draws the visitor's attention to Mt. Lykabettos. Such site organization is well-known since Doxiados[2], and we will look for similar features at our sites.

7. What features of the geology were altered or affected by human intervention?

We are thinking particularly of karst channels, shafts, and springs being altered for use by humans. Quarrying, port development, and irrigation systems have also altered the landscape. Some examples: At Delos, an inn was built around a natural karst shaft that alternately filled and emptied. At Priene, drainage from the western part of the city was poured into a karst shaft. At Corinth, karst channels were utilized in the agora and the Askelepion either for water supply or drainage, or as reservoirs. We will inspect all of our sites for such features.

We will know that we have completed the field work we set out to do when we have on hand:

1. Maps of the geology and hydrogeology of each site, correlated with maps of Greco-Roman buildings, streets, ramparts, etc. For each site, a new map will be created correlating the two kinds of information, geological and archeological.
2. For each site, a list of geological events during the period studied (800 BC to 400 AD).

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[2] C. A. Doxiadis, Architectural Space in Ancient Greece. Cambridge, Mass.: M.I.T. Press, 1972.

Correlation of these events with human building at the site, to the extent possible. Explanation of what kind of correlation was found (if any), how this correlation was arrived at, and the degree of certitude of these findings.

3. A brief catalog for each site of major buildings, houses, etc., and the sources of materials for each[3]. An account of the geological basis for the agriculture or grazing at each site, and for port facilities. For some of the sites, a detailed account of the karst geology that produced water year round and made settlement possible here.
4. Description of the features of the urban form that were determined by the local geology in materials, placement, events or all three. An example could be the theater at Morgantina, made from limestone blocks of the hill against which it leaned; it was buttressed against the movement of the layer of clay on which it stood; eventually the theater was partially destroyed by that movement. Discussion of the ways that the urban form referred to and exploited the geological base.
5. Lists of geological features at each site that were altered by humans, and description of how they were used. An example is the use of the caves called "latomia" at Syracuse, which are the outfalls of the karst system, as prisons (after the late fifth century war with Athens) and as ropewalks.

My team will be looking for evidence of interaction between geological processes and human construction efforts. We hope that this infusion of specific geological information will make more exact, specific, and plausible the urban history and archaeology of each site. Although we realize that more than one study will be needed to define the correlation of geological and human timescales, we expect our efforts to illuminate this question for the sites examined and germinate further research by others.

Our study brings together the broadest concepts of how human society relates to its physical environment, with the most exacting attention to underlying geological structure and processes, as well as to visible features such as hills and valleys, perennial springs, and quarries for building stone. Previously, only limited, site-specific, building-type studies of our sites have been done[4]. We are looking for the link between historical developments and geological change during the period from the eighth century BC to the fifth AD - a long time by historical standards, but a moment by geological standards. By correlating these entities which had not previously been thought to have much connection, we will achieve keener insights into how the sites functioned as loci of human development both tangible and intangible. Through this new way of seeing, our team's research could lead other scholars to apply geological insights to other groups of cities, such as those that ring the Swiss alps or the group of Caribbean ports.

Our study will demonstrate the importance of the physical base for the process of urbanization in the ancient world. At one site (Argos, for example) we will study the hydrogeology and correlate it with the long distance water lines and with water distribution within the city. At Miletus and Priene, the quite different forms of karst at the two sites

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[3] R. E. Wycherly, The Stones of Athens. 1978. Princeton University Press.

[4] e. g., B. H. Hill. 1965. American School of Classical Studies.

resulted in quite different water potential, since existing karst features became elements in Priene's water and drainage system but the "older karst" with fewer on-site springs at Miletus required development of long-distance water supply lines as early as the sixth century BC. In Sicily, if we can determine for Selinus where it obtained its water supply, that will give new insight into the relation of colony to hinterland on the frontier of Greek territory in the seventh through fifth century BC.

Another result will be the placement of science and technology firmly within the subject matter of history and other humanistic disciplines. It is common, at least in the United States, to assume that "the general educated reader" is concerned with literature, history, psychology, and art but not with science and technology. Yet if our survival depended on the invention of cities, and cities depended on careful resource management, and this in turn depended on profound understanding of the geography of urban location, we see that science and technology which learn about and control the environment are squarely at the center of human history, nor peripheral. Human culture includes water management and farming practices as well as religion, language, and marriage customs.

Anticipated results of our study will be first, understanding the geological constraints on social activity (such as colonization) in the Greco-Roman period. Second, correlation between geological features and details of urban form in these cities. Third, development of parallel chronologies of human construction and destruction with events of nature as revealed in the geological record during the period studied, by utilizing the documentary and archaeological record.

CASE STUDY

By checking the comparability of the geological situations of a mother city and a colony, this study will also make a contribution to the growing literature on colonization. Here as in other aspects of the geology of ancient cities, we will make no attempt to be study every possible example. Corinth and its eighth century BC colony Syracuse are ideal subjects for comparison, partly because each is well documented and partly because team members are thoroughly familiar with each of them.

After listing team members and their qualifications, this paper will cover the geology of the two cities as is known at the beginning of our study, a list and description of water technology available in the 8-7th century, the urban history clues for geological dating at these sites, and an analysis of each city's urban design in geological terms. Most unusually for Greco-Roman cities, Greek and Roman Corinth do not form a continuity. The Greek settlement was destroyed and left deserted for a century. Then the Roman city was built anew and populated by immigrants from Italy. This fact should prove useful in our attempts to correlate geological and architectural change.

To compare the geology of the mother-city Corinth with the daughter-city Syracuse will probably require not only numerous details about the geology of both cities, but also an intellectual leap to some level of abstraction. For instance, the karst or karst-like behavior of water in stone may have abstract similarities while being different in operational details.

We must ask whether any similarities we notice are intrinsic to the local geology in each case, or are merely artefacts of our modern mental construct.

TEAM

Investigatiors for Corinth are the author and Dr. Paul G. Marinos, who has already done studies of the water potential of the Corinth area and of the sea coast changes at the ports of Corinth. The cooperation of Dr. David Romano of the University of Pennsylvania Museum, who has been working on a topographical study of the area, will be valuable to our work, as will the accumulated knowledge of the present excavator, Dr. Charles K. Williams. For Syracuse, besides the author, the team consists of Dr. Laura Ercoli; Dr. Marina de Maio (a former student of Dr. Aurelio Aureli, foremost expert on the geology of Syracuse); Francesco Fanciulli, an hydraulic engineer and speleologist who has already investigated the water lines of the island of Ortygia, the original Greek settlement at Syracuse; and Dr. Rosario Ruggieri, another caver who does speleo-hydrogeological research; plus the collaboration of Dr. Deiter Mertens of the German Archaeological Inst. at Rome who is studying the Euryalus Fortress. We are hoping that Dr. Giovanni Bruno, who has already studied the springs of the harbor at Tarranto, will be able to join us for the study of the springs at Syracuse.

GEOLOGY OF CORINTH

The geology of Corinth as now known may be sumarized in a quotation from Donald Engels, Roman Corinth[5]:

The soil occupying the area of the ancient city is neogenic, that is, derived from the decomposition and weathering of underlying sandstones, limestones, marl, and conglomerate. It is not composed of alluvium washed in from elsewhere. Except near the steep north slope of Acrocorinth, most of the area of the ancient city was level, and there would be little probability of debris washing downwards for long distances within the city. Indeed, debris was found far up the northern slope of Acrocorinth and along the city's eastern edge, which slopes gradually to the west. This fact indicates that even after thousands of years, considerable debris has not yet washed down even from steep slopes, and that the area occupied by ancient buildings as revealed by surface debris has not been significantly distorted through time.

This general description may be supplemented by Hill's description of the geology at the location of the Peirene spring (Figure 1) immediately north of the Roman forum[6]:

The ledge... is formed of geologically recent sedimentary rock - conglomerate, sandstone, and poros - resting upon a deposit of clay of great but unknown depth, which doubt-

[5] D. Engels, Roman Corinth. 1990. University of Chicago Press.

[6] The Springs (Corinth), p. 16.

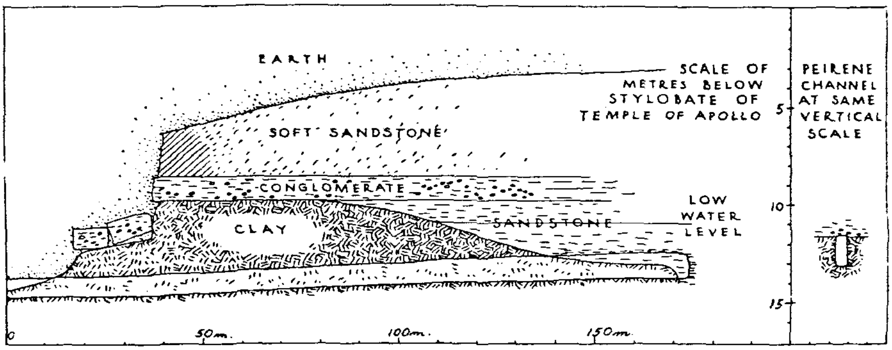

Fig. 1: Geological section at the location of the Peirene Spring, Corinth. Reprinted from Hill, The Springs, by permission of the American School of Classical Studies.
Sl. 1: Geološki prerez Peirene Spring, Corinth. Ponatisnjeno iz Hill, The Springs, z dovoljenjem American School of Classical Studies.

less underlies the whole terrace. The conglomerate and a fine hard sandstone are found immediately above the clay. Over them is a very soft reddish sandstone, perhaps more accurately described as extremely hard earth (known specifically as "stereo" in local excavation parlance. It is here called sandstone very loosely, as it contains little true sand, its principal constituent being decomposed limestone), which reaches up to within 3 to 6 m. of the modern surface and constitutes the chief material of the entire terrace. Along much of the north side of the terrace this sandstone becomes more compact and changes into actual rock - the soft limestone of calcerous tufa known as poros which constitutes most of Temple Hill, the rock-cut foundation of Glauke, and part of the seats and substructure of the Odion... The clay underneath this mass of porous material is very hard and uniform and quite impervious to water. It thus forms the floor of a great reservoir which holds the water that percolates from the surface through the upper strata of the terrace.

It is impossible to be satisfied with these descriptions since modern geologist have different ways of classifying and understanding the evidence. For example, Dr. Marinos interprets the so-called clay of the side walls of the Peirene reservoirs as marl. Certainly the marl would function like impermeable clay in trapping the percolating waters and making them available for human use, but because of its greater hardness, it would present difficulties in the creation of reservoir chambers. It is known from excavation that during late Greek and early Roman times the previous valley between the three springs and the race course was deliberately filled in to produce the large level area on which the Roman forum was built; this enormous fill was made of clay? sandy earth? decomposed limestone? skree from Acrocorinth? all possibly cemented now by 2000 years of inundation and seepage by calcium-carbonate laden water.

The geology of Syracuse as now known has layers (top to bottom) of clay and conglomerate, limestone, basalt, tufa, blue marble, and alluvial silt. Just from this list, we can see that clay, conglomerate, and limestone are found at both cities. The details of similarities and differences between the two are to be found in the kinds and clusters of the stone, clay, etc. and in the patterns of hydrogeological potential. We can get a sense of those details in the description of Syracuse by Burns[7]:

The plateau, its slopes, and its southernmost spur - the island of Ortygia - are parts of a calcerous massif that rests on a base of basalt and compacted sedimentary marine clays that form a continuous permeable stratum. This base has essentially the shape of a shallow bowl, slightly tilted, with the northwestern rim higher that the southeastern one. The bowl receives a great amount of water at its western end, where the Crimiti mountain range makes the prevailing winds shed their moisture. Because of the southward tilt of the bowl, the water trapped in certain sandy layers and pockets under the limestone is under considerable pressure, causing it to well up in copious springs wherever the edges of the impermeable strata reach the surface at lower elevations. Such springs are Arethusa near the southern tip of Ortygia, Ciane in the Anapo plain, and the so-called Occhio della Zillica, where sweet water wells up from the sea bottom in the Great Harbor. Mauceri experimentally confirmed these facts by drilling through the various strata into the aquiferous sands and bringing in artesian wells in selected places.

In the eighth century when Syracuse was founded from Corinth, the traditional knowledge of water management already included:
- collection and use of water from springs and rivers (since the prehistoric period)
- cisterns (since the third to second millennium)
- dams (since the third millenium)
- wells (since the third millemnium)
- reuse of excrement as fertilizer (since an unknown early date);
- gravity flow pipes, channels, and drains (no later than second millenium)
- long-distance water supply lines with tunnels and bridges (at least by the 8th century BC)
- intervention in and harnessing of karst water systems (at least by the 8th century)[8].

Not all of these techniques would necessarily have been in use at any one site. Pressure pipes had been used at Minoan sites during the second millenium, but their use seems to have been forgotten and not reinvented until the sixth century. Underground long-distance water supply lines were developed first in Armenia in the eighth century, thence to Persia, and thence westward no later than the sixth century. However, since the natural behaviour of karst channels seems to have served as the model for these aqueducts[9], it is certainly possible that the "invention" was made simultaneously in several areas, like the practice of intervention in karst channels for human purposes. Further, since the dating of water system elements is rather loose, especially for the eighth and seventh centuries BC, it is difficult to

[7] A. Burns, "Ancient Greek Water Supply and City Planning: A Study of Syracuse and Acragas". 1974. Technology and Culture, Vol. 15 #3, drawing on F. S. Cavallari and A. Holm, Topografia archaeologica di Siracusa. Palermo, 1883-91, pp. 95-142, and L. Mauceri, La fonte Aretusa nella storia e nell'idrologia. Siracusa, 1924, pp. 15-30.

[8] This chronology is explained in D. P. Crouch. 1993. Oxford University Press, pp. 338, and "Avoiding water Shortages - Some Ancient Greek Solutions", Diachronic Climatic Impact on Water Resources, forthcoming proceedings of NATO-sponsored conference in Heraklion, Crete, Oct. 1993.

[9] Crouch, Water Management, Chapter 10, "Natural Models for Water Elements", pp. 115-120.

ascertain whether any specific water element known at Corinth belongs certainly to this early period. If it does, then it could be a model for similar elements at Syracuse.

At Syracuse, the points of investigation of the present study include the latomie and the catacombs, both studied in terms of karst, earthquakes, and human intervention. Shoreline changes since antiquity, and the question of fresh-water springs in the sea. Springs supplying water to the site. Tunnels of the water system as old karst channels and as later catacombs (human intervention). Correlation of geological features with urban form, namely in the locations of public open space, locations of water supply elements and buildings, and the changing city limits during the period studied.

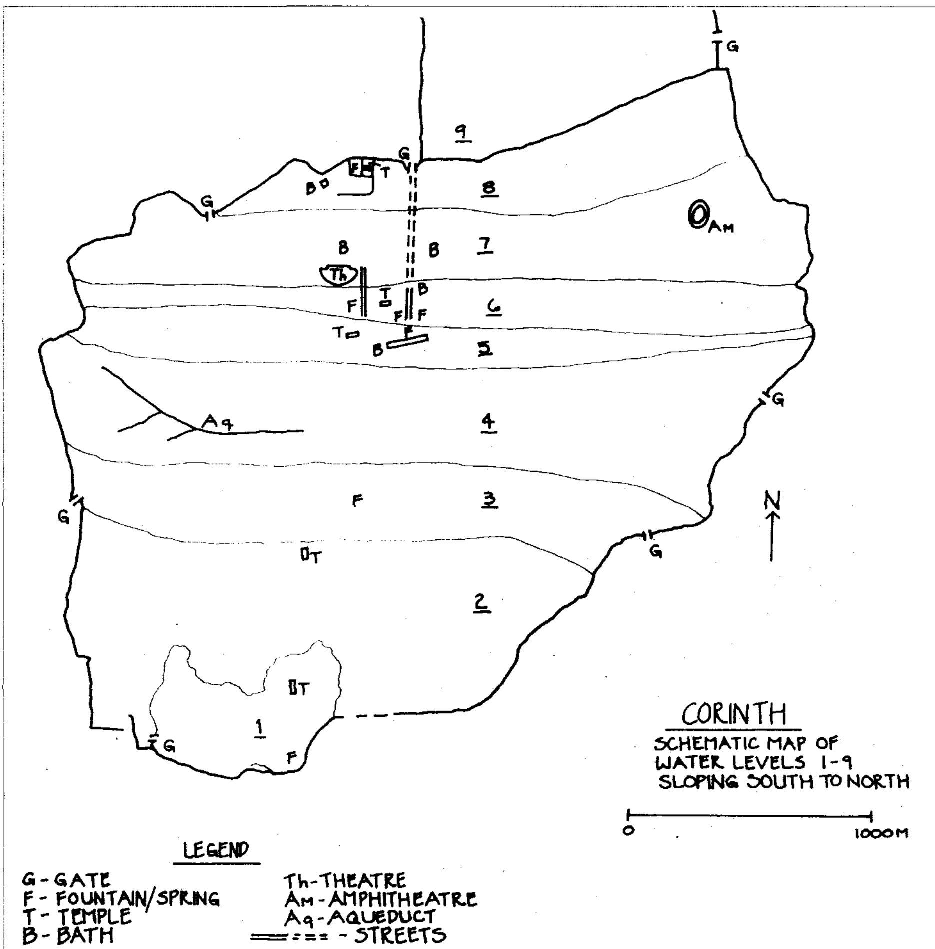

Fig. 2: Terraces of Corinth.
Sl. 2: Korintske terase.

Other aspects of the transfer of Corinthian water technology to Syracuse are less tangible and therefore more difficult to discover in the physical record. That is the mind-set that enabled the Greek engineers to integrate new data into their tradition and to continue to develope their water technology during the following centuries. I consider this aspect of their tradition just as important as knowledge of how to preserve the purity of spring water. Since water management is not discussed at length in the ancient authors[10], we are left to examine the physical evidence and then infer the thought processes that led to the evidence we are evaluating.

In Figure 2, the geological relief of Corinth, the terraces are numbered 1 to 9 as they descend from south at the bottom of the map. The ramparts of the city form the outline of its shape, with the long walls extending to the coast suggested by the north-south lines at the top of the map. The relief in terraces 1 and 2 is extreme, as they are the peak of Acrocorinth and its south slopes; the northern slopess, not shown, are even steeper. Note the spring at F just below the top of the peak. The placement of the temple (of Demeter and Kore) at the lower edge of terrace 2 is likely to have taken advantage of a source of water at this point. Another fountain in 3 is the still-flowing one with the Turkish name of Hadji Mustapha. In the fourth terrace, an extensive aqueduct has been discovered that served the Potters' Quarter west of the city center. Dating to no later than the 6th century, it was adapted to the changing needs of the people, part of it being walled off as a reservoir at a later period. In terraces 5 and 6, both fountains of the archaic period and a bath of the fifth century are known, testifying to the grouping of water sources that made this an ideal location for the earliest agora, continuing to serve the residents of all periods including today. Two more baths in terrace 7 were possible because of abundant water here, and the extensive complex of Asklepion, Lerna Fountain, bath, and gynnasium at the south edge of terrace 8 would not have been possible without still another outpouring of water. Just to the southeast of the numeral 9, a copious flow ("Baths of Aphrodite") supplied a palace of the Turkish era. This map does not extend all the way to the coast, but if it did we would see still further resurgences at the port of Lechaion (a 3rd century AD villa, etc.).

Figure 3 is a closer look at terraces 5 and 6 in the central area. At lower left at CB is the fifth century bath, which is seen to overlie some (probably karstic) channels running from the south. Immediately to its east is a former channel which later was used as a reservoir having a capacity of 100-245.000 liters. The south stoa along the southern edge of the agora/forum was built to take advantage of another channel running underground in this area; all but two of its shops had wells supplied by water from this channel.

A very early fountain (F) was placed at the north edge of the race course, and was abandoned when the agora became the forum of the Roman period. But one of the three fountains that ringed the original lower agora (the Sacred Spring, Periene Fountain, and the Cyclopean Fountain) persisted in use from the Geometric era until today. The Peirene fountain was remodeled and refurbished every few centuries and is still flowing. The Sacred Spring, in contrast, went out of use in the fourth century, suggesting that it may have been

[10] See Water Management, Chapter 6, "Greek Urbanization - Theoretical Issues" and R. Tölle-Kastenbein, Antike Wasserkulter. 1990. Munich: Verlag D. H. Beck, passim.

dewatered when the South Stoa was built. And the Cyclopean Fountain was abandoned to be used as a building site, then re-opened as a spring in Byzantine times. At the far left of the plan, the Glauke Fountain is shown at the edge of a scarp. The original topography of the upper part of this detail was a long east-west ridge on which the Temple of Apollo was built at the east end. Material for the temple (and probably other buildings) was quarried from the hill, so that eventually a valley was formed thorough which the "early road" ran. Only a single large block of the original surface was left, which became the fountain of Glauke. The grooves from which building stone was extracted became the reservoirs for this fountain. In spite of the indication here of a scarped edge, the fountain seems never to have been supplied by a resurgence at this place, but rather always to have had a pipeline from near the Hadji Mustapha fountain, with the pipes replaced from time to time as needed.

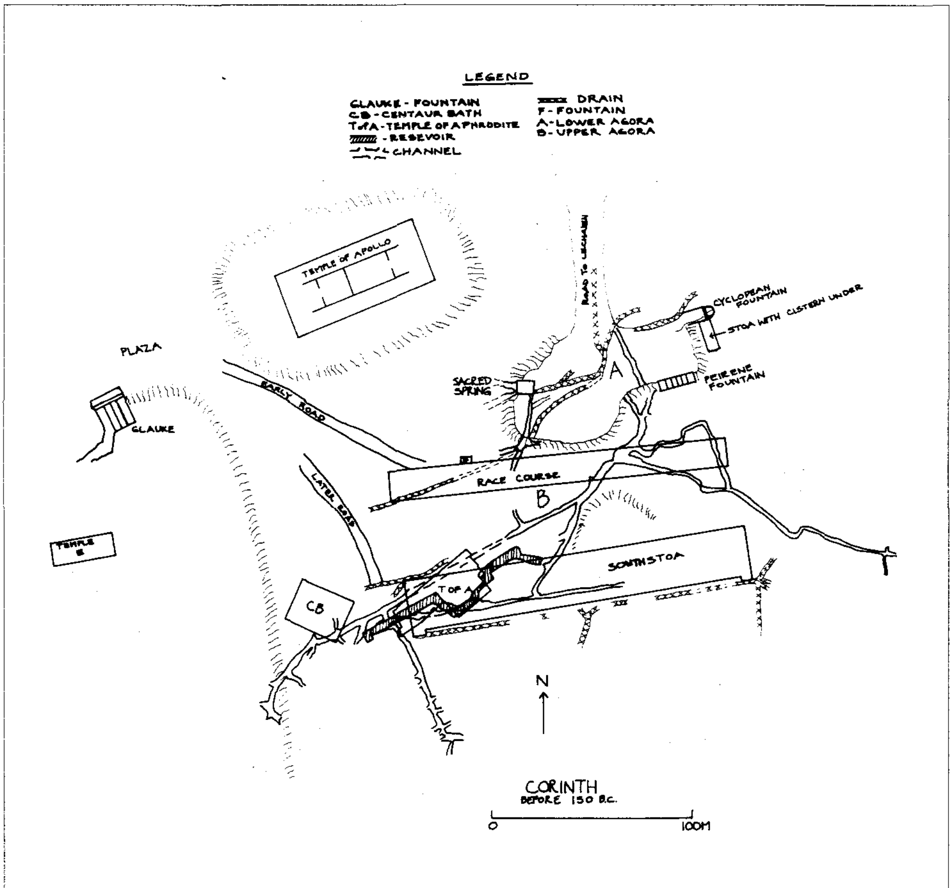

Fig. 3: Terraces 5 and 6 at Corinth, in the central area.
Sl. 3: Korintski terasi 5 in 6, v srenjem delu.

Placement of the original race course in Greek times was at a more acute angle that shown here, with its west end pointing toward the Centuar Bath. Already in the Hellenistic era, a second version of the race course was placed as we seen here, which had necessitated importing some of the fill to level the area, as mentioned above. It would be interesting to look under the Roman steps from the lower to the upper agora/forum (just about at A on the plan) to see whether earlier Greek steps bridged from level to another. I anticipate that such steps were necessary if the fourth century in-filling extended as far north as the north edge of the Sacred Spring, which went out of use at this time.

GEOLOGY OF SYRACUSE

Now let's see what we can determine from similar plans of Corinth's colony, Syracuse. Figure 4 is a map and profiles of the hydrogeology of Syracuse. The profiles are at upper right. From profile B-B, we get an idea of the dish-shaped result of the uplifting of the plateau and submergence of the isthmus between Ortygia and the mainland. On the map, the major water lines (dots along black lines) are laid out on a representation of the geology. As at Corinth, the upper layer of clay and conglomerate rests on limestone. The small crosses indicate catacombs and latomia, both to be construed as ancient karst channels pressed into later human uses. Note that the coastline shown is that of the ancient period, not modern, with major changes in the size and relationship of the Great and Small Harbors.

A closer look at the main settlement area of Syracuse is show in Figure 5. From bottom to top of the map we see first the island-peninsula of Ortygia with the Arethusa Spring at A and another fountain at F. Three large temples bracket what was probably the original agora area. From there, a major street led north to the second agora on the mainland, placed midway between the two harbors; some of this open space is preserved in the modern park called Foro Siracusana. The third agora at the left would have been convenient for trade in agricultural products from the plain to the west. An earlier and then a later wall were built to enclose the built-up area, the outer wall serving also to protect essential sources of water for the expanding city. Streets and large buildings on the map are known from excavation. Towards the top of the map, a scarped edge is the locus of a series of karst caverns. Three aqueducts entered from upper left, and supplied the grottoes above the theater (Figure 6) and a reservoir in the next cavern, called Paradiso. This last aqueduct also supplied a bath located just to the north of the Paradiso cavern. Aqueduct 1, the Galermi aqueduct, brought water from the Crimiti Mountains to the west, for at least 25 kilometers. This aqueduct, built in the fifth century BC, utilized siphons and pressure pipes to bring the water over hills and through valleys to the expanding city. (Such technology was not yet known in the eighth century when Syracuse was founded, but is known to have been used already in the sixth century at Olynthus, a modest agricultural town in northeast Greece.) the cavern farthest right on the map is that in the Santa Lucia area, a node of settlement from the second quarter of the fifth century BC until now.

Not visible on these plans was the equally important drainage system of Syracuse. We have seen some of the drains of Corinth in Figure 2. Drainage and waste disposal were important concerns as soon as ten or more families and their lifestock were living in close proximity. With the use of cisterns went the necessity for drainage pipes or channels under the streets or alleys. Sometimes these drain lines were made of pipes small enough to be handled by individuals, as in Figure 7, but often they were constructed of large blocks of stone. For these, community cooperation - and funding - was essential. So commonplace

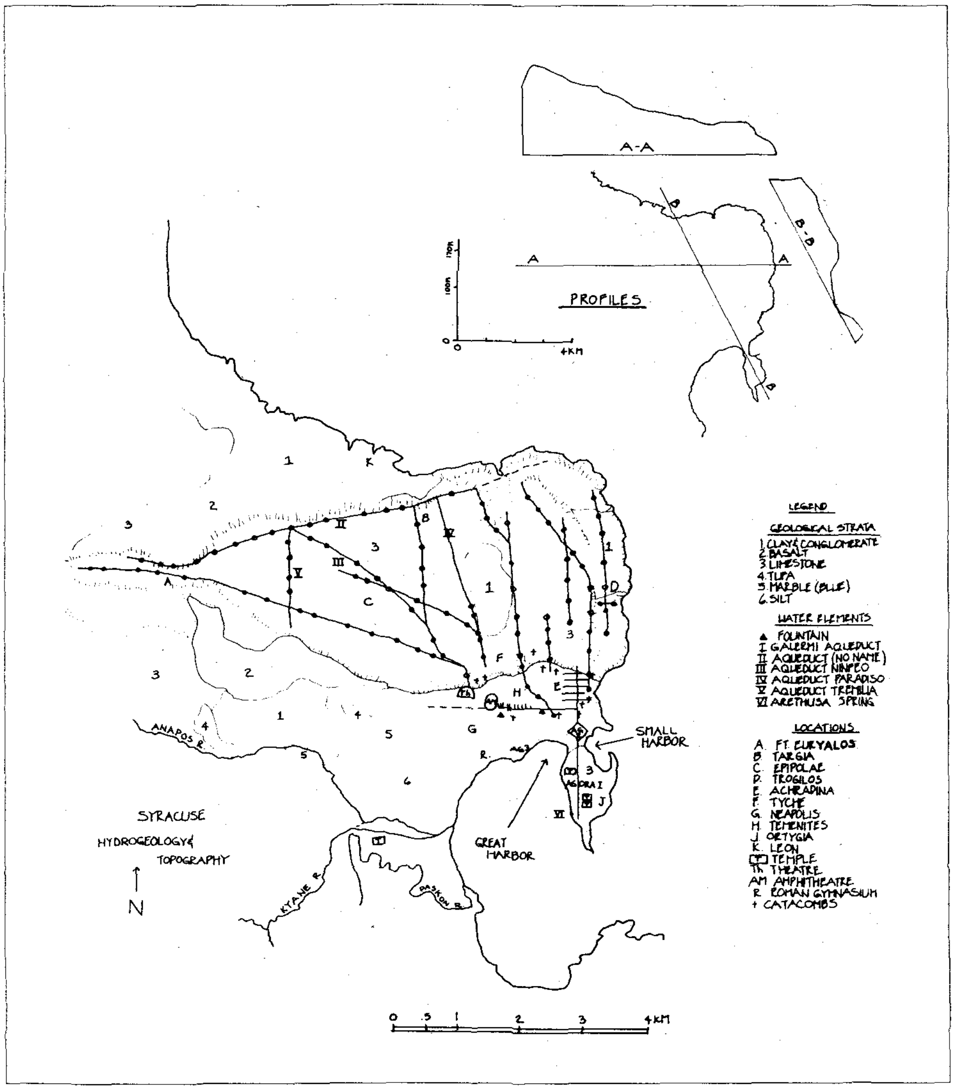

Fig. 4: Map and profiles of the hydrogeology of Syracuse.
Sl. 4: Hidrogeološka karta Sirakuz, s prerezi.

were such stone drains that we find them not only in capitals like Athens - where the Great Drain of the agora was built no later than the sixth century - but also in the mid-fifth century plan of Morgantina (later a colony of Syracuse) when that settlement was a very small town, a mere outpost of Greek culture (Figure 8).

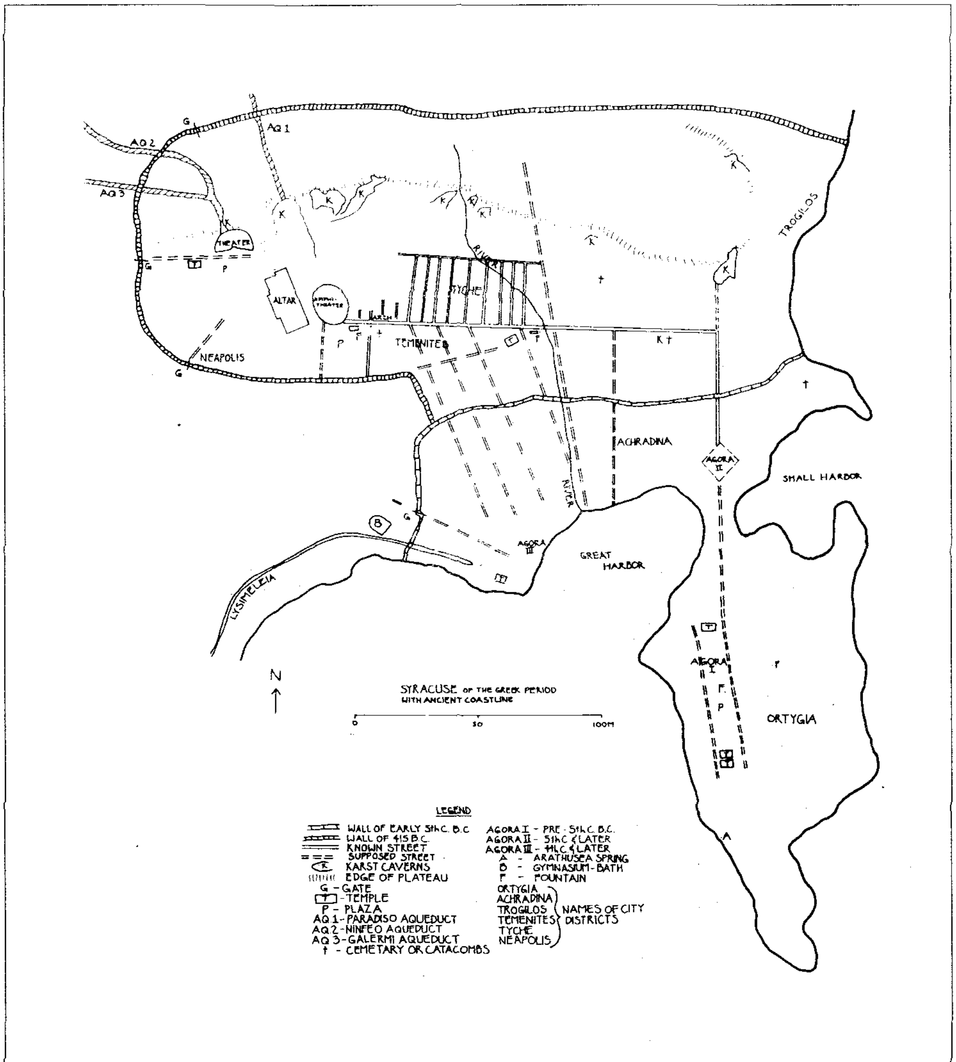

Fig. 5: Main settlement area of Syracuse. Note the three aqueducts entering from upper left, and the row of karst caverns along the scarp.

Sl. 5: Glavni poselitveni del Sirakuz. Vidni so trije akvedukti, vodeči z zgornje leve strani, in vrsta kraških jam vzdolž strmine.

Fig. 6: Grottoes above the theater at Syracuse.
Sl. 6: Jame nad sirakuškim gledališčem.

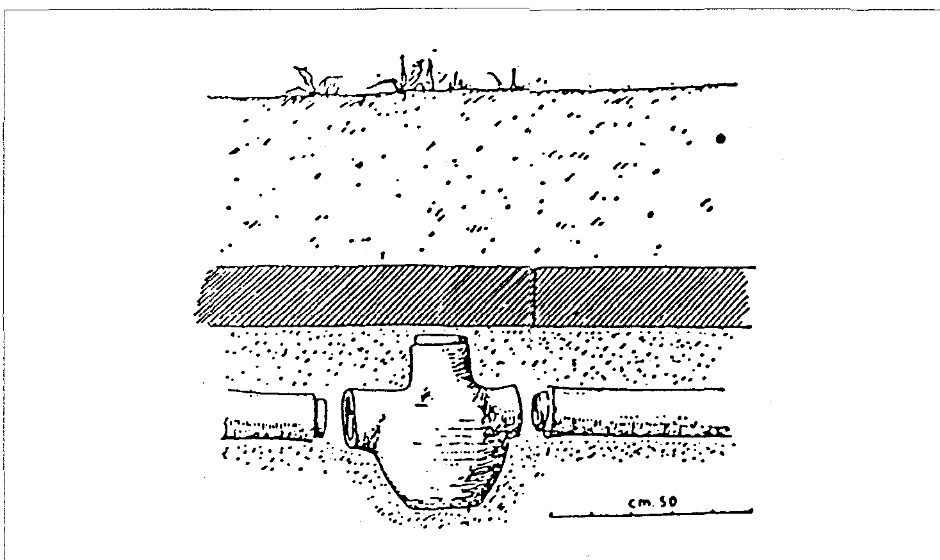

Fig. 7: Drain pipes and settling basin at Syracuse, as reported by B. Pace, Arte e civilita della Sicilia antica (4 vol.) Milan: Ed. Dante Alighiere, 1935-38.
Sl. 7: Dovodne cevi in usedalni bazen v Sirakuzah, po B. Pace, Arte e civilita della Sicilia antica (4 vol.) Milan: Ed. Dante Alighiere, 1935-38.

Thus, without even completing our current study, we can already indicate some of the correspondence between geological base and urban form. As yet, however, we cannot show much of the one-to-one correspondence between geological events and the events of architectural and urban history. We have scattered clues to the water management of each site,

Fig. 8: Stone drains of Morgantina, next to the House of the Official.
Sl. 8: Kamnite cevi v Morgantini, poleg Uradnikove hiše.
Figures 2, 3, 4, 5, 6, 8 are reprinted from Water Management in Ancient Greek Cities, by permission of the publishers, Oxford University Press.
Slike 2, 3, 4, 5, 6, 8 so reproducirane iz Water Management in Ancient Greek Cities, z dovoljenjem izdajatelja, Oxford University Press.

but not the detailed accounts we are working toward. We find it easier to discuss the provision of building materials and the utilization of the topography by ancient urban designers than to analyze the geological base for agriculture or port facilities. Our investigation of the way geological features were altered by humans is just beginning.

CONCLUSION

From this exposition, preliminary as it is, you can begin to see the implications for geology of its integration with many kinds of studies. With new consciousness of the earth as our mother, we turn to the twin sciences of geology and geography for the best information on the nature and behavior of our planet. The earlier studies of Kraft, Rapp, Bintliff, Davidson and Shackley[11], and others related geology to archaeology. More bridges are needed between geology and history, geology and the social sciences, geology and the history of architecture, geology and ecology, and so on. From my own training, I see that geology and the history of art are markedly similar disciplines that rely on chronology and visual nuance - though the chronologies are of vastly different scales. In this new study, I hope to callibrate the scales and promote cross fertilization between these adjacent disciplines.

GEOLOŠKE OSNOVE STAROGRŠKE KOLONIZACIJE

Povzetek

Prva naloga pričujoče študije je primerjava skupin mest z vidika geologije. Izmed 25 mest, prvotno zajetih v preučevanje, jih ta prispevek obravnava 11: na Siciliji Agrigent, Morgantino, Selinus in Sirakuze, v Grčiji Argos, Korint, Delfe in Delos ter v Turčiji Milet, Pergamon in Priene. Za vsak kraj posebej morajo raziskovalci odgovoriti na naslednja vprašanja:

1. Kakšne so geološke in hidrogeološke osnove mesta?

2. Kakšne geološke spremembe so nastale na posameznem mestu v preučevanem času? Kolikšne in kakšne so mogoče korelacije z datiranimi spremembami mestnih oblik v istem času?

3. Kako so od lokalnih geoloških razmer odvisni gradbeni material, voda in gradbene parcele? Kakšna je bila oskrba z vodo?

4. Kako geološke razmere vplivajo na tamkajšnje kmetijstvo ali pristaniške možnosti?

[11] J. C. Kraft and G. R. Rapp, Jr., "late Holocene Paleogeography of the Coastal Plain of the Gulf of Messenia, Greece..." Geological society of America Bulletin 86 (1975): 1191-1298; J. L. Bintliff, Natural Environment and Human Settlement in Prehistoric Greece, Oxford: BAR Supplement Series 28 (i & ii) 1977; D. A. Davidson and M. L. Shackley, (eds.) Geoarchaeology. Boulder, Colo.: Westview Press, 1976.

5. Kateri urbani elementi so neposredno odvisni od geološke osnove, faktorjev in dogodkov?
6. Kako vizualne oblike mest odražajo geološko osnovo?
7. Katere geološke oblike je spremenil oziroma je nanje vplival človek?

Za vzorčno študijo je zelo ugodna primerjava Korinta z njegovo kolonijo Sirakuze (8. stol. pr. n. št.). Posebno zanimiva je primerjava oskrbe z vodo, saj je bila do takrat razvita že vrsta ustreznih tehnik. Čeprav preučevanje še ni končano, že lahko pokaže na določeno ujemanje geološke osnove in mestnih zasnov. Iz tega je že mogoče videti pomen geologije in njenega vključevanja v najrazličnejša preučevanja. Prva preučevanja Krafta, Rappa, Bintliffa, Davidsona in Shackleya so povezala geologijo z arheologijo. Več povezav pa je potrebnih med geologijo in zgodovino, med geologijo in družbenimi vedami, med geologijo in zgodovino arhitekture, med geologijo in ekologijo, itd. Iz mojih osebnih izkušenj vidim, da sta geologija in zgodovina umetnosti močno podobni vedi, ki se opirata na kronologijo in na vizuelno niansiranje - čeprav sta kronologiji v zelo različnih merilih.

VALORI DI ABBASSAMENTO PER DISSOLUZIONE DI SUPERFICI CARSICHE

ZNIŽEVANJE KRAŠKEGA POVRŠJA ZARADI KOROZIJE

FRANCO CUCCHI & FABIO FORTI & FURIO ULCIGRAI

Izvleček UDK 551.44(450.36)

Cucchi Franco & Fabio Forti & Furio Ulcigrai: Zniževanje kraškega površja zaradi korozije

Raziskave raztapljanja karbonatnih kamnin na krasu Furlanije - Julijske krajine (SV Italija) kažejo, da se površje, izpostavljeno vremenskim dogajanjem, povprečno zniža za 0,02 mm/leto. Vrednosti znižanja so v mejah od 0,04 mm/leto do 0,01 mm/leto in so odvisne predvsem od petrografskih značilnosti kamnine.

Ključne besede: korozija, površinsko zniževanje karbonatnih kamnin, italijanski kras.

Abstract UDC 551.44(450.36)

Cucchi Franco & Fabio Forti & Furio Ulcigrai: Degradation by dissolution of carbonate rocks

Research on the dissolution of carbonate rocks in the karsts of Friuli - Venezia Giulia region (NE of Italy), indicate that the average degradation of surfaces exposed to atmospheric agents is 0,02 mm/year. The values of degradation ranges are included from 0,04 mm/year to 0,01 mm/year and depend essentially on petrographic characteristics of the rocks.

Key words: Karst dissolution, carbonate atmospheric degradation, Karst of Italy.

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Italia

RIASSUNTO

I risultati delle misure sull'entità dell'abbassamento per dissoluzione delle superfici carbonatiche eseguite nella regione Friuli - Venezia Giulia con la metodologia del micrometro portano a definire in 0,02 mm il valore medio annuo: l'abbassamento varia da 0,04 a 0,01 mm/anno essenzialmente in funzione delle caratteristiche litologico-petrografiche.

PREMESSA*

Per misurare il valore di abbassamento per dissoluzione di una superficie carsica, uno dei parametri fra i più interessanti per chi studia i fenomeni carsici, i ricercatori triestini hanno proposto tempo fa una metodologia che consente di misurare, direttamente sul posto, l'entità dell'abbassamento utilizzando un particolare strumento, posizionato su chiodi opportunamente infissi nella roccia in posto. Lo strumento è costituito da un telaio rigido a tre piedi sul quale è montato un micrometro la cui punta viene avvicinata delicatamente alla superficie consentendo di definire il progressivo abbassamento rispetto allo zero strumentale.

La forma dei chiodi, costruiti al tornio di precisione in acciaio, molibdeno e vanadio, due a testa sferica ed uno a testa piatta, posizionati secondo i vertici di un triangolo equilatero, consente la ripetitività delle misure in condizioni sempre uguali.

Misure ripetute ad intervalli regolari (solitamente un anno, in alcune stazioni 6 mesi) consentono di calcolare il valore medio annuo di dissoluzione, di definire il rapporto precipitazione/soluto, di quantificare la massa rocciosa asportata.

Sono ormai più di quindici anni che uno stesso operatore, utilizzando lo stesso strumento va assumendo misure in stazioni opportunamente ubicate e divenute via più numerose; e quindi è possibile tracciare un bilancio complessivo e proporre i valori indicativi di corrosione media, che confermano l'estrema lentezza dell'evoluzione dei fenomeni carsici,

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Durante l'International Karstological School tenutasi a Lipica nel settembre 1993, è stata presentata una videocassetta VHS, della durata di 12 minuti, in cui con immagini venivano presentati i risultati di questa ventennale ricerca. Il video è stato redatto da Action Video di P. Forti (Trieste) per conto dell'Istituto di Geologia e Paleontologia dell'Università di Trieste con finanziamento M.U.R.S.T. 60 %.

assegnando al valore di abbassamento delle superfici carsiche in condizioni climatiche simili a quelle della nostra regione un ordine di grandezza di alcuni centesimi di millimetro all'anno.

STAZIONI DI MISURA SPARSE IN REGIONE

Le stazioni di misura sono ubicate in quattro aree della regione caratterizzate da rocce carbonatiche affioranti in condizioni morfologiche e climatiche diverse: il Carso triestino, il monte Canin, le Prealpi Carniche presso Pradis, il monte Avanza (figura 1).

Sul Monte Avanza sono posizionate due stazioni ubicate su calcari leggermente metamorfosati del Paleozoico: l'abbassamento misurato, in condizioni climatiche di alta montagna con una piovosità annuale di circa 1800 mm, varia da 0,03 a 0,01 mm/anno nelle tre stazioni.

A Pradis, sui fianchi e sul fondo della forra del T. Cosa, in calcari biomicritici (essenzialmente frammenti di Rudiste in cemento micritico) cretacici, sono posizionate due stazioni di misura che indicano in 0,015 mm/anno il valore medio di abbassamento. Il clima è temperato collinare, la piovosità annua di quasi 2000 mm.

Sul monte Canin, ove le condizioni climatiche sono di alta montagna con altissima piovosità e frequenti nevicate (temperatura media annua 3°C, precipitazioni superiori a 3000 mm/anno) le 5 stazioni sono ubicate su calcari micritici più o meno fossiliferi della Formazione dei Calcari del Dachstein. Le stazioni sono posizionate su superfici a diversa inclinazione, da pochi gradi alla subverticalità: tuttavia i valori di abbassamento della superficie finora misurati sono molto simili per tutte le stazioni, con valori medi di 0,015 mm/anno.

Sul Carso triestino vi sono a tutt'oggi 21 punti di misura della dissoluzione sparsi ed ubicati su diversi tipi di rocce carbonatiche (alcuni sono duplicati sullo stesso affioramento e quindi fanno praticamente parte di un'unica stazione di misura) ed è stata recentemente attivata una stazione sperimentale nella quale 24 campioni di roccia, raccolti in diverse aree carsiche italiane, sono esposti agli agenti atmosferici.

La stazione sperimentale è posizionata nei pressi della Grotta Gigante ad una quota di circa 275 m, ove è anche in funzione, ormai da un trentennio, una stazione meteorologica ufficialmente riconosciuta, il che consente di conoscere con esattezza e continuità le caratteristiche climatiche dell'area ed in particolare l'entità delle precipitazioni.

Il Carso triestino è caratterizzato da un clima mediterraneo tendente al continentale, con inverni lunghi e freddi, primavere variabili e calde estati che si prolungano nell'autunno. La temperatura media annua è di 12°C con escursioni mediamente comprese fra 6°C e 11°C, minimi di -15°C e massimi di 34°C. L'umidità media è del 70 %; le precipitazioni sono mediamente di 1350 millimetri all'anno distribuiti secondo 135 giornate con precipitazioni, di cui circa 105 con valori superiori al mm. I massimi assoluti di piovosità giornaliera risultano dell'ordine di 163 mm (106 mm è il valore massimo giornaliero medio), con i periodi più piovosi concentrati in settembre (media di 144 mm in 12 giorni) e in novembre (media di 163 mm in 13 giorni). Mediamente inoltre si ha grandine 3 giorni all'anno, neve

7 giorni all'anno, brina 28 giorni all'anno (solo in dicembre 10 giorni), rugiada 47 e nebbia 15 giorni all'anno.

In queste condizioni meteoclimatiche l'abbassamento medio misurato nelle stazioni sparse sul Carso triestino risulta di 0,02 mm anno (figura 3), con valori minimi di 0,01 mm competenti a dolomie cristalline cretaciche (Stazione VC, n°6) e valori massimi di 0,03 mm competenti a calcari micritici cretacici (Stazione GG, n°1). Ne deriva una perdita in peso media di 550 mg/dm^2/anno.

Le stazioni sparse sul territorio sono una dozzina, di cui 8 particolarmente significative.

La Stazione n°1 (Stazione GG) è ubicata presso la Grotta Gigante, nelle immediate vicinanze della sopracitata stazione meteorologica utilizzata. E'posta su un affioramento di calcari fossiliferi cretacici (wackestone sensu Dunham, biomicrite sensu Folk) inclinato di 15°. Dal punto di vista mineralogico la roccia è composta da Calcite (92,53 %), Dolomite (2,38 %) e per il 5,09 % da residuo insolubile.

La Stazione n°2 (Stazione CS) è ubicata nei dintorni di Borgo Grotta Gigante ed è posta *su un affioramento di calcari fossiliferi cretacici (wackestone sensu Dunham, biomicrite sensu Folk) inclinato di 10°. Dal punto di vista mineralogico, la roccia è composta da* Calcite (91,05 %), Dolomite (2,50 %), con un residuo insolubile del 6,45 %.

La Stazione n°3 (Stazione VP) è ubicata a pochi centimetri dalla stazione n°2 (e quindi sullo stesso litotipo) ma al centro di una "kamenitza" del diametro di 15 cm.

La Stazione n°4 (Stazione DO) è ubicata sul fianco di una vasta dolina, su un affioramento di calcari fossiliferi cretacici inclinato di 17°. La roccia ha le stesse caratteristiche petrografiche di quella che caratterizza le stazioni n°2 e 3, con Calcite (92,63 %), Dolomite (2,37 %) e il 5 % di residuo insolubile.

La Stazione n°5 (Stazione BD) è ubicata nei pressi dell'abitato di Opicina su un affioramento di calcari cretacici (wackestone sensu Dunham, intrabiomicrite sensu Folk) che all'analisi mineralogica risultano composti da Calcite (91,95 %), Dolomite (2,85 %) e residuo insolubile per il 5,20 %.

La Stazione n°6 (Stazione VC) è ubicata in una valletta e posizionata su rocce dolomitiche cretaciche (dolomite anedrale da ricristallizzazione) che all'analisi chimica risultano composte da Dolomite (85,65 %), Calcite (10,13 %) e per il 4,22 % di residuo insolubile.

La Stazione n°7 (Stazione ML) è ubicata sulle pendici orientali di un rilievo (il Monte Lanaro) su un affioramento di calcari cretacici (mudstone sensu Dunham, fossiliferous micrite sensu Folk) che all'analisi chimica risultano essere composti da Calcite (91,95 %), Dolomite (2,85 %) e per il 5,20 % da residuo insolubile.

La Stazione n°8 (Stazione BR) è ubicata sul fianco settentrionale del Monte Carso in destra della Val Rosandra, su un affioramento suborizzontale di calcari paleocenici (packestone sensu Dunham, recristallized biomicrite sensu Folk) che risultano composti prevalentemente da Calcite (93,0 %) e da Dolomite (2,07 %), con il 4,93 % di residuo insolubile.

STAZIONE SPERIMENTALE

Nella stazione sperimentale di borgo Grotta Gigante sono stati esposti nel 1987 ben 24 campioni rocciosi provenienti dall'Alto Adige, dal Veneto, dalla Toscana, dalle Marche, dall'Abruzzo, dalla Puglia, dalla Sicilia, dalla Sardegna, dal Friuli - Venezia Giulia.

Si tratta di alcuni calcari micritici più o meno fossiliferi triassici (n°51, 52, 58), di calcari detritici organogeni (n°53, 60, 61, 73), di campioni di "Biancone" (n°54), "scaglia grigia" (n°55), "Rosso Ammonitico" (n°56 e n°59) in facies nodulare chiara, "scaglia rossa" (n°57) con selce, di "Calcare massiccio" (n°72), di "Ammonitico rosso superiore" siciliano (n°74), di diverse dolomie (n°64, 65, 66, 67), di calcari dolomitici (n°68), di gesso cristallino (n°69 e 70), di marmo (n°71). Un paio di campioni (calcari afferenti alla Formazione dei Calcari del Carso triestino: n°62 corrispondente alla stazione n°8, n°63 corrispondente alla stazione n°5) sono stati prelevati sul Carso triestino presso stazioni di misura operative da tempo.

I valori di dissoluzione delle rocce carbonatiche esposte variano fra 0,04 e 0,01 mm/anno, quelli delle rocce gessose sono di circa 1 mm/anno (figura 4). Valori alti competono a calcareniti mioceniche abbruzzesi e scaglia rossa veneta (0,04 mm/anno per il n°73 e 0,035 mm/anno per il n°57 rispettivamente); valori bassi competono ai campioni dolomitici (n°65 e n°66 con 0,01 mm/anno). Non risulta essere stato interessato da dissoluzione il marmo di Carrara (n°71).

OSSERVAZIONI

L'entità della dissoluzione superficiale delle rocce carbonatiche, misurata sul terreno in condizioni naturali con la metodologia del micrometro appoggiato a chiodi fissi nella roccia, risulta essere molto bassa, mediamente compresa fra 0,04 e 0,01 millimetri all'anno. Si tratta di valori che non sembrano tanto influenzati dalle condizioni climatiche (entita e regime delle precipitazioni e temperatura media) quanto dalle caratteristiche litologico-petrografiche.

Va quindi ribadito che, data in particolare la lentezza con cui si evolvono le forme carsiche, nell'analisi delle morfologie dissolutive (tanto delle "grandi forme" quanto delle "microforme", ma in particolare delle prime) e nella ricostruzione dell'evoluzione del carsismo epigeo ed ipogeo, è essenziale riconoscere un ruolo primario alle caratteristiche litologiche e strutturali delle masse rocciose interessate.

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ZNIŽEVANJE KRAŠKEGA POVRŠJA ZARADI KOROZIJE

Povzetek

V Furlaniji - Julijski krajini (SV Italija) smo neposredno merili zniževanje oziroma raztapljanje kraškega površja, izpostavljenega vremenskim pogojem, na več kot 50 mestih. Podatki so redno letno odčitavani s pomočjo mikrometrskega inštrumenta, postavljenega na kline iz nerjavečega jekla, zavrtane v kamnino.

Merilna mesta so na različnih karbonatnih kamninah: dolomit, apnenec (mudstone, wackestone, packstone, grainstone, boundstone), dolo-limestone, karbonatne breče, lapornati apnenec, itd, vključno dva vzorca sadre.

Podatki, nekateri beleženi preko 15 let kažejo, da je zniževanje površja na karbonatnih kamninah, izpostavljenih vremenskemu delovanju, 0,02 mm/leto. Vrednosti zniževanja so med 0,04 mm/leto in 0,01 mm/leto in so odvisne predvsem od petrografskih značilnosti kamnine (mudstones se npr. znižujejo dvakrat hitreje od grainstones).

DEGRADATION BY DISSOLUTION OF CARBONATE ROCKS

Summary

More then in 50 located in Friuli - Venezia Giulia region (NE Italy) stations we make direct measurements on the degradation and the dissolution of the karst surface exposed to atmospheric agents. The data are relies yearly on a special micrometric instrument layed on steinless-steel nails driven into the rock.

The stations are on many types of carbonates: dolostone, limestones (mudstones, wackestones, packstones, grainstones, boundstones), dolo-limestones, carbonate breccias, marly limestones, etc. Two samples of gypsum are exposed too.

The data, more of then collected since 15 years , point out that the average degradation of carbonate surfaces exposed to atmospheric agents is 0,02 mm/year.

The values of degradation ranges are included from 0,04 mm/year to 0,01 mm/year and depend essentially on petrographic characteristics of the rocks (e. g. mudstones have a degradation twice as the grainstones one).

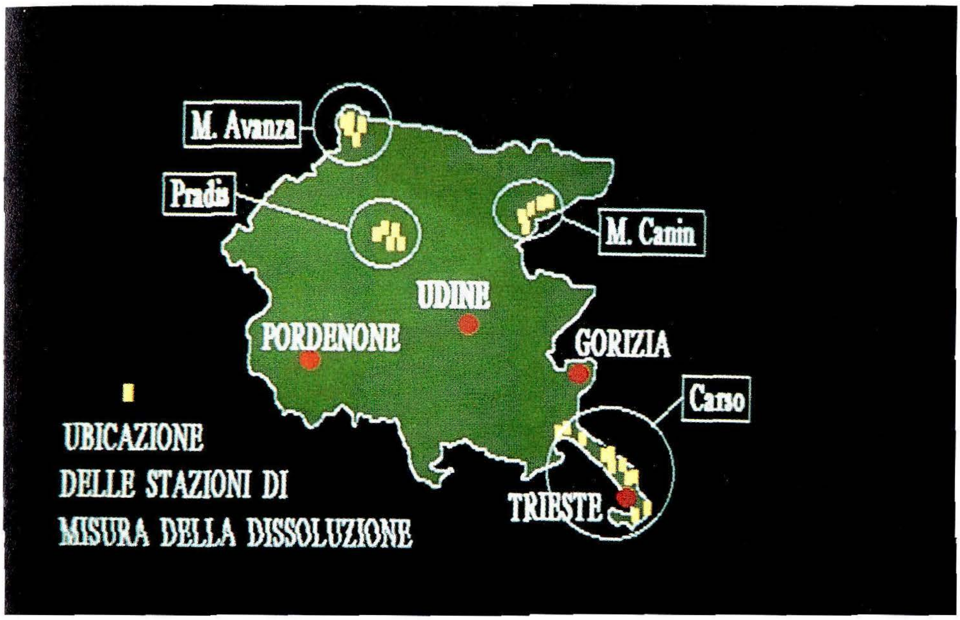

Fig. 1: Ubicazione delle stazioni di misura
Sl. 1: Lega opazovalnih mest

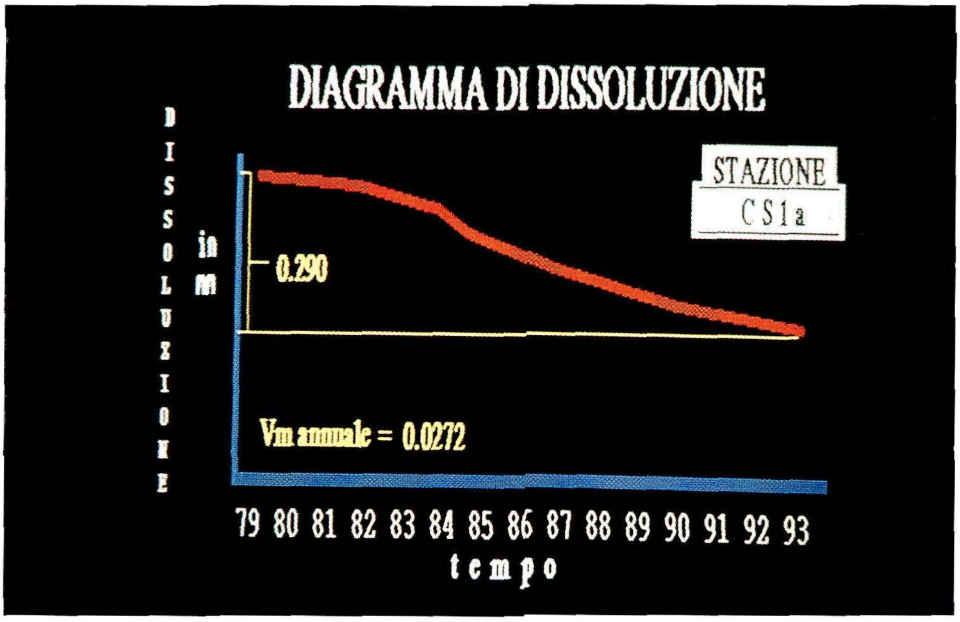

Fig. 2: Abbassamento nel tempo della stazione n.2 (CS)
Sl. 2: Zniževanje na opazovalnem mestu 2 (CS)

Fig. 3: Valori di abbassamento nelle stazioni sparse sul Carso triestino
Sl. 3: Vrednosti znižanj na opazovalnih mestih na Tržaškem Krasu

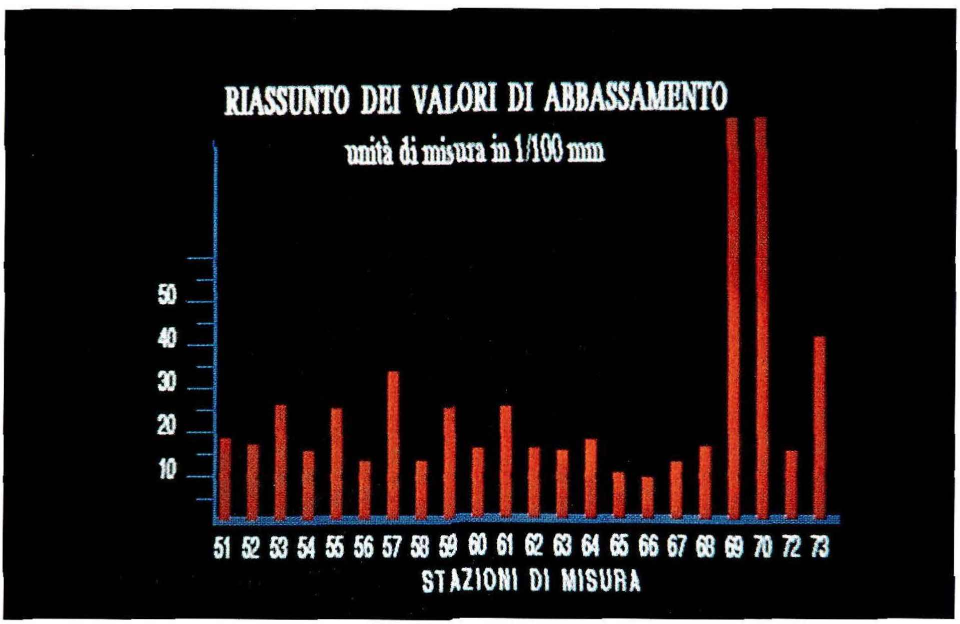

Fig. 4: Valori di abbassamento nella stazione sperimentale
Sl. 4: Vrednosti znižanja na poskusnem mestu

PHREATIC CHANNELS IN VELIKA DOLINA, ŠKOCJANSKE JAME (ŠKOCJANSKE JAME CAVES, SLOVENIA)

FREATIČNI KANALI V VELIKI DOLINI (ŠKOCJANSKE JAME, SLOVENIJA)

MARTIN KNEZ

Izvleček UDK 551.442(497.12)

Martin Knez: Freatični kanali v Veliki dolini (Škocjanske jame, Slovenija)

Tekst poroča o prvi fazi raziskav lezik v Veliki dolini (Škocjanske jame, Slovenija). Na podlagi maloštevilnih podatkov v literaturi je uspel zbrati dovolj trden temelj za poglobljene geološke raziskave oziroma aplikacijo že znanih podatkov na lezike, ki so v Veliki dolini.

Ključne besede: krasoslovje, geologija, lezika, podzemni vodni kanal, Škocjanske jame, Slovenija

Abstract UDC 551.442(497.12)

Martin Knez: Phreatic Channels in Velika dolina, Škocjanske jame (Škocjanske jame caves, Slovenia)

The author gives an account of the first phase of bedding planes research in Velika dolina (Škocjanske jame, Slovenia). Based on scarce data in literature he succeeded to gather enough solid theoretical foundation for in-depth geological researches, application of known data respectively of bedding planes existing in Velika dolina.

Key words: karstology, geology, bedding-plane, underground water channel, Škocjanske jame, Slovenia

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INTRODUCTION

From the beggining of the speleological science the researchers devoted attention to relation between geological facts (rock, structure) and forming of underground channels. Researchers map tectonic elements on the cave maps a long time already. But very few works were made from litopetrologic or stratigraphic aspect for the aim of the cave research till now.

Today's knowledge of the relation of forming underground channels and surface karst features and tectonic phenomenon is much greater.

Different authors (Čar 1986; Šebela 1992) stress today the signification of the fracture zone dinaric or transverse dinaric direction (NE-SW and NW-SE) especially, by which numerous underground water channels in Postojnska jama and Planinska jama, for instance, formed. Litopetrological characteristics were in this way put into the background.

Other authors (Čar & Gospodarič 1984; Garašić 1986, 1989) frequently refer to water channels along the bedding or else the active water channels are directed perpedicularly to folded beds. Such orientation of water channels, at least in Postojnska jama (Gospodarič 1976), was not yet satisfactory explained. Such connections were mostly interpreted from the tectonical point of view by the researchers (Habič 1982).

SOME DATA ON THE CONTRARY

The counter-evidence is also the fact that in the area of Mala gora Dinarically oriented fissures do not predominate although in the caves the Dinarically oriented passages do prevail (Kranjc 1981, 44).

During the mapping of Najdena jama (Šušteršič & Puc 1970; Šušteršič 1982,1991) it was indicated that the passages are much more conformed to the strike and dip of bedded limestone and dolomite than to the faults orientation (Gospodarič 1982, 169).

Karstification should depend mostly on the permeability which results on structure. According to this base some authors infer that more porous biomicrites and biosparites are more soluble than micrites, sparites respectively (Sweeting 1972, 18). White (1988) and Ford & Williams (1989) quote that in general the medium-grained micritic limestone is the most suitable for the genesis of the underground passages.

On Dolenjska it was stated (Kranjc 1981, 36), that in biomicritic limestone which dissication cracks are filled up by dolosparite the bigger and longer passages developed while in the area of pure dolomites they are more scarce. Some Italian researchers infer that on Kras the limestones with high rate of secondary sparitic calcite are less soluble than the dolomites.

In general in the Dinarids the limestones are far more pure than elsewhere in the world (White 1988). They have 1-2%, frequently even less than 1% of unsoluble particles (Gams 1974, 73; Knez 1989). However some authors quote that completely pure limestones are the best for the karstification (White 1988), and the others express the opinion that the most suitable for karstification are the limestones containing 70% $CaCO_3$ (Ford & Williams 1989). The limestones on Dinaric karst contain various ratio of $CaCO_3$ in respect to their age: from the Lower Triassic, having from 80 to 95% $CaCO_3$ to Lower Cretaceous (95-98% $CaCO_3$), Upper Cretaceous respectively with 98 to 100% $CaCO_3$ (Herak 1972, 28).

BEDDING-PLANE RESEARCHES IN VELIKA DOLINA

Geological data of the Škocjanske jame show that underground channels are formed in Turonian and Senonian thick-bedded limestone and in thin-bedded limestone of Maastrichtian and Danian (Gospodarič 1984). This litopetrologic difference of limestone reflects in morphology of the channels. The same author (1986, 22) accentuates that from the karstification

Fig. 1. Bedding planes in the limestone on the left bank of the Reka riverbed. The arrow points the bedding plane labelled 500 (Photo by M. Knez)
Sl. 1. Lezike v apnencu levega brega struge reke Reke. Puščica kaže leziko z oznako 500. (Foto M. Knez).

point of view the lithological-petrological composition of mostly Cretacoues beds is interesting. Similar properties of Cretaceous beds are referred to by the Croatian geologists too (Garašić 1986).

But by the side of the genetic relation underground channel - fracture zone, some authors for the forming of the underground channels mention also the bedding-planes (Figs. 1, 2) as a significant element (Waltham 1971, 1981; Ford & Ewers 1978; Čar 1982; Dreybrodt 1988).

Bedding-plane anastomoses (braided solution tubes) which are in Velika dolina in Škocjanske jame phreatic channels, occur in many sizes and appear to form a continuum from channels several millimeters in diameter to diametres of some tenth of metres (Figs. 3, 4). Bedding-planes where phreatic channels can form are common in areas of poorly jointed limestone (Fig. 2) and appear mostly on the undersides of the strata. The features extend over large areas of a bedding surface and often influenced by minor fractures. Bedding-plane anastomoses in Velika dolina are unquestionably phreatic in origin and often certainly predate adjacent or confluent cavern passages. In many cases it appears that a cavern passage results either from an extension of the anastomoses along a route predetermined by the presence of a minute fracture or from the breaching of a stratum by growth of anastomoses from below where two or more sets exist superimposed on adjacent bedding surfaces.

The definition of Ewers (1966) says that bedding-plane anastomoses are braided, freely interconnecting, networks of solution tubes which appear on the undersides of soluble sedimentary strata.

In general the smallest of these tubes are roughly circular in cross section with diameters as small as several millimeters. In Velika dolina in Škocjanske jame mostly the cross section with diameter of at least 5-10 cm appear. In world literature we find that these forms form a continuum with the largest type, which are channels of ovoid to trapezoidal cross section having broad bases and narrow tops, occasionally exceeding several feet in width. In Velika dolina largest cross sections of channels reaches 20 metres (Fig. 4).

In some places anastomosing solution tubes of intermediate size are usually charac-

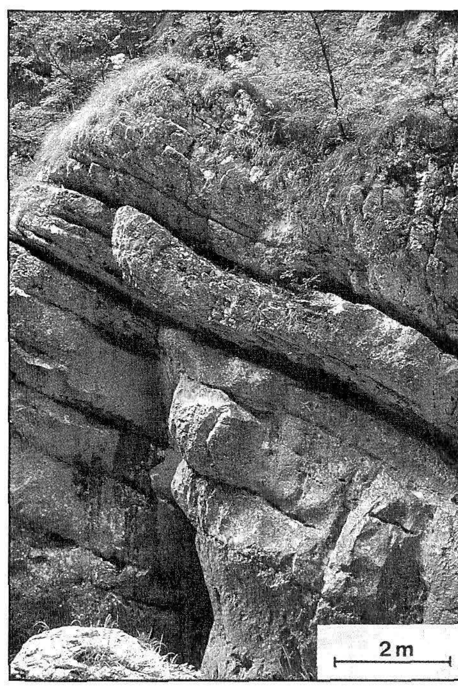

Fig. 2. Detail on the left bank of the Reka riverbed with distinctive bedding planes (Photo by M. Knez)

Sl. 2. Detajl levega brega struge reke Reke z močno izraženimi lezikami. (Foto M. Knez).

terized by vertically elongated cross section with narrow basses and broad rounded tops. Such types of channels Slabe (1987) named omega anastomoses chanels.

Bedding-plane anastomoses most frequently occur in areas of poorly jointed limestone where subsurface drainage is dependent upon bedding-plane-oriented routes for lateral percolation. In the cavern situation they are most often found as small, lateral extensions of meandering tubular passages. These extensions follow bedding planes which intersect the passages.

How a freely interconnecting network of similar-sized tubes can be developed, preserved and enlarged with the evolution of no large-scale integration is an important question. The answer (Ewers 1966) to this question seems to lie in the assumption that the enlarging process must be operating uniformly throughout the system, regardless of the position of a tube in the network. If the hydraulic head and flow rate were extremely large and remained so in spite of the growth of the system, considerable flow would be induced in all of its parts, and conditions at the interface between the ground water and rock would be similar throughout.

An alternate and more likely circumstance involving very slow ground-water movement may also produce uniform enlargement. Where the water movement in the system is

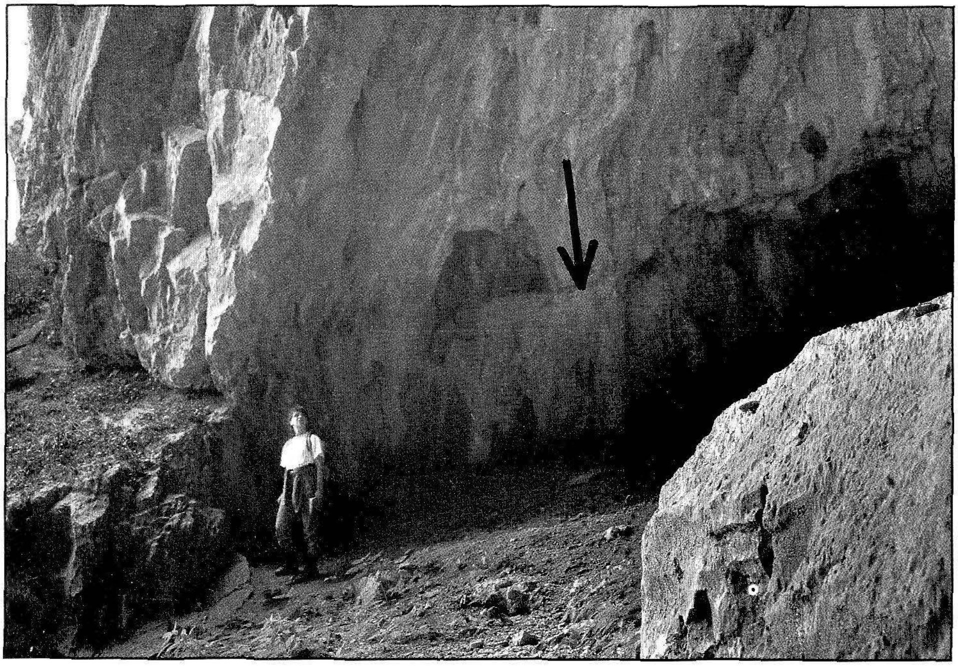

Fig. 3. Bedding plane labelled 400 (marked by arrow) above which variously large phreatic features are seen (Photo by M. Knez)
Sl. 3: Lezika z oznako 400 (označena s puščico) nad katero so različno velike freatične tvorbe. (Foto M. Knez).

sufficiently slow, the difference in resistance of the various paths may become insignificant, leading to similar rates of flow in all parts of the system.

In their relation to the stratum in which they are developed, a series of anastomoses exhibits a similarity to the cycle of stream erosion, and it is often convenient to speak of them in terms of their youth or maturity (Ewers 1966). In their early or youthful stage the tubes are small and cover a small fraction of the bedding surface. As they mature, they may cover nearly all of the under surface of their stratum.

A part of the under surface of the stratum is still clearly seen in the small remains of the former large scale "cheese-like structure" on the left side of the river Reka just in front of the ponor.

With the onset of old age their stratum is largely unsupported and in the case of thin or thick strata, breaching and collapse may occur (White 1988). Where anastomoses exist superposed on adjacent bedding planes, breaching and collapse may play an important role in the development of cavern passages or collapse dolinas as we have very illustrative example in Škocjanske jame.

On the basis of natural evidence and salt-block model experiments Ewers (1966) made some interesting conclusions which seem to be very similar to till now observed facts in Velika dolina (Škocjanske jame):

(1) Bedding-plane anastomoses are probably among the earliest solutional openings in soluble sedimentary strata. (2) They form in strata where bedding planes provide the most important avenues for ground-water percolation. (3) They continue to develop while flow rates are very small and the hydraulic head is large. (4) They cease to grow significantly when the system resistance becomes low. (5) Efficient flow paths through anastomoses may develop into cavern passage after head loss in the system. (6) Long, relatively straight tubes, resulting from the presence of minor fractures (joints), often provide the most efficient flow paths. (7) Anastomoses superposed on adjacent bedding planes may contribute to the formation of cavern passages through breaching and collapse.

In the literature one may find a similar

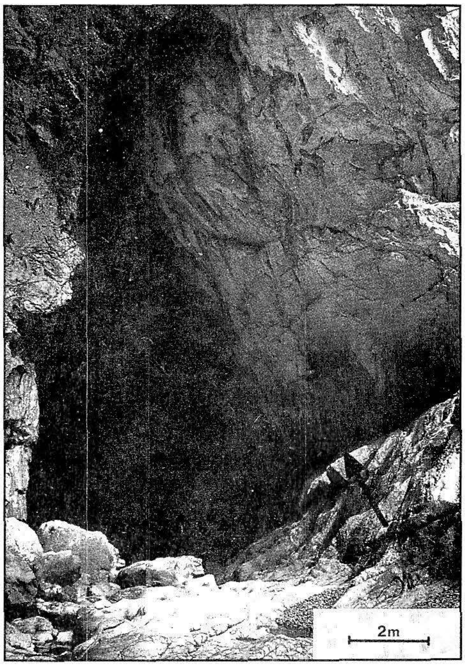

Fig. 4. Some of largest cross sections of channels reaches 20 meters. Ponor of river Reka. The arrow points the bedding plane labelled 500 (Photo by M. Knez)
Sl. 4. Nekateri preseki kanalov dosežejo 20 metrov. Ponor reke Reke. Poščica kaže leziko z oznako 500. (Foto M. Knez).

mechanism taking place, where you have horizonal beds, which the weight above tends to bend down, causing stress on the underside of the bedding. Then under solution, anastomoses would be formed. Some experiments with plaster of Paris were made and found out that solution is very definitely also stress dependent, if we talk about a total geologic system.

Therefore, cave segments may be guided by bedding planes, joints, faults, or intercepts of such fissures. Faults are surprisingly unimportant in many systems, stressed Ford and Ewers (1978)!

Whether bedding planes or joints plus faults are quantitatively the more important quides of cave segments can not be said. A priori, bedding planes should be more important, pointed out Ford and Ewers (1978), because they are continuous to the boundaries of the limestone mass or more nearly so. Joints are discrete features. In a great many cave systems there is a complex alternation of bedding plane-guided and joint-guided segments and it is apparent that the system could not have been created were not both simultaneously available for the transmission of groundwater.

I must agree with the observation remark of different authors who say that in any bedded limestone formation there are a great many bedding planes but only a small proportion are utilized during cave formation. This is very expressively seen in Velika dolina in Škocjanske jame.

In Velika dolina the lithostartigraphic column is aproximately 200 m thick. In this column 46 clear seen bedding-planes was found till now (There is not exact number because in the 164 m high vertical wall we didn`t deffine all of them yet). But there are only three (3) "trace bedding-planes" by which cave segments were guided before the colapse. So, only in not more than 6,5% of bedding-planes in Velika dolina important phreatic channels occur. We expect interesting results of proposed detailed researches.

Translated by Maja Kranjc

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FREATIČNI KANALI V VELIKI DOLINI (ŠKOCJANSKE JAME, SLOVENIJA)

Povzetek

Že od začetkov speleološke vede je pogled raziskovalcev usmerjen v odnose med geološkimi danostmi (kamnina, struktura) in oblikovanjem rovov. Raziskovalci slovenskega

kraškega podzemlja že dolgo beležijo na načrte jam tudi tektonske elemente, medtem ko je bilo pri proučevanju tvorbe rovov v kraškem podzemlju z vidika litopetrologije in stratigrafije narejenega malo. Delno so nakazani le nekateri parametri, večina pa je slutenih. Dejanski vpliv kamnine na razvoj podzemeljskih prostorov v prežeti coni (F. Šušteršič, 1991) bi bilo potrebno šele ugotoviti.

Sedanje poznavanje odnosov med tvorbo jamskih rovov in površinskih kraških oblik ter tektonskimi pojavi je znatno večje.

Različni avtorji (Čar 1986; Šebela 1992) danes poudarjajo pomen prelomnih con dinarske in prečno dinarske smeri (NE-SW ter NW-SE), ob katerih so se izoblikovali številni vodni rovi, kot naprimer v Planinski in Postojnski jami. Sedimentološke značilnosti kamnine so trenutno postavljene v ozadje.

Drugi avtorji (Čar & Gospodarič 1984; Garašić 1986, 1989) večkrat omenjajo vodne rove, ki potekajo po plastnatosti ali pa so aktivni vodni rovi usmerjeni pravokotno na nagubane sklade. Takega poteka vodnih rovov, vsaj v Postojnski jami (Gospodarič 1976), doslej ni bilo možno zadovoljivo pojasniti. Raziskovalci so tudi takšne povezave večinoma interpretirali le iz tektonskega zornega kota (Habič 1982).

O nasprotnem govori tudi podatek, da na področju Male gore ne prevladujejo dinarsko usmerjene razpoke, čeprav v jamah prevladujejo dinarsko usmerjeni rovi (A. Kranjc 1981, 44).

Ob kartiranju Najdene jame (Šušteršič & Puc 1970; Šušteršič 1982) se je pokazalo, da so rovi mnogo bolj prilagojeni smerem in vpadnicam skladnatega apnenca in dolomita kot smerem prelomov (Gospodarič 1982, 169).

Geološki podatki sistema Škocjanskih jam, ki jih predstavlja Gospodarič (1984, 30) kažejo, da se nahajajo dostopni rovi v turonijskem in senonijskem, pretežno debeloskladnatem apnencu ter v drobnoskladnatem apnencu maastrichtija in danija. Avtor meni, da se omenjena litološkostratigrafska razlika apnencev odraža v morfologiji rovov. Isti avtor (1986, 22) poudarja, da je s stališča zakrasevanja zanimiva litološko-petrološka sestava predvsem krednih skladov. O podobnih značilnostih krednih skladov pišejo tudi hrvaški geologi (Garašić 1986).

Poleg genetske zveze podzemni kanal-prelomna cona številni avtorji kot pomemben element oblikovanja podzemnih kanalov omenjajo tudi lezike (Sl. 1, 2; Waltham 1971, 1981; Ford & Ewers 1978, Čar 1982, Dreybrodt 1988).

Torej, deli jam se lahko oblikujejo po lezikah, vzdolž razpok, prelomov ali stikov posameznih elementov. Ford in Ewers (1978) poudarjata, da so prelomi v mnogih jamskih sistemih nepomembni!

Litostratigrafski stolpec v Veliki dolini (Škocjanske jame) je debel okrog 200 m. Tam je bilo do sedaj določenih 46 jasno vidnih lezik (natančno število lezik v 164 m visoki navpični steni še ni znano). Vendar od teh so samo tri (3) "vodilne lezike" v katerih so se izoblikovali pomembnejši jamski rovi (Sl. 3, 4). Torej, pomembnejši freatični kanali v Veliki dolini so se izoblikovali v ne več kot 6,5 % lezik. V nadaljevanju podrobnih raziskav pričakujemo zanimive rezultate.

IMPACT OF HUMAN ACTIVITY ON ŠKOCJANSKE JAME

ČLOVEKOV VPLIV NA ŠKOCJANSKE JAME

JANJA KOGOVŠEK

Izvleček UDK 502.3 : 551.442(497.12 Škocjan)

Kogovšek, Janja: Človekov vpliv na Škocjanske jame

Prispevek podaja kvaliteto reke Reke, ki ponika v Škocjanske jame in sicer od prvih italijanskih meritev v začetku tega stoletja, sistematičnih meritev v letih 1969-79, ki jih je opravil Inštitut Boris Kidrič, Ljubljana, do analiz Inštituta za raziskovanje krasa ZRC SAZU iz Postojne. Podana je kvaliteta prenikajoče vode v Škocjanskih jamah, ki je, z izjemo curka v Tihi jami in močno onesnaženih curkov v Mahorčičevi in Mariničevi jami, vzdolž Tihe in Šumeče jame ter Hankejevega kanala, še čista.

Ključne besede: krasoslovje, hidrologija, človekov vpliv, kvaliteta vode

Abstract UDC 502.3 : 551.442(497.12 Škocjan)

Kogovšek, Janja: Impact of human activity on Škocjanske jame

The article deals with the quality of the Reka river which sinks in Škocjanske jame from the first Italian measures at the beginning of the century to systematic observations in the years 1969-79 done by the Institute Boris Kidrič, Ljubljana and later measurements and analyses done by Karst Research Institute ZRC SAZU, Postojna. It treats the quality of the percolating water in the area of Škocjanske jame (measurements and analyses of the Karst Research Institute) and infers that with the exception of the trickle in Tiha jama, which has the increased values of nitrates contents and Mahorčičeva and Mariničeva jama with strongly polluted percolated water, the percolating water along Tiha and Šumeča jama and Hankejev kanal is still pure.

Key-words: karstology, hidrology, human impact, water quality

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INTRODUCTION

Wastes, thrown on the karst surface, in the dolines and pot holes are dissolved and the polluted water is washed into the karst underground. In addition to this pollution the sinking rivers contribute their amount of polluted water for in most cases the communal waste waters discharge directly into them. The occurrence of dark stains along the tourist walk-ways, where the polluted water percolates, smell resulting of decomposition of organic impurities, in particular in heavily polluted sinkstreams and various many-coloured packings transported by the sinking streams into the underground where it is deposited in some calm places does not speak in any case of well displayed karst cave.

The protection of natural heritage on the karst does not mean the protection of the underground only but also the surface above it as they are tightly connected (the precipitations and the pollution within them could appear in a cave after half an hour already). If a sinking river flows through the cave the assurance of the water quality in the underground means that the quality must be safeguarded on the entire superficial flow.

Our researches in Škocjanske jame included the study of the quality of percolated water in various parts of the cave. Systematic researches lasted for several years in Tiha jama, seasonally in Hankejev kanal and in Tominčeva and Mahorčičeva jama. The quality of the Reka river was observed seasonally too.

THE QUALITY OF THE PERCOLATED WATER

In percolated water in Tiha jama no pollution was registered. The chlorides, nitrates and o-phosphates contents were very low. On one point only the increased nitrates content (30 $mgNO_3^- l^{-1}$) was registered due to intensively cultivated field on the surface. Along Šumeča jama, in Tominčeva jama, in Svetinova dvorana and in Hankejev kanal no values indicating the pollution were registered (Kogovšek 1984).

Unfortunately the same cannot be said for Mahorčičeva and Mariničeva jama. On the surface above the cave a small village lies, inhabitants cultivate the land, sewage system does not exist, thus the waste waters discharge directly into the karst. The cave ceiling is from 50 to 80 m thick. In the year 1992 the percolated water was analysed several times in order to find out the actual state.

In August, during drought, we did not succeed to take the samples and we explain the fact by small amount of the waste water. After the rainfall in June and October the drops on some places developed into abundant trickles indicating that the waste waters were strongly diluted by the rainfall. The water of particular trickles was polluted in various degree. The most were polluted the trickles in the central part where dark stains were perceived on the ceiling. Thus the measured values of the specific electric conductivity did not surpass 700 $\mu S\ cm^{-1}$, but the caught water in the solution cups indicated considerably higher values - more than 1000 $\mu S\ cm^{-1}$ - and at the same time the highest values of nitrates (175 mg $NO_3^- l^{-1}$), sulfates (63 mg $SO_4^{2-} l^{-1}$), chlorides (49 mg $Cl^- l^{-1}$) content together with high values of COD (24 mg $O_2\ l^{-1}$) in comparison with freshly taken samples of infiltrated water.

In freshly infiltrated water we have measured up to 85 mg $NO_3^-\ l^{-1}$ of nitrates, up to 5.5 mg $PO_4^{3-}\ l^{-1}$ of phosphates, up to 53 mg $SO_4^{2-}\ l^{-1}$ and up to 16 mg $Cl^-\ l^{-1}$ of chlorides. The water had the COD up to 8.7 mg $O_2\ l^{-1}$, and BOD_5 did not surpass 2 mg $O_2\ l^{-1}$. The difference in quality among the particular trickles was registered. Obviously the pollution is considerable but it must be defined it in future more in detail in order to find out the capacity of the autopurification through the cave roof. Maximal registered values of measured parameters of the percolated water in Mahorčičeva and Mariničeva jama are gathered in Table 1.

TABLE 1

Polluted infiltrated water in Mahorčičeva and Mariničeva jama - maximal registered values

infiltrated water	SEP	Cl^- µS/cm	NO_3^- mg/l	SO_4^{2-} mg/l	PO_4^{3-} mg/l	COD mgO_2/l	BOD_5 mgO_2/l
fresh water	656	16	85	53	5.5	8.7	1.7
in sol. cups	1060	40	175	63	1.1	29	3.5

THE QUALITY OF THE REKA RIVER

G. Timeus (1912) cites the results of the first measurements of Reka at the end of the last and at the begining of this century already, when its quality could still be compared to the quality of Bistrica in Ilirska Bistrica. Some values are given in Table 2 for comparison with later measurements.

But in this century due to progressive industrialization and urbanization the pure Reka had to receive more and more untreated waste waters. The decrease of its quality was observed before 1960 already. The first serious warning happened when in 1966 the capture of Reka was stopped for the Divača water supply. In the years 1969-79 systematic 24-hours observations of Reka in Ilirska Bistrica, in Nova Sušica and in Matavun followed. B. Mejač, M. Roš, M. Dular, M. Rejic and P. Ponikvar- Zorko (1983) reported about the results.

According to the measurements from 1969-1979 the ratio COD/BOD_5 in Ilirska Bistrica was 1.5 which means that the pollution mainly consisted of organic matters having fast decomposition and using all the oxygen transported by Reka into Ilirska Bistrica. In Matavun this ratio was 2.5 to 5 which means that easy degradable organic substances were up to Matavun in general decomposed and the ratio of hardly degradable substances increased. In that time Reka was on the section Ilirska Bistrica - Nova Sušica a virtual sanitary sewer where intensive anaerobic processes of decomposition have taken place. Such decay is accompanied by gas and easy volatizable products causing an odour in the valley of Reka and in Škocjanske jame which was unpleasant surprise for the visitors.

In particular unfavourable effects to the Reka quality were caused by heavy short lasting showers which released the seasonal increase of pollution washing off and transporting the sedimented particles from the bottom of the river bed, the decay products originating during the decomposition and the biomass even. When the water lowered its transport power decreases as well and the conditions for progressive resedimentation of the suspended particles arise, this time in downstream direction, in Škocjanske jame and further in the underground where anaerobic processes start again. A. Mihevc (1984) reported on the methane gas in Kačna jama. When Reka leaves Škocjanske jame it reappears after 1.5 km (aerial distance) of subterranean flow in Kačna jama. A. Mihevc reports about the channels in lower level of Kačna jama where a typical smell was felt and he linked it with piles of decomposed leaves and other organic material and brushwoods accumulated on the bottom and he mentions the methane gas in such a quantity that it could be lighted.

The example clearly shows that in case of excessive pollution received by Reka, the solid impurities are in great extent deposited on the bottom of the river bed. Under certain circumstances this pollution is carried over by the water stream, from the surface deep into the karst underground. It is not only the pollution of the underground with the impurities dissolved in the river, but with solid organic substances which need for their decay much more oxygen and much more time. The same was inferred by the researches of the polluted percolated water in Pivka jama (Kogovšek 1987) and by the measurements of the Nanoščica brook quality at the occasion of liquid manure spill (Kogovšek 1992).

In 1982 the daily quantity of pollution from the Factory of the organic acids and Lesonit from Ilirska Bistrica was diminished for one third due to various measures. Although even the analyses of the Reka showed the diminishing for one third the total pollution received by Reka was to far too big to be autopurificated. Obviously the measures of pre-purification should be followed by construction of common biological treatment plant.

The Karst Research Institute has analysed in the second half of 1981 and in 1982 within the percolated water sampling in Škocjanske jame the water of Reka river five times. BOD_5 and dissolved oxygen at the ponor to Škocjanske jame were analysed. BOD_5 oscillated from 2.9 to 8.5 $mgO_2\ l^{-1}$, the contents of dissolved oxygen was from 10 to 12.1 $mgO_2\ l^{-1}$, or 78 to 103% of saturation with oxygen being the contents of the dissolved oxygen inversely proportional to the values of BOD_5.

From July 1982 to June 1983 we observed the Reka quality near Ribnica with monthly sampling. The water temperature oscillates between 3 and 19^{0}C, specific electric conductivity between 254 and 672 $\mu S\ cm^{-1}$, the chlorides content between 3 to 30 $mgCl^-\ l^{-1}$, nitrates between 0.3 to 2.7 $mgNO_3^-\ l^{-1}$, phosphates below 0.35 mg $PO_4^{3-}\ l^{-1}$, dissolved oxygen oscillated between 0 and 10.1 $mgO_2\ l^{-1}$, BOD_5 was from 8.5 to 48 $mgO_2\ l^{-1}$ and more, as we several times used to small a dilution. Low values of dissolved oxygen and the highest

BOD_5 occurred during low water level; in October, November, December and March the oxygen content was higher, BOD_5 usually lower.

Seasonally though the improvement of the Reka quality was observed probably due to pre-purification in the factories Lesonit and Organic acids. But, from time to time the quality was extremely bad and we suspected that the water is retained and later released in bigger quantities from the industrial plants into Reka.

In autumn 1990 the production in the factory of the Organic acids was stopped and very soon the positive changes in the Reka river were seen. The abatement of pollution indicated what a burden were the waste waters from the factory of Organic acids, in particular huge amount of undegradable pollution. Within the Karst Research Institute we have analysed Reka in Mahorčičeva jama several times in connection with water studies in Škocjanske jame.

On December 18, 1991 at low water table COD was 7.5 $mgO_2\ l^{-1}$, on June 6, 1992 the COD was 6.1, BOD_5 was 2.3 $mgO_2\ l^{-1}$ at 100% of saturation with oxygen. On October 8, 1992 at medium water level the COD was 6.9 $mgO_2\ l^{-1}$, on October 23, 1992 at high water level we have measured the COD of 3.3 $mgO_2\ l^{-1}$. The nitrates and chlorides concentration was at all the measurements below 5 mg l^{-1}, o-phosphates were below 0.12 mg l^{-1}.

In considerably less loaded river the autopurification processes started again. During extremely low water level in July 1993 we analysed the water of Reka in Svetinova dvorana again. COD was 12, BOD_5 2 mg $O_2\ l^{-1}$ only. Chlorides and nitrates were low 5 mg l^{-1} as they were in 1992 too, and nitrates were below 0.01 mg l^{-1}. The ration COD/BOD_5 was 6 even which is probably due to absence of dilution because of low water table. The decomposi-

TABLE 2

Reka river quality

	Il.Bistrica	Matavun
1974-79		
BOD_5 ($mgO_2\ l^{-1}$)	100 - 200 (400)	10 - 15
COD "	160 - 300 (700)	25 - 80
Dissol. Oxigen "	0.1 - 0.5	5 - 8
COD/BOD_5	1.5	2.5 - 5
1981-82		
BOD_5 ($mgO_2\ l^{-1}$)	2.9. - 8.5	
Dissol.Oxigen "	10.0 - 12.1	
1991-92-93		
COD ($mgO_2\ l^{-1}$)	3.3 - 12	
BOD_5 "	1.3 - 2.3	
COD/BOD	2.7 - 6	

tion of degradable substances was all the same successful while the one of the non-degradable components obviously less. At high water level in October 1993 the COD was 7, BOD_5 1.3 $mgO_2 l^{-1}$, the ration COD/BOD_5 was 5.4. All results are in tabel 2.

Literature treating the autopurification ability and its results at karst waters flow over the surface and in the underground (Preka & Preka-Lipold 1976; Sket & Velkovrh 1981; Kogovšek 1991) and the knowledge of the effects at vertical percolation of the polluted water through the carbonate rocks (Kogovšek 1987) gives the basic information on otherwise not well known proceeding of the autopurification processes in the underground.

The above mentioned results indicate rather improved quality of the Reka river on its ponor to Škocjanske jame. Pollution flowing into the river is in some extent eliminated on its way to the ponor. The actual ratio COD/BOD_5 nevertheless shows the presence of hard degradable pollution due to gradual washing off out of the river bed after purification of degradable substances, or else it is a property of the actual waste waters. In any case the improvement is considerable but we must find out the source of hard degradable pollution.

Translated by Maja Kranjc

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ČLOVEKOV VPLIV NA ŠKOCJANSKE JAME

Povzetek

Onesnaževanje kraškega površja ogroža tudi kraško podzemlje. Odpadne vode, ki se stekajo v kraške ponikalnice se tako pojavljajo v podzemju, kot tudi onesnaženje ki prenika s kraškega površja. Takih vidnih primerov je kar precej, zato je pomembno preučevanje vrste onesnaženja, hitrosti pojavljanja v podzemlju ter procesov samočiščenja v krasu, kar je pomembno za varovanje zalog kraške pitne vode, kot tudi kraškega podzemlja kot naravne dediščine.

Gradnja industrije v dolini Reke, predvsem v Ilirski Bistrici, je povzročila postopno slabšanje Reke do leta 1966, ko so zaradi slabe kvalitete ustavili zajetje Reke za vodovod v Divači. To je sprožilo tudi sistematične raziskave kvalitete Reke v letih 1969-79, ki jih je opravil Inštitut Boris Kidrič. Reka je imela v Ilirski Bistrici visoko kemijsko potrebo po kisiku (KPK) in biokemijsko potrebo po kisiku (BPK_5), razmerje KPK/BPK je znašalo 1.5 in ni vsebovala raztopljenega kisika. Tako je bila Reka na odseku Il.Bistrica - Nova Sušica praktično odvodni kanal. Do Matavuna, ponora v Škocjanske jame, se je njena kvaliteta izboljšala, vendar je voda vsebovala še vedno le malo raztopljenega kisika, razmerje KPK/BPK_5 pa je znašalo 2.5 do 5, kar je kazalo na znatno večji delež težko razgradljivih in nerazgradljivih organskih nečistoč v primerjavi z lahko razgradljivimi. Najbolj neugodne razmere so nastopale v Matavunu ob intenzivnih nalivih, ko se je občasno močno poslabšala kvaliteta Reke na ponoru, saj je vodni tok spiral organsko onesnaženje iz struge v zgornjem toku Reke in ga nosil s seboj, tako, da je prišlo do njegove sedimentacije tudi globoko v kraškem podzemlju, Škocjanskih jamah in dalje v Kačni jami, kjer pa so se nadaljevali anaerobni procesi razgradnje. Kasnejše spremljanje kvalitete Reke, posebno po letu 1990, ko je prišlo do vidnega izboljšanja Reke zaradi zaprtja tovarne TOK v Ilirski Bistrici, je pokazalo znatno izboljšanje njene kvalitete in upad vrednosti merjenih parametrov, tako da so v Reki lahko zopet potekali samočistilni procesi. Vendar pa je bila ob nizkem vodostaju v letu 1993 KPK kar 12, razmerje KPK/BPK_5 pa 6, kar nakazuje sorazmerno večji delež težko razgradljivih organskih snovi v primerjavi z lahkorazgradljivimi.

Vzorčevanja in analiziranje preniklih voda v različnih delih Škocjanskih jam so pokazala v večini primerov še čisto vodo, z izjemo curka v Tihi jami, ki ima povišane nitrate zaradi intenzivneje obdelane njive na površju ter curkov v Mahorčičevi in Mariničevi jami. V te curke priteka tudi odpadna voda iz naselja Škocjan na površju po prenikanju skozi 50 do 80 m debel jamski strop. Očitno je količina odpadnih voda majhna, saj so ob suši le posamezna kapljanja. Ob dežju pa se pojavljajo v jami večji curki onesnažene vode, ki kljub precejšnjemu razredčevanju dosega do 85 mgNO_3^- l^{-1}, do 5.5 mg PO_4^{3-} l^{-1}, do 53 mg SO_4^{2-} l^{-1} in do 16 mg Cl^- l^{-1} ter KPK do 8.7 mg O_2 l^{-1} in BPK_5 do 2 mgO_2 l^{-1}. Hitro in direktno prenikanje odpadnih voda skozi jamski strop onemogoča učinkovito samočiščenje, zato bi bilo potrebno odpadne vode na površju čistiti, odtok očiščene vode pa speljati izven območja jam, kjer bi v karbonatnem masivu prišlo do dokončnega samočiščenja te vode.

ABOUT THE NAME AND THE HISTORY OF THE REGION KRAS

O IMENU IN ZGODOVINI POKRAJINE KRAS

ANDREJ KRANJC

Izvleček UDK 001.4 : 551.44

Kranjc, Andrej: O imenu in zgodovini pokrajine Kras

Avtor podaja zgoščen pregled, kako je iz antičnega pokrajinskega imena "Carusadus (Carsus)" nastalo slovensko ime "Kras" in iz njega mednarodni strokovni termin "kras (karst)". Meni, da pokrajina Kras ne potrebuje pridevnika "matični" ali "klasični", pač pa bi "matični kras" moral obsegati, če že ne vsega slovenskega dinarskega krasa, vsaj ves primorski in notranjski kras.

Ključne besede: krasoslovje, zgodovina krasoslovja, imenoslovje, Slovenija, Kras.

Abstract UDC 001.4 : 551.44

Kranjc, Andrej: About the Name and the History of the Region "Kras"

A condensed review how from the antique regional name "Carusadus (Carsus)" the slovene name "Kras" sprang up and from it the international professional term "Kras (Karst)". The author thinks that the region Kras does not need the adjective "Mother" or "Classical", but "Mother Karst" must include, if not the whole slovene dinaric karst at least the karst of Littoral and Notranjska.

Key words: karstology, history of karstology, terminology, Slovenia, Kras.

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ABOUT THE NAME AND THE HISTORY OF THE REGION KRAS

In the ancient Greece and Rome the karst phenomena were well known:

- Zeus passed its childhood in the cave on Mt. Ida,
- Hermes hid the cattle stolen from Apollo in the cave,
- in the Greek mythical underground Styx and Letho rivers flow,
- the Romans shouted at the entrances to the potholes during the Lemuraliae: "Mundus subterraneus patet!" if I mention some small points of interest only.

Two karst phenomena from the actual Kras were famous in particular - Reka sinking into Škocjanske jame and Timavo karst springs which were already mentioned by the authors before Christ.

The landscape named Kras entered the history by the Roman assault upon this area in the 2nd century B.C. (178 and 177) (Curk 1976) and by its occupation and later annexation into the Roman Empire. Kras and karst pecularities were mentioned among the navigation itineraries - periplos (Pseudoskilax's Periplos from the middle of 4th century B.C.) (Suić 1955). Posidonios of Apameia (135-50 B.C.) studied Timava springs and mentioned Škocjanske jame (Baucer 1663; Clozier 1972), Vergilius (70 - 19 B.C.) mentioned these resurgences in Eneida, the martyr St. Servus (Socerb) (killed in 284) lived in the Sveta jama cave near the actual castle of Socerb.

The classical name of the actual Kras should be "Carusadus, Mons Carusad, or Karusad, Carsus" (Gams 1973; Linhart 1788) and similar forms which have for sure the pre-indoeuropean root "ka(r)a/ga(r)a" - stone (Rostaing 1974). Carniola, Carnia, Karavanke Mts. etc. have probably the same origin. The ancestors of actual Slovenians, Slavic tribes came over the Eastern Alps and Pannonian plain and reached the Vipava valley about the year 600, and for the year 804 we know the Slavic peasants were settled already in Istria and peacefull as well as aggressives contacts with old (romanised) inhabitants were reported (Paulus Diaconus 1988) and that surely contributed to the preservation of the topographic name as well.

The oldest known slovene form of the name Kras is "Grast" in the chart of 1177 (Kos 1915) where we meet the early slovene liquid metathesis "kar-" into "kra-" (Gams 1973). What were the boundaries of the Kras in the Antiquity is hard to delimite, but probably the area was not a lot different than the actual Kras is: between the Adriatic and the Vipava valley, between the Friuli plain and Čičarija, Brkini and Pivka. The inhabitants were called "Kraševci" and it was, according to Valvasor equally wide term as Pivčani, Notranjci or Gorenjci.

With New Age, when sciences, discoveries, travels began to flourish, when the print was discovered, Kras was becoming more and more known. First were geographers, cartographers, cosmographers, and topographers (Aistingerus, Cluverius, Mercator, Merian, Münsterus, Ortelius), scientists of the epoch (Agricola, Baucer, Faber, Kircher) and the travellers (Brown) who published the descriptions of Kras and its phenomena, later the predecessors of nowadays sciences as geographers, geologists, and hydrographers (Kranjc 1989).

The geographical, geopolitical, and political situation during 16. - 19. centuries were the reason why just Kras became the synonyme for the "karst phenomena" and not some other part of the Europe and specially of the Balkans, were such phenomena are often more important and more tipically and spectacularly developped:

- part of Kras, Istria and the Triest were Habsburg (Austrian) domaine, Triest got the status of "free port" in 1719;
- most of Istria and Dalmatia were Venetian territory;
- the inner part of Balkans was in Otoman Empire, with unsafe and dangerous border regions;
- the lowest passes between the Middle Europe and Danube regions connecting them with Adriatic Sea go across Kranjska (Carniolia) karst.

For the passengers, who travelled from Middle Europe across the Eastern Alps towards Triest, the only possible route passed Kras and there was the only authentic "karstic" landscape during the whole journey. In that time Kras was barren, rocky, deserted land, hot and dry in summer, with icy "burja" (=boreal) wind and snow-drifts in winter leaving a deep impression on the passengers. Kras passes can not be compared with the Saint-Bernard pass, but also on Kras the passengers had to wait appropriate weather, had to take water and food, and were happy when the blue sea and Triest emerged in front of their eyes.

So the original and specially the German form of the Slovenian Kras, Karst respectively, entered the common description of a special kind of landscape and slowly appeared in the international scientific terminology, with variations according to different languages: Karst and Carso. Karst is one of the rare types of relief, which is called after the regional name. One who contributed a lot that the "karst" entered the international terminology, was without doubt Jovan Cvijić with his fundamental work "Das Karstphänomen", published hundred years ago (1893).

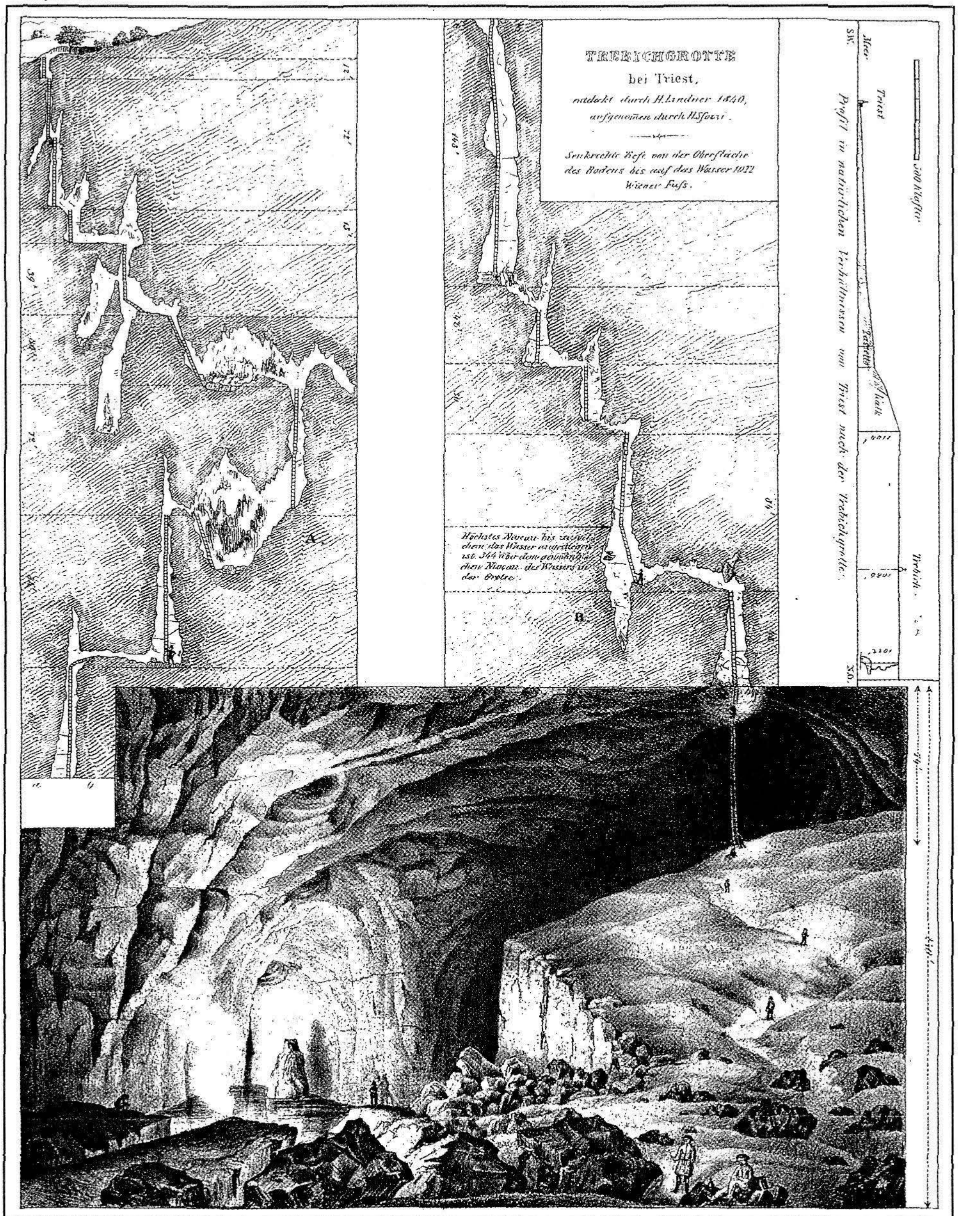
Among the scholars who essentially contributed to the understanding of our karst and to putting into force its name we must mention at least two who were interested in the karst hydrology in particular. In 1599 Father F. Imperato tried to prove, to ascertain respectively by the help of floaters the connection between Reka, sinking into Škocjanske jame and the Timavo springs. The Jesuit A. Kircher (1678) is the author of the idea of "hydrophilatia", it means huge underground water basins which are fed by siphons from the sea and drain the water to big karst springs and are also the reason for the floods on the karst poljes. His hypothesis is supported by two examples from our karst: Cerkniško polje and Timavo springs, the water flowing below the Timavus Mons, being a part of Pennine Alps and an example of direct outflow of hydrophilatium into the sea (Kranjc 1992).

I shall not extra speak about the Valvasor's work I'd like to mention only that he may be

Sl. 1.: Izsek iz karte W. Laziusa - A. Orteliusa "Goritiae, Karstii, Chazeolae, Carniolae, Histriae et Windorium Marchae Descrip(tio) 1561, 1573", na kateri sta narisani tek Reke in vas Škocjan "ubi Recca flu, absorbetur, et in Timaui fontibus erumpit" ter zapisano ime "Karst".

Fig. 1: A part of W. Lazius's - A. Ortelius's Map "Goritiae, Karstii, Chazeolae, Carniolae, Histriae et Windorium Marchae Descrip(tio) 1561, 1573", where the Reka river flow and the village Škocjan are drawn "ubi Recca flu, absorbetur, et in Timaui fontibus erumpit" and the name "Karst" is written.

Tafel III.



Sl. 2.: Brezno Labodnica, priloga III Morlotovega dela "Über die geologischen Verhältnisse von Istrien" (1848).

Fig. 2.: Grotta Trebiciano, the 3rd annex to Morlot's work "Über die geologischen Verhältnisse von Istrien" (1848).

considered as the author of the first "comprehensive" Kras description and not only of single karst phenomena and curiosities which, obviously, are not missed in his topography (Kranjc 1990).

The work of B. Hacquet, his Oryctographia Carniolica (1778, 1781, 1784, 1789) in particular, although in other works too he treats karst, and his importance for the understanding of karst, slovene Kras and karstology in general are not yet valued by the same way as it was done by J. Wester (1954) for Hacquet as the first investigator of our Alps. On one hand Hacquet described in detail particular (actual) Slovene countries or their parts and on the other hand he is probably among the first who estimated karst as an exceptional phenomena, as a geological and hydrological speciality. By detailed review of his work one must find out in which degree he speaks about "karst" phenomena, about "karst" rocks as a general conception and the positive answer should place him among the first considering karst as a phenomenon and not only as a regional or single curiosity.

In 19th centry the geologists and the geographers essentially contributed that the regional name Kras entered the general geological and geomorphological terminology. A. v. Morlot (1848) speaks in the commentary to his geological map of Littoral and Istria about "karst limestone" (Karstkalk) and about "karst landscape" (Karstland) (Fig. 2). A. Schmidl (1854) writes about the characteristic orographic shape "terraced mountains of Kras" including the whole Istria and Dalmatia. J. Lorenz (1858) too states in his works that it is not correct that the name "Kras" is given to the area between Vrhnika and Triest only as the Liburnian "Kras" is not the least different. W. Urbas (1874, 1877) distinguishes within the Slovene karst the karst of Primorska, Notranjska and Dolenjska.

Thus in the second half of 19th century Kras became on the dinaric landscape the synonym for the "karst landscape" and later synonym for each area on the limestone or for any landscape or phenomenon which are karstic or similar to karst. Beside correct expressions of the lava tubes or caves in ice we frequently meet the word karst on the glaciers or in lava, which is wrong but indicates the continuing process of widening the conception of karst. E.A. Martel, considered by mostly French speaking circles, according to my view unduly, as the initiator of modern speleology and science about karst, did not like the neologismes and he strictly refused the use of the adjective "karstic" for the occurrences and processes on limestone. Instead of today generally used "karstification" and "phénomènes karstiques" he wrote about the "phénomènes du calcaire" (Martel 1894). In spite of his great authority, also out of France, he did not succeed: today on the whole world we speak about karst, almost all civilized nations use for karst and karst processes the terms derived from the name of our Kras with exception of Chinese who use for the process of "karstification" the chinese expression "to gnaw at the stone".

In the Slovene speaking former Austrian lands, in Slovenia respectively, there remained two partly unsolved questions connected to term "kras".

The laymen often have problems to distinguish "Kras" and "kras" (the name of the country and the name of the phenomenon). Despite the name of the country has to be written in capital first letter, misunderstanding can occur. Therefore frequently the descriptors as "Tržaški" (= Triestin), "Tržaško-komenski" (Triest-Komen) and similar were added, after the Second War omitting the name Triest. In the sixties the geographers suggested the solution and introduced the expressions as "Classical" or "Mother" Kras ("klasični" or "matični" kras) (Radinja 1966). Trying to stress the original country Kras (where the word derived from), i.e. original Kras, Kras in proper sense of meaning, Kras strictly speaking, Karst "proprement dit" as say the French, the idea is good and would be used mostly when we write in a foreign language as the foreigners, the experts included (who anyway used the form "karst") hardly distinguish between Kras and kras. Unfortunately these two adjectives, "classical or mother" are more and more frequently used when we write about the landscape Kras in the Slovene language which is superfluous as we have only one region Kras and there could not be a doubt about which area we write.

The second question includes the extent, the limits respectively of "classical" or "mother" karst. When it comes to Kras the matter is clear. By using the words "classical" or "mother" in connection with Kras we make ourselves a bad turn, according to my view, as we narrow the "classical karst", which should be from the universal point of view the reference karst to the region Kras where many a "classical karst phenomenon" is missed. For the describers and explorers in the past centuries up to the First World War "classical Karst" meant all the karst of Carniola, this is the area which is called nowadays the "Slovene Dinaric Karst". In the oldest topographies as well as in the "classical" karstological works three "classical" karst phenomena are mostly known from the Carniola: Kras, Cerkniško jezero and Postojnska jama. I do not see the reason why we should like to cancel the last two from our "classical Karst" hence I submit: Kras should remain Kras only (if it is necessary an explanation in a foreign language we may use "strictly speaking", "proprement dit" etc., while "classical karst" and "Mother Karst" should mean the "Slovene part of the dinaric karst". In the time of "classical" explorations of the actual Slovene karst, the town Pivka, f.e. was still called Šempeter na Krasu (St. Peter on Karst). That my opinion about the "Mother Karst" is shared by the foreign karstologists is the best evidenced by the fundamental work of the history of cave science written by T.R. Shaw (1992).

Translated by Maja Kranjc

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O IMENU IN ZGODOVINI POKRAJINE KRAS

Povzetek

Kraški pojavi kot tudi naš Kras so bili v antiki že dobro znani, s Krasa ponikanje Reke v Škocjanske jame in izviri Timave. Kras je prišel v zgodovino z rimskimi napadi na te kraje v 2. stol. pr. n. št. pod imenom Carusadus, Mons Carusad, Carsus in podobnimi oblikami iz predindoevropejskega korena "ka(r)a/ga(r)a" - kamen. Predniki današnjih Slovencev so dosegli Vipavsko dolino okoli l. 600 in za l. 804 vemo, da so se slovenski kmetje naseljevali v Istri in imeli stike s staroselci, kar je pripomoglo h kontinuiteti topografskih imen. Najstarejša znana slovenska oblika za Kras je "Grast" zapisana 1177.

Geografska, geopolitična in politična situacija od 16. do 19. stoletja je bila vzrok, da je ime Kras postalo splošni pojem, termin za "kras" in za "kraške pojave ter procese": Kras je bil pod Avstrijo oziroma Habsburžani, Dalmacija pod Benečani, notranjost Balkana pa pod Turki; najnižji prevali med Jadranom in Srednjo ter Podonavsko Evropo vodijo preko kranjskega Krasa. Popotniki in učenjaki so pričeli opisovati to pokrajino in njene značilnosti ter kraške pojave, v 18. in 19. stoletju pa so strokovnjaki te pojme širili tudi na druge podobne pokrajine.

Med slovenskimi pisci je danes težnja, da se imenu Kras dodaja razne pridevke, predvsem Matični ali Klasični. Menim, da je to nepotrebno, saj ne smemo pozabiti, da je Kras le eden. Pač pa bi moral "Matični ali Klasični kras" po mojem pomeniti "slovenski dinarski kras" ali vsaj pokrajino med Ljubljanskim Barjem in Jadranom, med Furlansko nižino in Blokami, saj so "klasični" kraški pojavi v svetovnem smislu Cerkniško jezero, Postojnska jama in Kras.

HYDROGEOLOGICAL ASPECTS OF CRETACEOUS LIMESTONE KARST IN WESTPHALIA, FRG

HIDROGEOLOŠKE ZNAČILNOSTI KRASA NA KREDNIH APNENCIH V VESTFALIJI (ZRN)

E. P. LOEHNERT

Izvleček UDK 556.34 (435.6)

Loehnert, E. P.: Hidrogeološke značilnosti krasa na krednih apnencih v Vestfaliji (ZRN)

Izvir Pader v Paderbornu (Zvezna država Severno Porenje - Vestfalija) je glavni iztok iz zbirnega območja, ki ga predstavlja na jugovzhodu ležeči odprti kras paderbornske "Visoke planote". Glavne smeri podzemeljskega toka so znane že skoraj sto let, zahvaljujoč številnim sledenjem. Za vodo ponikalnih potokov, ki so bili pred kratkim sledeni, je dokazano, da se ponovno pojavlja v globokih vrtinah, odkoder dobiva mesto vodo in sicer tako, da iz njih črpajo "ujeto" talno kraško vodo. Skladno s tem je torej ves sistem med seboj hidravlično povezan, kar ima neposredne posledice tako za količine vode v izvirih kot tudi za varovanje pitne vode.

Ključne besede: globoki kraški sistem, prosta/zajezena voda, zgornjekredni apnenci, izvir Pader.

Abstract UDC 556.34 (435.6)

Loehnert, E. P.: Hydrogeological Aspects of Cretaceous Limestone Karst in Westphalia, FRG

The Pader Springs of Paderborn (Federal State of Northrhine-Westphalia) constitute the main outlet of recharge taking place over the open karst High Plateau to the south-east. Principal underground flow directions are known for almost hundred years due to numerous tracer tests. Traced water of losing streams was recently proved to reappear in deep boreholes of the City Works withdrawing groundwater under confined karst conditions. Consequently, the whole system is hydraulically interconnected, with practical implications for both spring discharge and drinking water protection.

Key words: deep karst system, unconfined/confined conditions, Upper Cretaceous limestones, Pader Springs, second largest spring in Germany.

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INTRODUCTION

This paper is aimed at summarising two contributions by the author to the "Classical Karst - International Karstological School", Lipica, and the International Symposium "Man on Karst", Postojna, entitled

- Specific karst features in Westphalia (Germany) and
- Interpretation of environmental isotope data in karst waters of Paderborn (Northrhine-Westphalia, Germany), respectively.

Most of the facts and findings presented at these congresses are published but not all of them are in English nor in easily available journals either. It might, therefore, be justified to draw the attention of interested karst's researchers to a small but attractive subject, the aquifer system of Paderborn located in the eastern part of the federal state of Northrhine-Westphalia (Fig. 1). For graphs, diagrams, maps, sections etc., the reader is referred to the list of selected references below.

HYDROGEOLOGICAL SETTING

The karst aquifer system under consideration is located within Upper Cretaceous calcareous sediments at the eastern margin of the bowl-shaped Münster basin which contains marine sediments of up to 1800 m thickness in the centre. Three hundred meter thick of limestones and marlstones of Cenomanian, Turonian and Lower Coniacian age are uplifted along the southeastern margin of the basin forming the Paderborn High Plateau, an area of approximately 300 km^2. This plateau and parts of the neighbouring Egge Mountain constitute the recharge area of the Pader springs at Paderborn with a discharge rate of 4-5 $m^3 s^{-1}$ as the second largest spring in Germany (after the Aach spring in Swabia).

Typical karst features such as dolines, dry valleys, sinking streams, estavelles etc. are encountered at the high plateau. With respect to underground flow conditions, tectonic faulting and fracturing seem to play a major role. Underground flow paths were delineated by Stille (1903) and subsequent researchers, which represent the paths taken by lost water in stream beds to emerge in the Pader springs. This, however, represents only a minor portion of the recharge, the major portion being derived from rainfall over the plateau area.

The Pader springs including others with smaller discharges emerge along a line which separates the open from the confined system. Northward from this dividing line, the fractured-karstified strata dip beneath impervious clayey-marly sediments of Upper Cretaceous

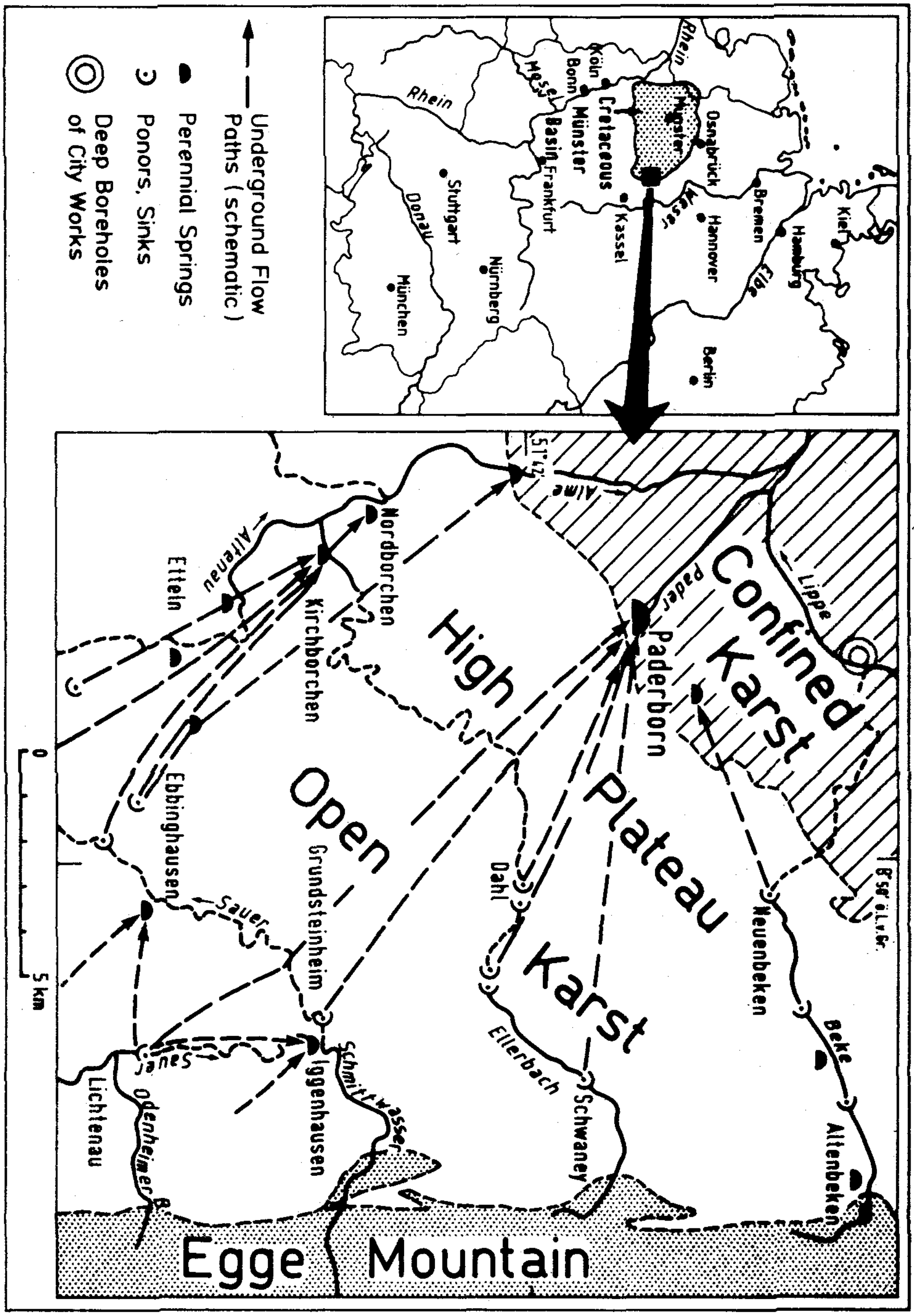

Fig. 1: Location Map.
Sl. 1: Pregledna karta.

age. Beneath this impervious cover, deep boreholes of the City water works abstract roughly 10 million m^3 fresh water per year. It has been a point of controversy whether this amount of water could be proved as deficit in the Pader springs. The author of this paper succeeded in proving the interrelationship by applying different techniques, among others, conventional tracing.

PREVIOUS AND CURRENT RESEARCH

Merit is due to H. Stille (1903) who laid the foundations for subsequent researchers in his pioneering work which included dye tracing and a classification of Pader springs. After the second world war the Geological Survey of Northrhine-Westphalia continued to investigate the system by mapping and a variety of tracer tests (Baskan 1970, Koch & Michel 1972, 1984). The discovery of fresh water reserves under confined karst conditions (Hederer 1977) was a boost, which eventually brought about the application of environmental isotopes in deep borehole waters in order to trace their origin and to monitor the equilibrium of the fresh/saline water interface (Geyh & Michel 1974, 1979, 1987). These activities stimulated our own work to a considerable extent.

The author recently reviewed tracing tests executed over almost hundred years in the Paderborn karst system (Loehnert 1992). Since tracers injected in sinks on the high plateau are to be recovered after 3 - 4 days (equal to 100 - 300 m h^{-1} dominant flow velocity) in many separate Pader springs, the system is ideal to make students familiar with various techniques including discharge measurements and hydrochemical analyses. The latter aspect is particularly of interest because the "Warm Pader spring" located in the western area is enriched in NaCl and this is suspected to be due to a higher share of uprising deep basin brines in accordance with spring discharges. Latest findings by Loehnert & Struffert (1994, in press) employing tritium and oxygen-18 revealed slightly higher calculated residence times for the western springs as compared with the eastern spring waters where injected artificial tracers commonly appear. It is these eastern springs which tend to become turbid after heavy rains (Stille 1903).

CONCLUSIONS

Much research activities were devoted to the Paderborn karst aquifer system but no final conclusions can be drawn yet. Further research is particularly required with respect to the confined section of the system which is hydraulically interconnected with the open section where recharge takes place. Our suggestion is to combine the monitoring of both surface as well as rain waters in the recharge area and groundwaters in the springs and deep boreholes. Promising environmental tracers such as selected chemical parameters (both of geogenic and anthropogenic origin) and isotopes in their variability are to be studied. The karst system, being one of the oldest investigated by a number of researchers in Germany, provides excellent chances for interdisciplinary studies.

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HIDROGEOLOŠKE ZNAČILNOSTI KRASA NA KREDNIH APNENCIH V VESTFALIJI (ZRN)

Povzetek

Rezultate hidrogeoloških preučevanj od konca 19. stol dalje lahko povzamemo, kot sledi:

- Globoki kraški sistem, razvit v zgornjekrednih apnencih vzdolž vzhodne meje münsterskega bazena, bodisi odprt (nezajezen) ali zaprt (zajezen), predstavlja v prvem

primeru cono napajanja, v drugem primeru pa odtočno cono, dokazano z izviri in vrtinami. V zadnjih nekaj letih se je skušalo kvantificirati določene tipe kraške talne vode glede na njihove fizikalno-kemijske lastnosti in glede na rezidenčni čas v podzemlju. S temi raziskavami bo treba še nadaljevati tudi v bodoče.

CONTACT KARST OF BRKINI HILLS

BRKINSKI KONTAKTNI KRAS

MIHEVC ANDREJ

Izvleček UDK 551.44 (497.12 Brkini)

Mihevc, Andrej: Brkinski kontaktni kras

Vzdolž južnega obrobja flišnega hribovja Brkinov ločeno ponika 17 potokov. Potoki so na tem mestu oblikovali najbolj značilen kontaktni kras v Sloveniji. Reliefne oblike tega kontaktnega krasa kažejo na postopen razpad starega kraškega reliefa. Vanj so se do višine kraške vode poglobile slepe doline, ki imajo korozijsko razširjena dna. Na kraškem površju pa se je ohranilo še nekaj fluvialnih reliefnih oblik. Na nekaterih se odražajo sledovi recentne tektonike.

Ključne besede: krasoslovje, kraška geomorfologija, kontaktni kras, Kras, Brkini, Slovenija

Abstract UDC 551.44 (497.12 Brkini)

Mihevc, Andrej: Brkini Contact Karst

Along the southern border of the flysch Brkini Hills some 17 brooks sink forming the most characteristic contact karst in Slovenia. Relief forms of this contact karst show gradual dissection of former karst relief. Blind valleys with corrosionally widened bottoms developed by strong water table control while some fluvial forms, preserved on the karst surface, show differential tectonic movements.

Key words: karstology, karst geomorphology, contact karst Kras, Brkini, Slovenia

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PREFACE

One of the possible morphological karst classifications is the division according to the main morphological process. Karst relief formed by the influence of the allogenic flow could be designated by the term of the contact karst (Gams 1965).

The term grows familiar in Slovenia on the Classical Karst where the karst contacts non carbonate rocks and marked relief forms developed. The term is reasonable as such karst essentially differs from the karst which surface was formed without such influence. In the international karstological literature such forms and phenomena are treated as karst influenced by allogenic flow (Ford & Williams 1989).

Once the contact karst at the foot of Brkini was treated within the frame of cyclic geomorphological theory. The period of fluvial relief development should be followed by the karstification when the impermeable cover was removed. (Melik 1955, Radinja 1985) At the karstification beginning the superficial streams shortened and the last remains of this pre-karstic phase should be the blind valleys. Various forms of the blind valleys were later contributed to the climatical changes (Roglič 1957). Corrosionally widened and levelled bottom of the blind valleys and also bigger planations spread all over the Dinaric karst should be the result of the warm climate mostly. Cold periods in the Pleistocene accelerated the incision of the valleys, erosion and denudation in the water basins of the superficial rivers. Corrosion capacity of the sinking streams should affected the forms and dimensions of the blind valleys and it depends mostly on the aggressivity and quantity of the allogenic rivers (Gams 1962).

Karst is built by various morhostructural units and each of them is controlled by different conditions of water drainage which is the main morphological factor. It is well reflected there where from the continuous non-carbonate surface the waters flow in various morphostructural units and in spite of rather similar conditions different relief forms of contact karst develop (Mihevc 1990).

GEOLOGICAL AND HYDROLOGICAL PROPERTIES OF THE TREATED AREA

Brkini Hills are built by flysch non-carbonate rocks of the Eocene age consisting of beds of marl, non carbonate sandstones and conglomerates. Flysch rocks build erosionally dissected hills which contact the karst plain on the south western side. This one is built by

Paleocene and Cretaceous limestones dipping steeply below the flysch. The contact of flysch hills and limestones is 20 km long.

From flysch hills to the border limestones 17 separated sinking streams flow, draining altogether 29.2 km^2 of the flysch area. Water basins of the sinking streams vary from 0.5 km^2 to the biggest 13.2 km^2.

The brooks sink in the altitudes between 490 to 510 m a.s.l.. Some ponors continue in the accessible caves ending by the siphons of captured water in the altitudes between 370 to 430 m. The deepest cave is 150 m deep, and the longest is 6 km long.

There are more than hundred vadose caves in the karst plain and in one cave only the water could be reached at 350 m of the altitude.

Water tracing showed the diversion of the sinking streams water into three groups of springs. The lowest are along the coast in the Kvarner Bay and the highest are the Rižana springs at 70 m a.s.l.

MORPHOLOGICAL PROPERTIES OF THE CONTACT KARST

Characteristical forms of the Brkini contact karst are blind valleys with corrosionally widened bottom. A characteristic example of such valley is Odolina blind valley.

The blind valley was formed by the sinking stream draining 4.3 km^2 large water basin. The average discharge of the brook is about 15 l/s, but oscillations due to precipitation regime are frequent. The floods are rare and reach the narrow belt along the brook only. Periodical water hardness measurements indicated 111 mg of dissolved carbonates originating from the flysch marls.

Close to the brook's passage to the limestones the narrow fluvial valley widens. A valley, 1 km long and 300 m wide, developed on the limestones. Close to the contact it is 150 m deep and on the southern end it is deepened into the karst plain for 60 m.

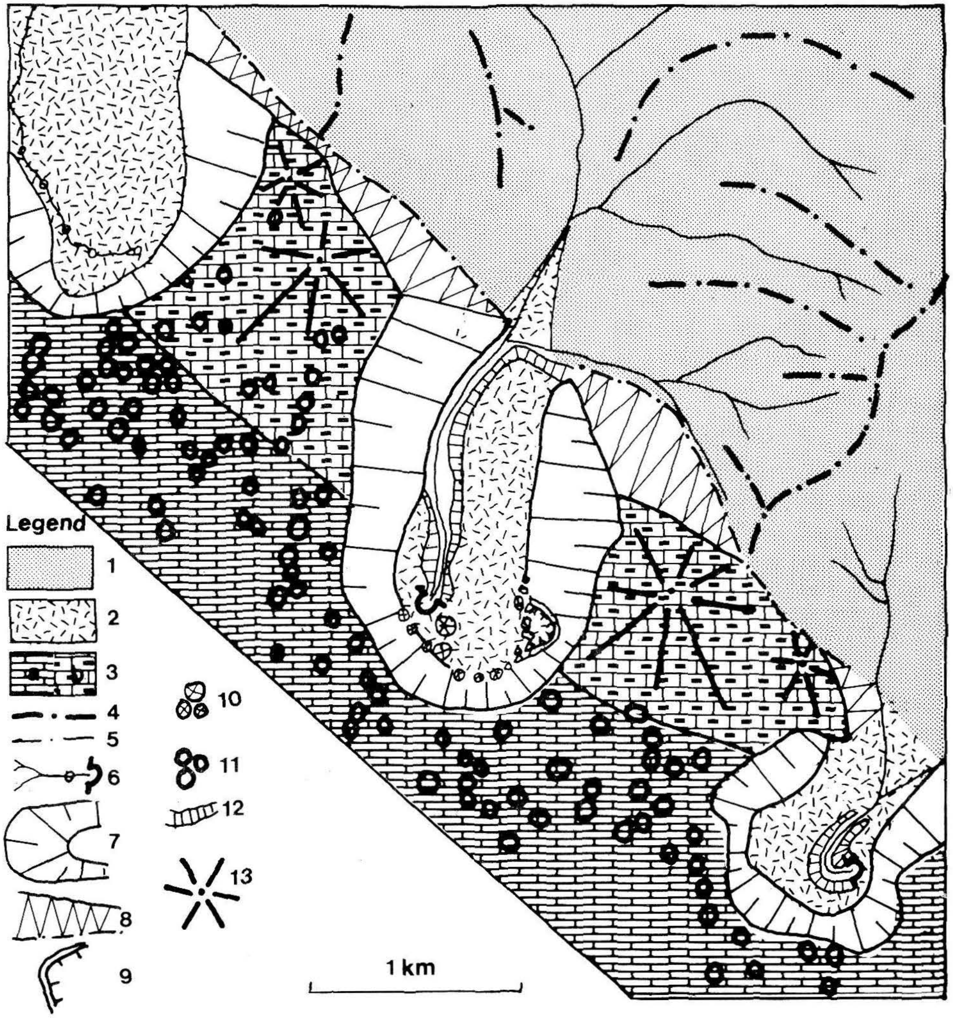
Fig. 1.: Morhological sketch of the Odolina blind valley. Legend: 1. surface on flysch, 2. blind valley bottom - flat corrosion widened surface covered with sediments on limestone, 3. surface on limestone, a. Matarsko podolje karst plain, with solutional dolines as dominant form, b. surface with dominant conical hills, 4. watershed, 5. contact flysch - limestone, 6. brooks with ponors and ponor caves, 7. slope of blind valley, 8. slope formed along the lithological contact, 9. ponor steephead, 10. alluvial dolines and sinkholes, 11. solutional dolines , 12. edges of alluvial terraces in the bottom of blind valley, 13. conical hill.

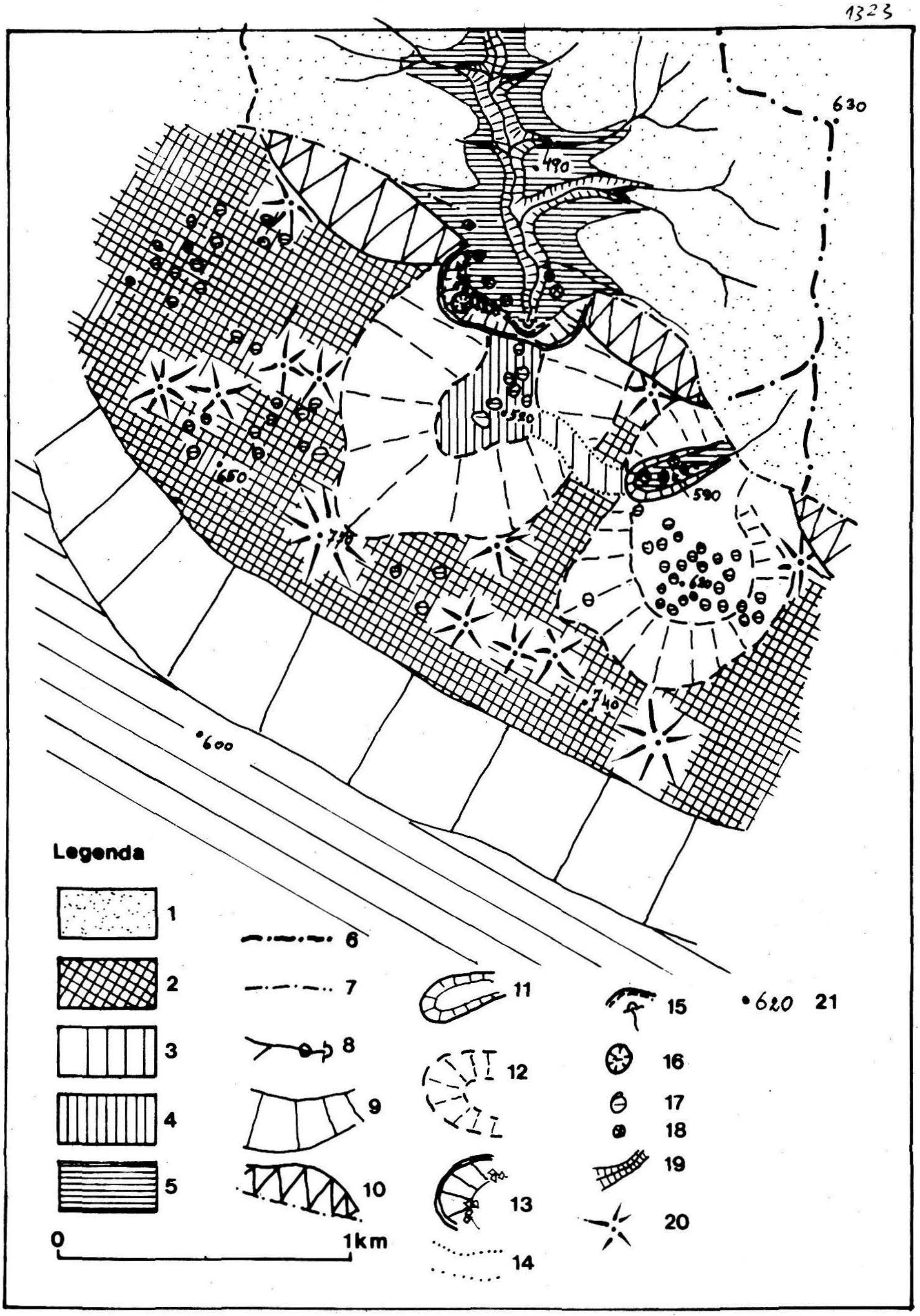
Sl. 1: Geomorfološka skica slepe doline Odoline in sosednjih dveh slepih dolin. Legenda: 1. površje na flišnih kamninah, 2. ravna naplavljena dna slepih dolin 3. površje na apnencu a. Matarsko podolje z vrtačami kot dominantno kraško obliko, b. površje s prevladujočimi kopasrtimi hribi 4. razvodnice na flišu, 5. kontakt fliša in apnenca, 6. vodni tokovi s ponori in ponornimi jamami, 7. pobočje slepe doline, 8. pobočje, oblikovano v apnencih na stiku s flišem, 9. strmejša zatrepna stena, 10. aluvialne vrtače in grezi, 11. vrtače, 12. ježe akumulacij v dnu slepih dolin, 14. kopasti vrh.

The valley's bottom is covered by the sediments, gravels and sands. Flood plain is cut by some younger, up to 25 m deep alluvial ponors and sinkholes and riverbed of the brook, sinking in the final part of the valley. In the sinkholes and in the riverbed the rocks are exposed having the relief below the sediments ranging up to 20 m (Fig. 1).

During the normal water level the brook sinks in the riverbed immediately after the passage to the limestones, during higher water level it flows into 117 m deep ponor cave composed by potholes and shorter channels. The cave is basically phreatic with strong traces of vadose transformation. It ends by the siphon of caught water on 370 m a.s.l.

Beside some blind valleys where the brooks sink there are some fossil blind valleys with corrosionally widened bottom without existing brook. It was either captured by other brook or the brook formed clearly separated shorter blind valley with corrosionally widened bottom, as is it the case with Račiška dana blind valley (Fig. 2).

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The Matarsko podolje is 20 km long and 2-5 km wide. Lowered surface is not a base-levelled plain, cross sections indicate that the bottom, disseminated by the dolines, is inclined southwestwards. In the longitudinal section the lowered surface gently raises from about 490 m on NW to 650 m on SE side. The lowered surface continues towards SE but from the highest point near the blind valley Brdanska dana it lowers on the distance of 2 km for 200 m.

The geomorphological sketch of the entire contact indicates a certain diversity of the forms of the brooks flowing from the flysch.

The first sinking streams in a series flow to the border limestones in the altitudes about 500 m in the lowest, NW part of the lowered surface. These brooks, for instance the brook Krvavi potok have deeply cut riverbeds in flysch but did not form the blind valley on the limestone. It sinks in his own riverbed on the levelled surface (Figs. 3, 4).

Most of the brooks namely developed blind valleys with corrosionally widened bottom. The bottoms of these valleys are situated between 490 to 510 m. As the valleys are incised in the border of the karst, uplifted towards SE, the blind valleys lying more to the south are deeper. The first deepened blind valley is cut for 50 m only while the deepest is the last one, deepened into border limestones for 250 m and its bottom lies 120 m below the bottom of the lowered surface.

CONCLUSIONS

The Brkini series of blind valleys with corrosionally widened bottoms with its situation along the karst plain, upraised lowered surface and some relief forms offer enough data to indirectly classify the sequence of the morphological events and dominant factors which were decisive for the formation of the actual relief forms.

Fig. 2.: Morhological sketch of the Račiška dana valley. Legend: 1. surface on flysch, 2. surface on limestone- Gradine, 3. limestone surface of Matarsko podolje, 4. Bottom ob fossil blind valley, 5. sediments in the bottoms of blind valleys, 6. watershed, 7. contact flysch - limestone, 8. brooks with ponors and ponor caves, 9. slope betveen Gradine and Matarsko podolje, 10. slope formed along the lithological contact, 11. Blind valley of Zavnja brook, 12. blind valley of Račiška dana, 13. ponor steephead, 14. blind valley of Zavnja, 15. vall in the ponor steephead, 16. collapse doline, 17. solutional dolines, 18.aluvial sinkhole, 19. edges of alluvial terraces in the bottom of blind valley, 20. conical hill.
Sl. 2: Geomorfološka skica kontakta pri Račiški slepi dolini. Legenda: 1. površje na flišnih kamninah, 2. kraške Gradine 3. Matarsko podolje, 4. dno fosilne slepe doline Račiške ponikalnice, 5. flišna naplavina v slepih dolinah, 6. površinska razvodnica, 7. kontakt fliša in apnenca, 8. vodni tokovi s ponori in ponornimi jamami, 9. pobočje Gradin nad Matarskim podoljem 10. pobočje oblikovano v apnencih na stiku s flišem, 11. slepa dolina Zavnja, 12. fosilna slepa dolina Račiške ponikalnice, 13. ponorni zatrep 14. dno suhe doline Zavnje, 15. stena in ponor v ponornem zatrepu, 16. udornica, 17. vrtača 18. aluvialni grez, 19. ježa v flišni naplavini 20. kopasti vrhovi 21. značilna višina površja.

The former shape along the ponors on the border of impermeable hills was karst corrosional plain. The water flowing on it had modest gradient in karst and was capable of the aplanation of the surface only.

The lowering of the piezometric level in the karst enabled the development of the relief depressions along the ponors. The deepening and the contemporaneous widening of the

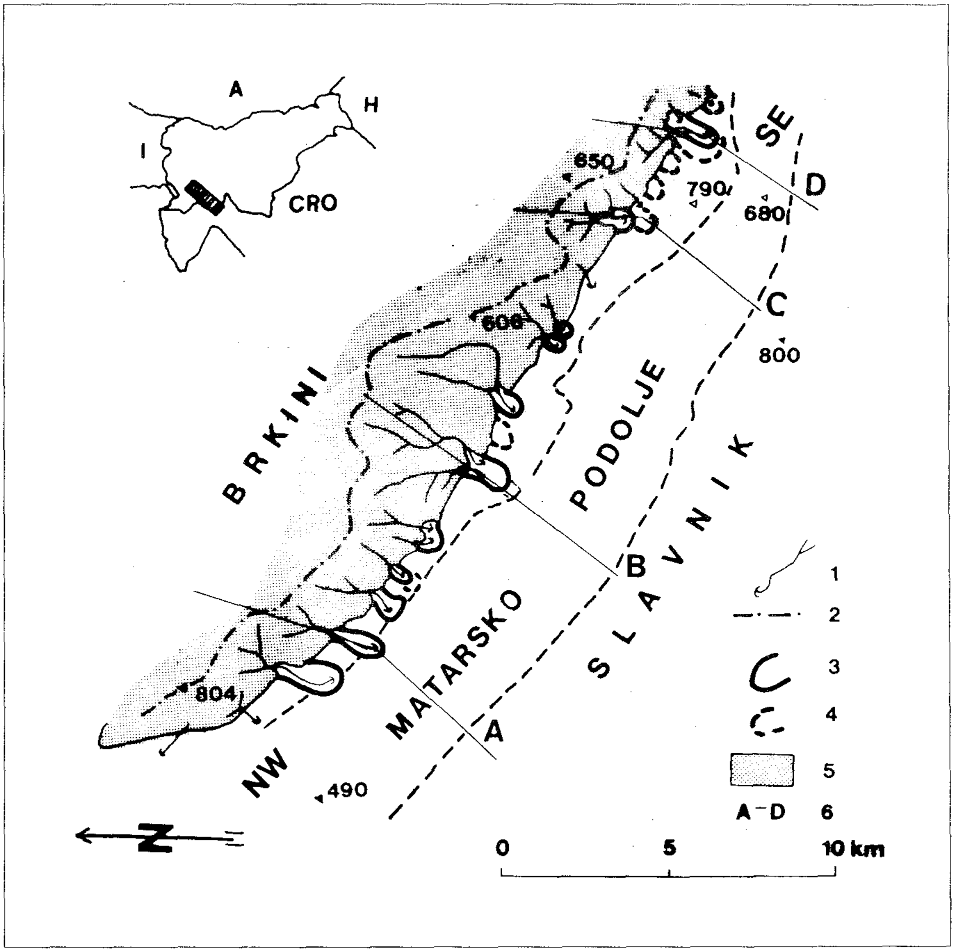

Fig. 3.: Geomorphological sketch of the contact karst at the foot of Brkini. Between Brkini hills and corrosion plain Matarsko podolje is narrow belt of higher relief formed in limestones. Legend: 1. Brook with sinkhole, 2. watershed, 3. blind valley, 4. fossil blind valley, 5. flysch, 6. cross section over blind valleys.

Sl. 3: Geomorfološka skica kontaktnega krasa ob robu Brkinov. Med Brkini in Matarskim podoljem je na apnencih ozek pas višjega reliefa. Legenda: 1. Potok s ponori, 2. razvodnica, 3. slepa dolina, 4. fosilna slepa dolina, 5. fliš, 6. profili čez slepe doline.

valleys followed the lowering of the karst water to the altitudes about 500 m. Bad permeability of the karst caused the deposition of the sediments in front of ponors and the deposits affected the planation and corrosion of the bottom of the blind valleys. The sedimentation was extremely intensive in the cold periods of the Quaternary and these deposits are preserved on the bottom of most of the blind valleys.

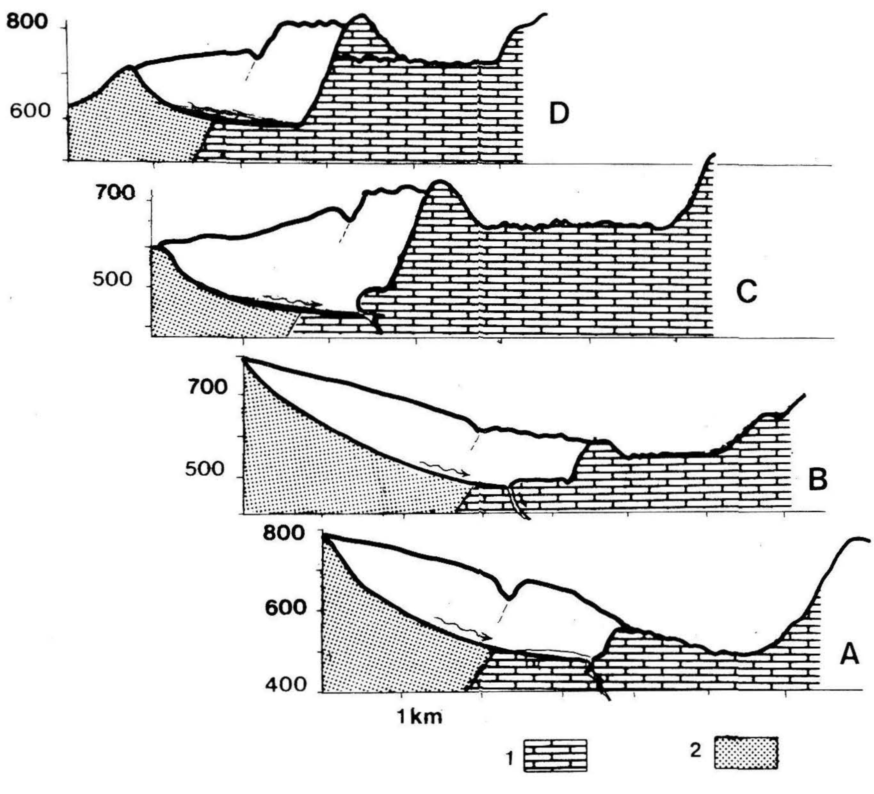

Fig. 4: Cross sections over the catchment areas of the sinking streams on flysch, blind valleys of the sinking streams and the bottom of Matarsko podolje. Blind valleys: A Odolina, B Jezerina, C Račiška dana, D Brdanska dana. Legend: 1. limestone, 2. flysch.
Sl. 4: Profili čez povodja ponikalnic na flišu, slepe doline in dno Matarskega podolja. Slepe doline: A Odolina, B Jezerina, C Račiška dana, D Brdanska dana. Legenda: 1. apnenec, 2. fliš.

INVENTARISATION OF THE NATURAL HERITAGE

INVENTARIZIRANJE NARAVNE DEDIŠČINE

DANIEL ROJŠEK

Izvleček UDK 712.23 (497.12)

Rojšek, Daniel: Inventarizacija naravne dediščine

Termin inventariziranje pomeni evidentiranje in vrednotenje naravnih pojavov, ki jih uvrščamo med naravno dediščino. Veliko kraških pojavov lahko inventariziramo kot naravno dediščino. Nekaj najpomembnejših naravnih znamenitosti matičnega Krasa in Posočja je bilo predstavljenih v Postojni in Great Malvernu. Avtor predstavlja izpopolnjeno metodologijo inventariziranja s kriteriji vrednotenja naravnih pojavov, inventarnim listom in nekaj primeri z zavarovanega ozemlja Škocjanskega jamskega spleta, enote vpisane v Seznam svetovne dediščine in s Posočja.

Ključne besede: methodologija inventariziranja naravne dediščine, naravne znamenitosti, kraški pojavi, inventarni list oziroma računalniško obdelana zbirka podatkov, Slovenija, Posočje, matični Kras, Škocjanski jamski splet.

Abstract UDC 712.23 (497.12)

Rojšek, Daniel: Inventarisation of the Natural Heritage

Verb inventory is understood as a process of recognition and evaluation of natural heritage. Many of karst phenomena shoud be inventoried as parts of natural heritage. Some of the most important natural features of matični Kras and of Posočje were presented in Postojna and in Great Malvern. Methodology of inventarisation has been upgraded and it will be presented by criteria of evaluation, an inventory foil and by some examples from the protected area of the Škocjanski jamski splet - the World Heritage Site and Posočje.

Key words: methodology of natural heritage inventarisation, natural features, karst phenomena, inventory record and foil, Slovenia, Posočje, the Soča river basin, matični Kras, Škocjan Cave System

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INTRODUCTION

Methodology of natural heritage inventarisation is perceived as a recognition and evaluation of natural phenomena uneconomical characteristics. The methodology was being improved during a long study of the natural heritage and of the Škocjanski jamski splet characteristics (Rojšek 1983, 1987, 1989-93). Inventories shoud be introduced to public (Peterlin/ Ed. 1976; Skoberne & Peterlin/Eds. 1980, 1990; Rojšek 1992-1) and must be maintained by field controls and by office processing.

There is no especial methodology and inventory foils for the karst, but the methodology is relevant for all kinds of natural phenomena.

Karst phenomena in proper sense can be found in the 1st group, but in wider sense all groups of natural heritage units (Fig. 2) may be found in a karst region. A karst can be also treated as a natural heritage system of abiotic and biotic features.

METHODOLOGY OF NATURAL HERITAGE INVENTARISATION

Natural heritage is composed of natural phenomena and noncommercial worths. Elements of natural heritage are coupled into physical and cultural-anthropological group. In the first group natural processes and phenomena are found, cultural worths or positive relationship to nature respectively recognition of exigency Men and Nature pertain to the

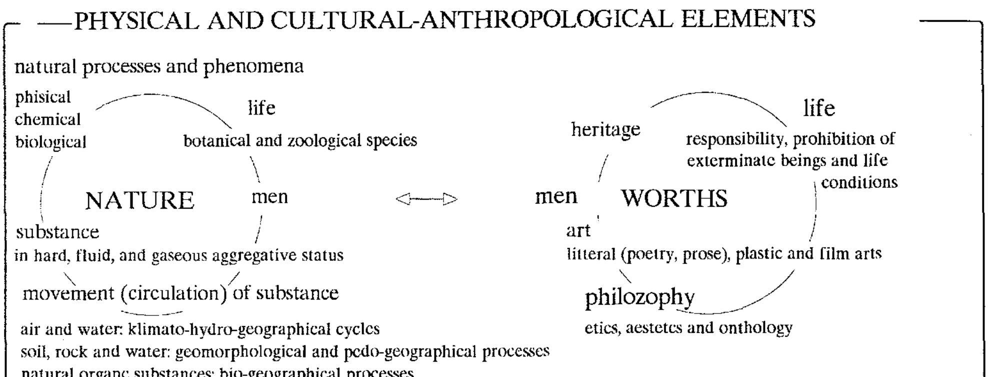

Fig.1

second one (Fig. 1). Parts of natural heritage are called units of natural heritage. Understanding of natural heritage partitioning is dependent to comprehension of complexity principle (--> 1.1). Units of natural heritage are encircled in 5 groups (Fig. 2).

Even one element of each group is enough to inventory a natural phenomenon as a natural heritage unit, more elements fetch higher rank to the unit.

Criteria of evaluation are divided as elements of natural heritage in two gropus, physical and cultural-anthropological. Physical respectively earth science and biological criteria are resumed from methods of geology, geography, biology (botany, zoology and ecology), and mathematics (statistics), but cultural-anthropological ones from ethnology, cultural-anthropology (arheology, history, cultural and physical anthropology with quartarology and sociology of culture), philosophy (onthology - axiology, aesthetic) and artistry (prose and poetry, painting and sculpture, photography, film and video, history of art and literature).

EVALUATION AND INVENTARISATION OF NATURAL HERITAGE

THE FIRST GROUP OF CRITERIA

Basis for evaluation of natural phenomena are modified methods of earth science and ecological research by aspects of natural heritage inventarization. In the 3rd figure the criteria are displayed.

CRITERIA OF COMPLEXITY

Principle of complexity represents basical characteristic of geographical research. Nature is formed of more or less intervolven phenomena, which could be parsed or gathered in groups. Principle of complexity is used for determination of cohesions and/or intervoluations

Fig.2

I. group of natural heritage units - some elements of relief or geological and geomorphological heritage
I. I.

II. group of natural heritage units - hydrological and nival-glacial or hydrogeographical heritage
II. II.

III. group of natural heritage units - some elements of soil and vegetation or pedological and botanical, botanical, dendrological and forestal heritage III.
III. III. III.

IV. group of natural heritage units - some elements of animality or zoological heritage
IV.

V. group of natural heritage units - natural heritage with anthropogencal elements or formed heritage
V. parks, gardens V. collonades of trees

among natural processes and phenomena. Outcomes of evaluation are ranked units of natural heritage. A rank of complexity onsets with basical unit, upwards the rank is limited by purport of further evaluation. Units of natural heritage may be simple or complex. Reflexive effect must be regarded by complexes, which is fundamental for its subsistence. Worth of natural heritage unit of higher rank is widened by number and grade of lower rank units and vice versa.

Units of natural heritage complexity are distinguished by three groups.

Basical units can not be divided, namely sense of a phenomenon is lost. For example a stalagmite, which represents a simple unit of geomorphological heritage can be divided into a foot, a middle part and a top, but this parts are senseless without totality.

Complexes of natural heritage are those with phenomena of the same group (collapsed doline with karren, pothole and cave = geomorphological heritage) or that of higher rank with various kinds of natural heritage (collapsed doline with a fossil site, a growing site of rare species, springs, a waterfall and a ponor = geomorphological, geological, botanical and hydrogeographical heritage) lying in a small encircled area. The area may be treated as a geomorphological heritage.

Systems of natural heritage are the highest rank among the complexes. Units of the systems may be found even in different macro-regions. For example hydrological phenomena in drainage areas of Rakuljščica, Sušica and Mrzlek or Škrnik brooks, Velika voda - Reka, Soča and Timav (Il Timavo) springs seeming unvolven phenomena, but hydrogeographical analyses indicate system of natural heritage linked by running water, lying in different Slovene mesoregions.

Relative small complexes of natural heritage, for example: Ukmarjev dol with two potholes, and wide composite systems, for example: Velika voda-Reka - Vipava - Soča - Doberdobško jezero (Lago del Doberdo) - Timav (Il Timavo) springs are distinguished in the Kras and Posočje regions.

Cohesion and/or intervoluation among natural phenomena is more important then extent of natural heritage units. The highest grade of cohesion is represented by direct genetical relationship, for example Martelova dvorana of Škocjanski jamski splet and Škocjanski kanal of Kačja jama. The lowest grade is represented by distant indirect junction, for example changing of water level in Rakuljščica brook, in Lindnerjeva dvorana of Lobodnica cave and in Timav springs.

Extent of natural heritage units should not be overlooked. Upper limits of units have been set up accordingly to extent of Republic Slovenija and its physico-geographical regions.

Situation or geographical position of natural phenomena is a particular problem. Direct genetical relationship (at least one the same and/or coactive process) is generally conditioned by geographical position. For instance: Vremska dolina - Škocjanski jamski splet - Kačja jama - Lobodnica - Timav - Dobrdobško jezero and Kras are of the similar origin. Units of natural heritage are ranked higher because of position in Kras, but the region is known just by the mentioned phenomena.

The position of natural heritage unit is not conditioned by the relationship in many cases. For example limetrees near the church in Škocjan are not junctioned by genesis of Škocjanski Kras, but the trees grow in the central settlement of the World Heritage Site and so they have been inventorised natural heritage.

ECOLOGICAL CRITERIA

The five criteria are resumed from (Skoberne & Peterlin/Eds. 1988; 1991, 22), the sixth one have been added in a study of natural heritage in the Škocjan World Heritage Site.

MATHEMATICAL CRITERIA

Numerical data of natural heritage may be surveyed by exact instruments or estimated. There are many difficulties by statistical processing of very rich natural heritage in Slovenija, the data are unverified or even unknown (speleological and other geomorphological phenomena) and/or of unknown origin. Many of natural heritage units have not been inventoried, yet.

Diskriminantal and cluster analysis (Ferigoj 1989; SPSS 1975) of elements of the physical and of the cultural-anthropological groups are mentioned among statistical methods.

CULTURAL-ANTHROPOLOGICAL CRITERIA

Interbraids of natural and cultural heritage, role of natural heritage in community life and human relationship to natural heritage are evaluated by criteria of this group by outcomes and/or methodes of archaeological, historical, cultural-anthropological, ethnological, cultural-sociological, history of art and philosophical (ontology, axiology, aesthetic) research.

Criteria are codified in two groups. The groups and the criteria are displayed in the Fig. 3.

- Natural heritage and residues of material culture is a name of the first group of cultural-anthropological criteria.
- A unit may be ranged by one criterion: Wittnessstand or interbraid of natural and cultural heritage. For instance archeological sites in natural monuments Tominčeva jama, Ozka špilja and Velika jama na Prevali.
- Natural heritage and social and spiritual or mind culture. The second group of the criteria enclosed relations among natural heritage and sphere of human nonmaterial activities. A unit may be ranged by five criteria.
- Symbolic sense of natural heritage is established when society identifies itself by the unit. For instance Triglav is Slovene symbol of more than millenium long combat for equality and freedom, which was realised by independent Republic of Slovenia in 1991.

- Picturesqueness by the criterion aesthetic proportions of natural heritage unit may be found. Picturesqualy unit strikes visitors and/or it is/may be favourite motive of artists.
- Exceptional features created by natural processes is a reason to range a natural phenomenon to natural heritage. Determining of fito-, zoo- and anthropo-morphical phenomena can be sapid. Žena (woman) in Svetinova dvorana of the Škocjan System is an example of anthropomorphical phenomenon.

FIGURE 3

LIST OF CRITERIA FOR NATURAL HERITAGE EVALUATION

EARTH SCIENCE CRITERIA

COMPLEXITY

a simple unit of natural heritage
a simple unit direct part of a natural heritage complex
a simple unit a typical natural pheneomenon

a simple complex ($F < 1\ km^2$) of a *single natural heritage group*
a simple complex of typical natural phencomena
a simple complex ($F < 10\ km^2$) of various natural heritage groups

a simple system ($F < 10\ km^2$) *of natural heritage*
a small composed ($F > 10 < 100\ km^2$) system of natural heritage
a middle composed ($F > 100 < 500\ km^2$) system of natural heritage
a big composed system ($F > 500\ km^2$) of natural heritage

a phisical-geographical meso-region ($F < 500\ km^2$), abundant by natural heritage
a phisical-geographical macro-region, ($F > 500\ km^2$), abundant by natural heritage
a natural heritage unit as a part of phisical-geographical region, abundant by natural heritage

ECOLOGICAL CRITERIA

high degree preserved ecosystem
ecosystem with large variety of habitats (stable ecosystem)
rare ecosystem with a biotop or a biocenosis rare in *Slovenija*, Europe or even in the Earth
ecosystems with botanical and zoological species - endangered - relics or endemits - with *locus classicus* - in disjunctional, azonal, ekstrazonal and/or marginal areas
areas of many diverse ecosystems
ecotop of typical vegetation of characteristic pedological profile

MATHEMATICAL CRITERIA

rarity of natural heritage
exceptional rare (up to 5 specimen in *Republika Slovenija*
very rare
rare
rare in a region

dimension/s in space
maximal units of natural heritage (absolute maximum of all three dimensions)
very big units of natural heritage (absolute maximum of two dimensions)
the ...st (highest, deepest ...) units of natural heritage (absolute maximum of one dimension)
relative big unit of natural heritage
miniature natural phenomenon

dimension/s in time
age of natural heritage unit
natural heritage unit of active processes

quantity, quality, ratio, distribution and condition of natural heritage elements and units
exceptional quantity
high quality,
ratio and distribution
exceptional condition

frequency of natural features emerging in the same place
permanent phenomena
periodic phenomena

CULTURALANTHROPOLOGICAL CRITERIA

NATURAL HERITAGE AND RESIDUES OF MATERIAL CULTURE

witnesstand or interbraid of natural and cultural heritage

NATURAL HERITAGE, SOCIAL AND MIND OR SPIRITUAL CULTURE

symbolic sense
picturesqueness
exceptional shapeness
natural heritage unit, important landscape element
local remarkable natural feature

• Natural heritage unit, important landscape element. Some units are important landscape elements. Importance may be establised like picturesqueness and symbolic sense in a process of establishing subjective relationship among vision and perceiving.

• Local remarkable natural feature. Somewhere natural heritage units were recognized famous local features. Even settlements were named by natural features. For example natural window called Luknja (hole) or Otlica (something hollow) lending its name to the village (Rojšek 1992, 6, 170).

NATURAL HERITAGE INVENTORY RECORD AND FOIL

Inventory foil is appropriated to all kinds of natural heritage units. The foil exists in two forms as a print and as a digital record.*[1] It is composed of 135 fields. Records are organised in inventory as a printed register and as a data base. The most important data are that, which are gathered *in situ*. Quality of data (surveyed, estimated, resumed by sources and so on) must be clearly designated. Data fields of the record and the foil are classified in three groups. In the 1st one data for identification are found, in the 2nd one data for evaluation are used, and the 3rd one is documantary. Contents of the foil is presented in Fig. 4.

CONCLUSION

Natural heritage is composed of natural phenomena and noncommercial worths. Elements of natural heritage are coupled into physical and cultural-anthropological part (Fig. 1). Evaluation and inventarisation of natural heritage is a process linked to cultural rank of social development. Results of the process must be scientifically undoubtfull, and so respected and appreciated by authorities, individuals and society.

Natural heritage is divided into units, which are organised in five groups (Fig. 2).

In the first step of inventarisation natural phenomena are recognized. In the next one criteria of natural heritage evaluation are used and natural heritage units are formating. The criteria are divided into two groups of elements. In the first one earth science and biological criteria are resumed from methods of geology, geography, biology and mathematics. In the second one cultural-anthropological criteria are abstracted from methods of ethnology, cultural-anthropology, philosophy and art (Fig. 3).

In the last step inventory foil of natural heritage unit (Fig. 4) is processed up, but inventories shoud be introduced to public, and have to being maintained by field controls and by office processing.

The role of geography is very important during inventarisation of natural heritage (Rojšek 1991).

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*[1]during processing softwares STeve and EVE by P. Jakopin (1989, 1993) were being used.

INVENTORY FOIL - 135 FIELDS

001 regional or local evidence number
002 central state evidence number

003 settlement 004 commune 005 local community
006 land cadastre district 007 land cadastre parcel number
008 ev. number in Slovene cave cadastre 009 ev. number in former Italian cave cadastre VG

010 NAME 011 synonym/s 012 toponym/s

013 natural heritage unit - a "point" (F < 79 m^2 map sign - point of 1 mm diameter)
014 natural heritage unit - an "area" (F > 80 m^2 map sign - square of 1 mm side)
015 Gauß/Krüger coordinates: **Y** 016 **X** 017 **Z**
018 Z max. = the highest point a.s.l. 019 Z min. = the lowest point a.s.l. 020 Z pop. = mean sea level
021 after (map of of big scale (1:5.000, 10.000 - TTN, 1:25.000 - TK 25/G), altimeter/depthmeter ...)
022 name of map TK 25/G 023 TTN 10 024 TTN 5
025 1st remark

026 SIGNATURE
027 DIMENSION/S: - lenght 028 - width 029 - height 030 - depth
031 - circumference 032 - area 033 - volume
034 2nd remark
035 accuracy (+/- %) 036 Instruments

037-047 GROUPS AND SPECIES OF NATURAL HERITAGE (--> figure 1)

048 LOCATION: on surface 049 in underground 050 beetwen surface and underground

051-95 EVALUATION (--> figure 2 - LIST OF CRITERIA FOR NATURAL HERITAGE EVALUATION)

096 FUNKCTION/S: - "monumental" or witnesstand 097 - reserve 098 - scinetific-researchal
099 - biotopic 100 - breeding-educational 101 - recreational

102 PLANE - JURISTIC STATUS: - republic obligatotry starting-point in planning
103 juristic status 104 juristic act 105 plane phase
106 conservaton status of *Republika Slovenija*
107 conservaton status of IUCN
108 conservaton status of European community
109 basic conservaton regime (number) 110 other conservaton regime/s (number/s)

111-114 BRIEF DESCRIPTION: 4 chapters
115 date/s of visit/s 116 date of last visit

117 STATUS: - of preservation 118 - of endangerness
109 photo-documentation - BW 120 - color slide/s 121 - color negatives 122 - film 123 - video
124 basic reference/s 125 other reference/s
126 basic source/s 127 other source/s
128 author/s of data 129 author/s of description 130 processed by
131 3rd remark 132 4th remark 133 5th remark
134 date/s of processing 135 date of the last change/s

Fig. 4

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INVENTARIZIRANJE NARAVNE DEDIŠČINE

Povzetek

Pojem naravna dediščina je sestavljen iz dveh polov. Prvega tvorijo naravni pojavi, v drugem pa najdemo vrednote. Tudi prvine naravne dediščine so zaokrožene v dveh skupinah, fizični in kulturno-antropološki (slika 1).

Ovrednotenje in inventariziranje naravne dediščine je proces, ki je povezan s kulturno stopnjo družbenega razvoja. Rezultati tega procesa morajo biti znanstveno neoporečni, kot take pa bi jih morali spoštovati posamezniki, oblast in družba.

Naravno dediščino sestavljajo enote, ki so združene v petih skupinah (slika 2).

Inventariziranje začnemo z evidentiranjem naravnih pojavov, nato jih ovrednotimo in izbrane uvrstimo med enote naravne dediščine. Merila za vrednotenje so razvrščena v dve skupini. V prvi najdemo naravoslovna merila, ki temelje na spoznanjih geologije, geografije, biologije in matematike (statistike). Drugo skupino tvorijo kulturno-antropološka merila. Ta so utemeljena na osnovi spoznanj etnologije, kulturne-antropologije, filozofije in umetnostne zgodovine (slika 3). Na koncu uredimo podatke v računalniški zapis oziroma zbirko podatkov in jih izpišemo na obrazcu, inventarnem listu (slika 4).

Vendar inventariziranje ni končano, kajti inventarje je potrebno vzdrževati s spremljanjem stanja v naravi, novimi odkritji, pisarniško obdelavo podatkov in besedil ter predstavljanjem naravne dediščine javnosti. Geografija igra pri multiinterdisciplinarnem inventariziranju naravne dediščine pomembno vlogo (D. Rojšek, 1991).

CLASSIC DOLINES OF CLASSICAL SITE

KLASIČNE VRTAČE KLASIČNEGA KRASA

FRANCE ŠUŠTERŠIČ

Izvleček UDK 551.442 (497.12)

France Šušteršič: Klasične vrtače klasičnega krasa.

Ponovno je bilo proučenih nekaj vrtač, ki jih Cvijić navaja kot šolske primere. Izkazalo se je, da objekt, katerega presek je objavil v svojih monografijah, sploh ni vrtača. Zato je vrtža na lokaciji Skalčen Kamen, označena SK-022, predložena za novi holotip. Na istem kraju je bilo podrobno proučenih 17 vrtač. Kot kaže, so nastale z razpadom kaminov, ne pa kot zbirna območja krajevnih ponorov. Njihova podrobna oblikovanost je posledica pleistocenskega, perinivalnega preoblikovanja.

Ključne besede: vrtača, brezno Cvijić, statistika, klasični kras, pliocen

Abstract UDC 551.442 (497.12)

France Šušteršič: Classic dolines of classical site.

Some karst depressions referred by Cvijić as examples of solution dolines were revisited. It came out that the structure presented in section in his works is not a doline at all. Consequently, doline matched SK-022, at the location Skalčen Kamen, is proposed to be new holotipe. 17 dolines at the same location were studied in detail. It appears that they originate from desintegration of dome pits, rather than they evolve from local sinks. The particular shape of their "bowls" is predominantly controlled by the pleistocene peiglacial processes.

Key words: (solution) doline, dome pit, Cvijić, statistics, Classical karst, pleistocene.

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As in many cases concerning the karst, the story began with Jovan Cvijić. This paper presents ideas which arose while revisiting the century old sites of Cvijić'c classical dolines research. The text reproduces my paper given at the session, as well as the topics covered by the field excursion to the sites in question.

ABOUT THE ROOTS

In 1893 (1895) J. Cvijić published his fundamental work, (the) Karst[1]. Among other karst phenomena he exhaustively discussed the medium sized closed karst depressions named dolines[2]. Since that time much work has been carried out on this topic. Surprisingly, at the moment, it does not seem that our understanding about dolines is any clearer. Rather than increased consistency, an overview of the literature reveals quite a divergenece in concepts. Sometimes it is evident that the students are not dealing with the same material, although they are using identical terminology. On such occasions one has to get back to the roots, reinspect the basic literature and - possibly - check the examples in situ.

J. Cvijić (1893, 1895) subdivided dolines into four main groups, and his divisions have in general remained used until the present (D.C. Ford, P.W. Williams, 1989, 398, Fig. 9.13), see also A. Bondesan & al. (1992, 6). Among these, solution dolines[3] have been

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[1] The two books are of identical title and have essentially the same contents. It is sure that the German version (1893) is the one which set the fundamentals of modern karstology. The Serbian (1895) version is sligtly better elaborated and it presents some Cvijić's responses to the discussions inspired by the first one. I take in consideration the both.

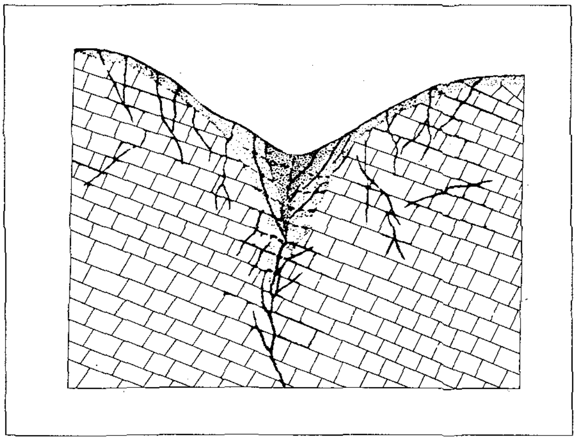
[2] For home use Cvijić introduced the term "vrtača" instead of "dolina(e)". (See footnote 8!) The term "vrtača" has been generally explained as to originate from the verb "vrteti" (= to rotate, to whirl). Two decades of field work in several parts of the classical Karst have convinced me that this explanation may not be proper. Though the expressions "dolina" and "vrtača" prevail, at several places local people use the term "vrt" (= garden). They explain it that a "polje" (= field) is ploughed but a "vrt" is done by hand. The modest extent of fertile soil at the bottoms of many dolines really does not permit any other way of cultivation than rudimentary gardening. However, this linguistic digression would be of little interest for a non-Slav reader, had the "whirling" explanation (tacitely, but selfunderstandably containing the idea of a swallet) not turned at least a part of the research of the dolines in wrong direction.

[3] As in many papers covering the same topic, in the following text the expression "doline" is used in the sense of "solution doline".

the most studied, but also remain the most obscure. Cvijić (o.c.) explained them as the places of more intensive corrosional lowering of surface, controlled by rock fracturing. Obviously such an explanation requires intensive studies of doline cross sections. Though he lists a number of examples from the whole area of former Yugoslavia, he offers only one example of a doline section (J. Cvijić, 1893, 43; 1895, 63). This figure has become one of the most reproduced in the all geomorphological literature (Fig. 1). The remark (o.c.) "Ich habe solche angeschnittene Dolinen in dem zweiten Eisenbahneinschnitt suedlich von Unterloitsch[4] in Krain[5] beobachtet (Siehe Profil)" promises an easy check of our understanding of his ideas.

Unexpectedly, my first visit to this location was fruitless. Even though I searched a number of railroad cuttings some kilometers south of Logatec, no location fitted the drawing. Later I learned that since Cvijić's times the Logatec railway station has been enlarged. Eventually, the first cutting completely disappeared and the last remains of the second one are now part of the station complex. It came out that the object (Fig. 2) is the present state of the "doline", described by Cvijić.

A closer inspection and the map[6] of pre-reconstruction state revealed that Cvijić (Fig. 3, double circle) had observed a section of longitudinal terrain lowering along a



Sl. 1: Cvijićeva skica, ki jo je pomotoma imel za središčni prerez vrtače (J. Cvijić, 1893, 43; 1895, 63).
Fig. 1: Reproduction of Cvijić's drawing, by mistake explained as the central section of a doline (J. Cvijić, 1893, 43; 1895, 63).

[4] "Unterloitsch" is the German form of the Slovene place name "Dolenji Logatec". Logatec is Slovene derivation from Roman expression "Longaticum", marked in Tabula Peutingeriana.

[5] "Krain" is German form of the Slovene expression "Kranjska" (= Carniola), covering the central part of Slovenia, predominantly the basin of the river Sava.

[6] Fig. 3 is redrawn and slightly simplified after the 1:1000 map used during the main reconstruction in the fifties.

crushed zone[7], rather than a doline. If the parent rock were not a quite dolomitized limestone, a good example of a bogaz (Fig. 3, see the linar depression behind the cutting face!) would develop there.

Undoubtedly, Cvijić had seen a number of sagittally transected dolines, and the structure he believed to be a centrally transected doline did not differ a great deal from them. So he was able to continue the former citation (o.c.): "Unter denselben kommen keine Hoehlen vor, der Schichteverband ist nirgends gestoert; vor dem Dolinenboden setzen sich aber zahlreiche Kluefte durch eine Zone verwitterter Kalksteine fort und sind bis in das frisch aussehende, wenig zersetzte Gestein zu verfolgen, welches die Unterlage bildet und ebenfals entbloesst ist.... Alle durchschnittenen Dolinen zeigen dieselben Erscheinungen in groesserem oder kleinerem Masstabe." This is well illustrated by his sketch, and its constant reprinting has only proliferated his notion. But he never did actually see a central section of a doline!

The further expansion of his ideas is easily understood. For him, dolines were the attack-points of surficial waters on the parent rock (o.c., 57 (81): "In den sproeden, reinen Kalksteinen finden sich zahlreiche Angriffspunkte, naemlich verschiedenartige Fugen und Kluefte, es findet laengs derselben eine starke vertikale Erosion oder eine Intensive Aufloesung des Kalksteines statt und bleiben dabei unbedeutenede Loesungsrueckstaende, durch welche die Erweiterung und Vertiefung der entstandenen Dolinen nicht wesentlich beschraenkt wird. In solchen Kalksteinen werden oft die Absorptionsspalten und schmale Roehren zu Ponoren erweitert".

Combined with general belief of the time that the karst is just an episode between two fluvial phases in relief development his misobservation introduced several notions which have become almost axioms. A. Bondesan & al. (1992, 1) say: "From a morphodynamic point of view the doline constitutes an elementary hydrographic unit, comparable to a simple basin, which, with its system of slopes, conveys water to the absorbing points at the bottom into an underground network." Only few readers of Cvijić's later citation (o.c., 57, (81)) feel that the expression "Ponor" is not used in the way it is used elsewhere in the book, i.e.: a swallet, leading to a well formed karst channel, but is used in the way local people do, i.e.: any, even the tiniest, opening able to receive water.

Thus, there are at least two weak points jeopardizing the present expansion of Cvijić's ideas:

1. From his false example it follows that dolines result from locally intensified surficial, possibly subcutanean karstification.

2. Too rigid understanding of the term "ponor" brought about the notion that dolines[8] are small catchement areas.

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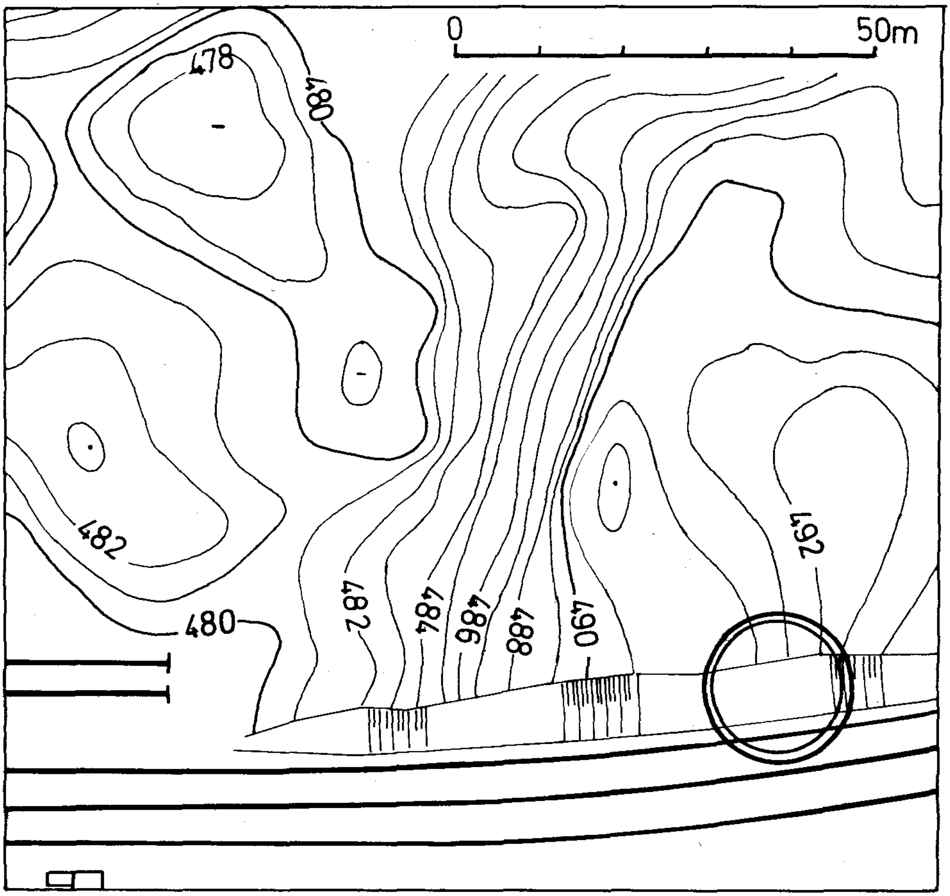
[7] The expression is meant in the sense of S. Šebela and J. Čar (1991, 221).

[8] Even the term "doline" seems to be misunderstood in the least detail. A. Bondesan & al. (1992, 4) wrote "Cvijić (1893) first introduced the name "doline" which means "small valley", to underline the analogy between this form and a small normal hydrographic basin." Cvijić just followed the terminology introduced in 1848 by Morlot (I. Gams, 1974, 20). He was completely aware of very vague meaning of this term in Slav languages, so he used the expression "vrtača" (see footnote 2!) in his Serbian text. "Dolina" (see Fairbridge, R. W., 1968) primarily



Sl. 3: Tloris Cvijićeve "vrtače" in soseščine pred širitvijo postaje v šestdesetih letih.
Fig. 3: Plan of the Cvijić's "doline" and its neighbourhood, before the reconstruction works in the sixties.

means any negative relief form. In the fluvial circumstances it is any stream valley, in the high mountains it is its glacier analogue. In the karst, where surface fluvial features are unknown, it predominantelly means solution or collapse "doline", but sometimes even polje (popularly, the Planinsko polje is called "Planinska dolina"). Cvijić found no reason why to abandon the term "doline" in the scientific language, but he did not intend to stress the analogies with the fluvial system. It was Grund (1914) who "considered their place in the karst landscape to be similar to that of valleys in fluvial terrain" (Ford, D. C., P. W. Williams, 1989, 396). Yet, it is questionable whether the notion of catchment area was so precisely defined at his time as it is today.

The two ideas are hardly consistent, if not contradictory. Nevertheless, a tenet is common for both: dolines are product of surficial processes and the role of underground voids is completely passive.

In order to avoid ambiguity if the holotype of a fossil is lost, paleontologists define paratypes. Cvijić did not reason in this way, but, fortunately, he did mention a number of locations where examples of dolines appear. Among them, the citation (o.c. 44 (65)) "Die Karstplatten und Karstplateaus sind die wichtigsten Obeflaecheformen, auf welchen Dolinen in der Regel in ungeheuerer Menge auftreten. .., wie die Umgebung von Unterloitsch (Ravnik und Scalcen Kamen), ... u.s.w." is very useful, as the location Skalčen Kamen lies only 6 km SE from Logatec station, and it is a well known road crossing.

The location lies in the middle of a forest and it is practically untouched by human activity. In order to check what kind of closed depressions he really did mean when using the term "doline", a detailed study of 17 dolines at this location was carried out in 1992 and 1993.

THE METHOD

In this paper, I present and discuss primarily the results of morphometry. Within a 150 m wide strip in the direction 95° all karst phenomena, including 17 dolines, were studied in detail, and within an about 1 km wide area along the same line, all dolines were mapped. Their position attributes are the locations of the lowest elevation (= "bottom point" in the following text), which were surveyed by compass and meter tape, and later related to the spot elevation points (given grid coordinates), marked on the technical map 1:5000.

The dolines which centres lie within the inner strip were measured, and data processed according to the method described in F. Šušteršič (1985, 1987, and 1989), and discussed by A. Bondesan & al. (1992, 31). The elevation data of 72 measuring points within the doline, arranged in a regular pattern, are shrunk in a small number of Fourier coefficients. It permits a comprehensive reconstruction of the whole doline and computation of practically all descriptive parameters ever defined (see A. Bondesan, o.c.).

When determining the dolines the definition of the perimeter is crucial. If the surrounding terrain were absolutely flat it would probably be no problem. However, clints and other forms of surface karstification induce short wave undulations of about 1 m amplitude, to say nothing about longer waves, or the general trend of the relief. Many authors advocate two boundaries:

1. The terrain divides betwen dolines, as the borders between their influence areas.
2. The actual contour of the closed depression (overflow contour).

According to the experience of my previous work (F. Šušteršič, 1985, 1987), both can be abandoned. The primary reason is operative. Despite the opposite opinion, based predominantly on the use of aerial photos or large scale maps (1:5000), it is relatively easy to determine the doline perimeter on the spot. It is marked by an abrupt change of the slope, though small in its value, dividing the "normal karst surface" and the area influenced by slope processes, induced by local centrical mass defficiency (doline)[9].

On the other hand, there are more substantial reasons. In the karst of the Skalčen Kamen (and the large karst area hundreds of kilometers around it, too) there are no traces of any recent subaerial or epikarstic drainage. The karst is "pure" in the sense of F. Šušteršič (1982, 1986) and the notion of stable divide is untenable. The "overflow contour" would be of paramount importance if the doline depressions operated as lakes during at least one stage of their development. Opposingly, the study of their slopes (F. Šušteršič, 1987) revealed a number of indications of processes which do not respect the "overflow" contour at all.

The method is oriented in the presentation of dolines as a whole, rather than evaluation of single, possibly linear parameters. Nevertheless, the program "VRT" computes 30 simple parametres, some of which are discussed in the following. The numbers, which are used in tables also relate to the numbering in the program output.

(5), (6) - The shortest and the longest radius of the perimeter, according to the bottom point. In Šušteršič(F., 1987) I showed that the opposite slopes of a doline are usually the most different, too, and there is no reason to discuss the diameter.

(8), (9) - The lowest and the highest elevation of the perimeter, according to the bottom point. The measured dolines lie in, although undulating, predominantelly flat terrain, and these parameters express the surface roughness rather than the slope of the general surface.

(10) - Relative volume of the doline, i.e. the volume of the space between the doline sides and the general relief trend. The doline is cut into 360 slices which partial volumes are computed analytically and then added together. However, the notion of the volume depends on dolines history. If they are superimposed in a relatively inert relief the definiton is fair. But if the dolines display different lowering rates between different spots the idea becomes untenable.

(11) - Planimetric area. The doline area within the horizontal projection of the perimeter is cut in 360 slices which partial areas are computed analytically and then added together.

(15) - Shift of the gravity center. Grid coordinates, relative to the bottom point, of the gravity center of the planimetric area are computed. The shift is their Pythagorean sum.

(16) - Azimuth of the shift of the gravity center. In general, dolines are neither symmetric nor of regular shape, and this results in the shift of the gravity center. If there exist preferred directions, the shift may result from some oriented process.

(17) - Normalized shift of the gravity center. When divided by square root of the planimetric area, the shifts of dolines of different sizes become comparable.

(20), (21) - Lengths of the major and minor axis of the (normative) ellipse with equal planimetric area and equal momentum of inertia to the doline ground plane is

[9] It holds true only for the dolines which remained untouched by man. In cultivated land, farmers had obtused their "lips" a long time ago in order to facilitate ploughing or mowing.

computed. Axes of the ellipse were introduced instead of various "diameters" which are highly unstable parameters.

(22) - Direction (azimuth) of the major axis of the normative ellipse.

(23) - Elongation of the normative ellipse. Ratio between the major and the minor axis.

(24) - Length of the axis of the normative cone. The doline is approximated by a rotational cone of equal volume and equal planimetric area of its basal plane. Beacause dolines do not generally lie in flat terrain, the basal plane is obtained by truncation of a vertical cone by the plane, best fitting to the elevations on the doline perimeter. The length of the axis is the vertical distance between the apex and the basal plane. This parameter was introduced instead of various "depths" of the doline.

(25) - Inclination of the normative cone surface. Replaces "average inclination of slopes".

(28) - Shift of the apex. Similar to (15), taking the apex of the cone instead of the planimetric area gravity center.

(29) - Normalized shift of the apex. Similar to (17), taking coordinates of the cone's apex instead of the planimetric area gravity center.

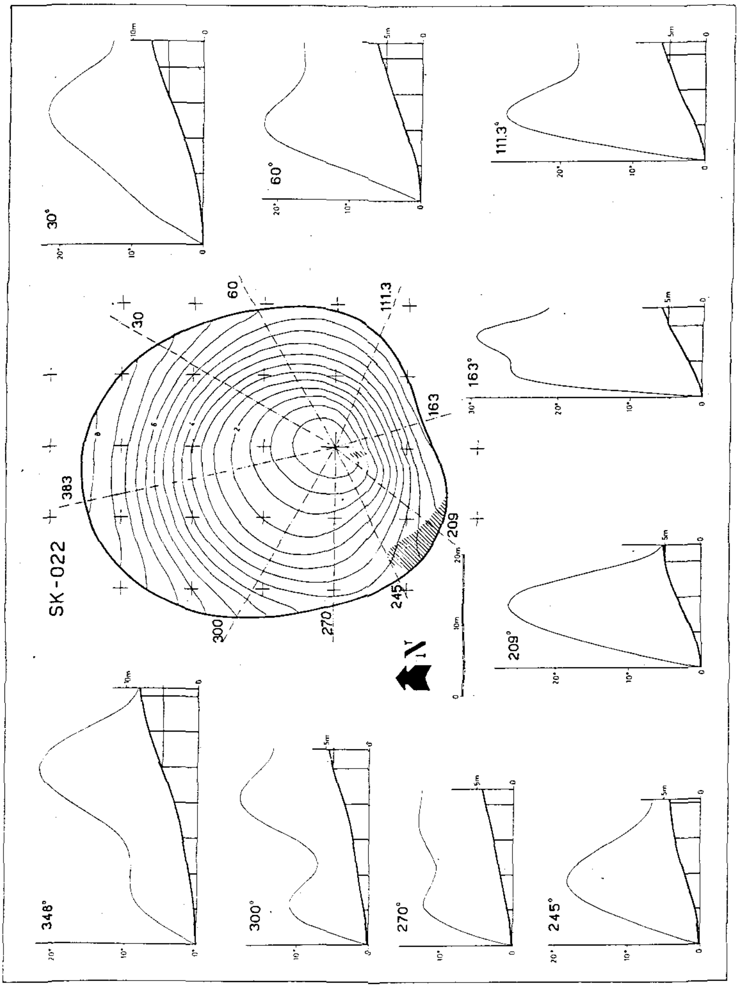
(30) - Direction of the apex position. Similar to (16), taking coordinates of the cone's apex instead of the planimetric area gravity center.

(V/A) - Relative denudation (d) within the doline space may be viewed as the thckness of a slab of equal planimetric area (V = A*d).

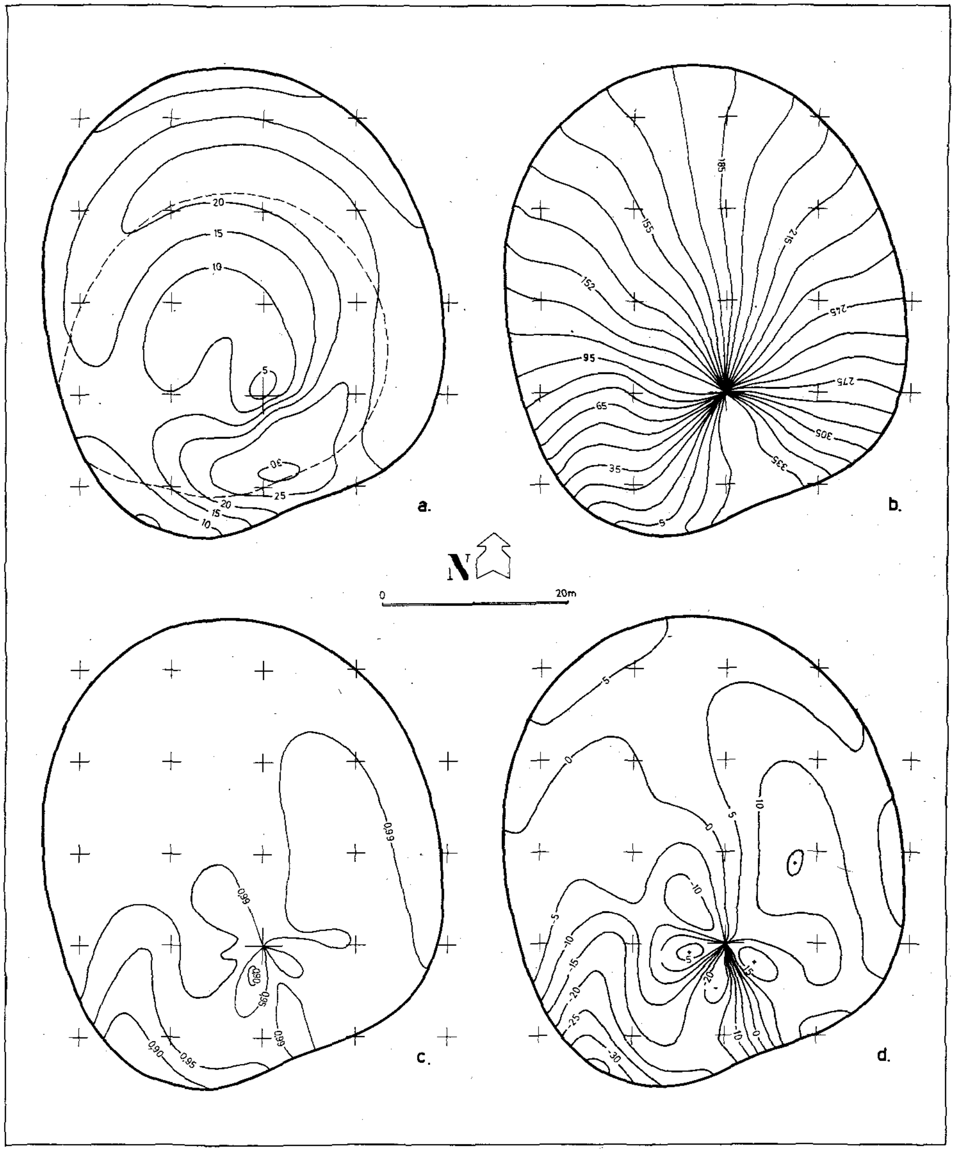
When processing, the information about the doline geometry is transformed into the Fourier coefficients. During further procedure (F. Šušteršič, 1985), it is separated into two packs, containing fundamental shape of the doline, and the noise, respectively. On the base of the former data "undistorted" shape of the doline is recomputed (o.c.). An example is ground plane and some semiprofiles of the doline SK-22 (Fig. 4).

The shape of a geometric figure is described by its derivatives, that is formalized into inclination and aspect angles in geomorphology. Fig. 5/a displays the inclination of the slopes of the same doline, and Fig. 5/b presents their aspects. The broken line in Figs. 5/a and 5/b is the "overflow" contour. The spatial distribution of inclinations within a slope section (see also semiprofiles, Fig. 4) displays a very common pattern: relatively gentle slopes close to the perimeter, evidently greater inclinations further towards the center, and a practically flat area in the middle of the doline. The extreme inclination is south of the bottom point, and will be discussed in the next section. The strip of the minimum inclination west of the bottom is probably a weakly pronounced suture (according to F. Šušteršič, 1987, 80) that is visible also on Fig. 5/b. It is also evident that the aspects tend to approach some preferable directions (and vice versa) rather than to point straight to the center.

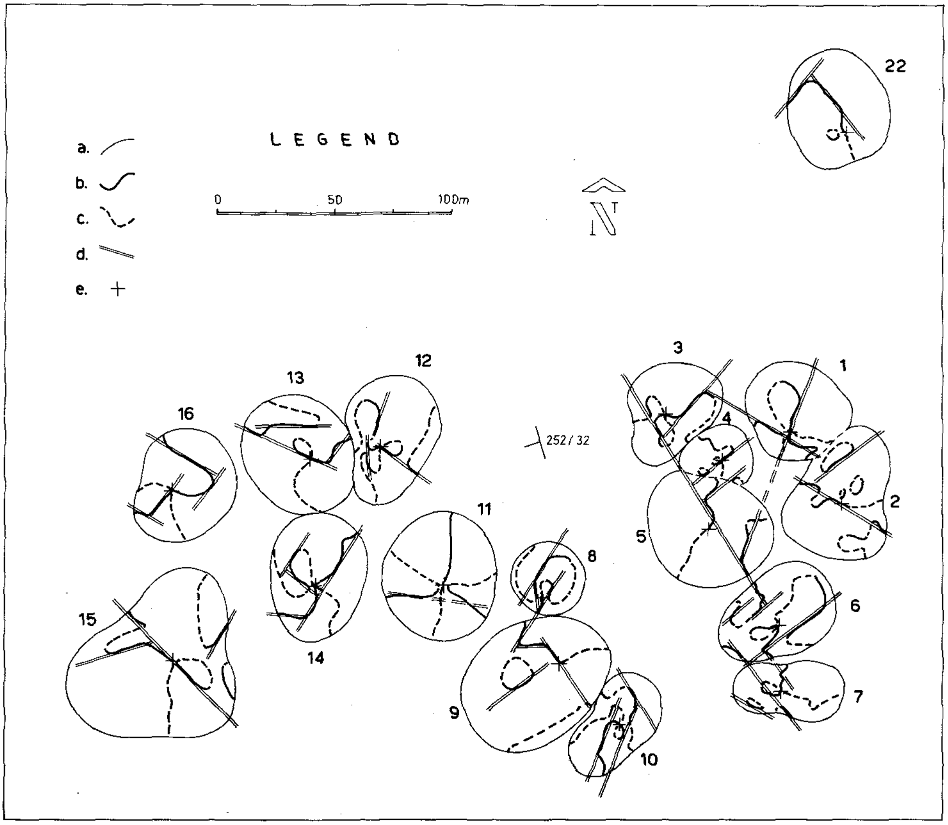
The directional distortion of the slopes provides even more information. At each position the difference between the aspect and straight direction towards the bottom point is computed. Taking cosines of these angles one obtains correlation coefficients between true and ideal shape of the doline (Fig 6/c). At same positions (hatched areas) correlation



Sl. 4: Tloris in nekaj polrezov vrtače SK-022. Korak plastnic znaša 0,5 metra. Črtkana so območja, kjer se padnica pomočja preveč odklanja od smeri proti središču.
Fig. 4: Plan and some semiprofiles of the doline SK-022. Contour lines per 0.5 m. "Nonproper" areas (see text!) are hatched.



Sl 5: Pobočja vrtače SK-022: a/ nakloni pobočij (črtkana črta je "prelivna" plastnica): b/ smeri pobočij; c/ korelacija smeri pobočij s smerjo proti središču; d/ odstopanja od idealne oblike (v stopinjah).
Fig. 5: Slopes of the doline SK-022: a/ slope angles (hatched is "overflow" conture), b/ aspect angles, c/ correlation with the ideal shape, d/ deviations from the ideal shapes (in degrees).



Sl. 6: Privlačne (debelo) in odbojne (črtkano) črte ničelnega odklona v vrtačah pri Skalčem Kamnu. Dvojne tanke črte predstavljajo možne nosilne strukture.
Fig. 6: Attractive (bold) and repulsive (broken) zero deviation lines within the measured dolines at Skalčen Kamen. Double thin lines represent possible geological structures.

is lower than 0.90 (absolute deviation approx. 25°). It means that semiprofiles across these areas are not proper (F. Šušteršič, o.c., 81). They may serve just as information, but must be omitted in numerical taxonomical operations.

Deviation angles are both positive and negative, and obviously there do exist lines of zero deviations (Fig. 5/d). Again, they are attractive if the radial component of the neighboring slope vector is directed towards them, and repulsive if the radial component is directed away. Physically, this means that the attractive zero lines reveal the positions of relative mass deficiency, and the repulsive ones a mass surplus. In other words, the attractive zero lines appear where the karstification is faster (possibly tectonically affected areas), and the repulsive zero lines are found where the rock is either more resistive, or accumulation of slope material appears.

These structures do not generally run in a radial direction; most probably they form a trellis-like network. This pattern is very usual with the buried grikes-and-clints surface outside the dolines (Fig. 6). So, it is quite possibile that there is no difference between the processes acting upon the rock surface, beneath the soil veneer within the dolines and outside of them.

But one restriction must be imposed. Due to relatively small number of measured semiprofiles (6), aliasing in tangential direction is very likely, and along the semiprofiles the higher harmonics were abandoned intentially. Consequently, the pattern may be detected in general lines only, and its details would be better revealed when studying the "noise".

Doline SK-22 is formed in mechanically relatively unresistant rock, so that downslope transport has obscured the underlying limestone surface shaping. Nevertheless, a Dinaric structure and one of its normals are quite distinguishable.

DOLINES AT SKALČEN KAMEN

LOCATION

The location Skalčen Kamen is part of the transect Borovnica and Grčarevski vrh. The project is explained in more in detail in F. Šušteršič (1987, Fig 1.). At the location, roughly indicated by Cvijić (o.c.), all the dolines fitting the main strip of the transect vrh were surveyed. It must be noted that only the area west of the "Krožna pot"[10] has been studied up to the present. The only exception is the doline matched "SK-22" which lies the closest to the actual crossing Skalčen Kamen.

The Skalčen Kamen lies in the Ravnik[11], an approximately 1.5 - 3 km wide, and 13.5

[10] In Slovene it means "circular road". The road was built for forestry purposes as the master communication for effective removal of logs. At the location Skalčen Kamen a secondary road branches off it.

[11] Within the delimited area which was used for density calculations there are 62 dolines while 68 dolines were mapped in total.

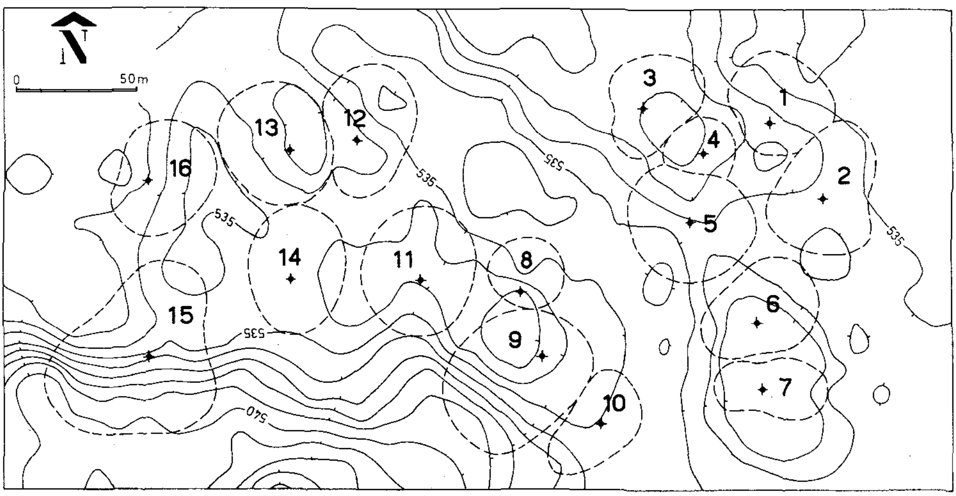
km long strip of grossly flat terrain between Begunje and Logatec. In its axial direction it is inclined about 30'. According to occurence of typical sediments it is evident that at some time in Pleistocene, a surface stream running in NW direction penetrated the Ravnik. However, it was just an episode in the completely karstic evolution, and its surprisingly straight flanks imply a predominantly tectonic origin. Unfortunately, a complete geomorphic study has not carried out yet.

The Ravnik surface crosses several carbonate formations of the Mezozoic. At the Skalčen Kamen the bedrock is of Malmian age, mainly limestone with an approx. 38 m thick dolomite intercalation. The dip is uniform, 252.3 / 31.6 (21 measurements, spherical variance = 0.0156). Detailed studies of the rock and the structure have presently been undertaken.

At present, the main courses of the sinking river Ljubljanica, between Cerkniško polje, Planinsko polje, and the Vrhnika springs pass about 100 - 150 m below the surface. Traces of some fossil river caves were found, but vertical shafts prevail, typically not deeper than 20 m. At the actual location there are only five shafts, and two rather ambiguous segments of phreatic tubes.

*

The spatial position of a doline is identified with the grid coordinates (Y, X and Z) of its "bottom point". The central parts of the dolines are generally filled with loose material and relatively flat. Consequently, Easting and Northing coordinates should be taken with



Sl. 7: Računalniška rekonstrukcija "idealnega" reliefa brez vrtač, in njihovi obodi (črtkano)
Fig. 7: Computer reconstruction of the "ideal" relief in the neighbourhood of the measured dolines, and the "lips" of the dolines (broken lines).

relative (about 1 m) tolerance. In order to enable further investigations these positions were marked with metal markers.

The area where all the dolines (62 in total)[11] were registered covers 0.174 km^2, that means the density of 356.1 dolines/km^2. Thus, the influence area of a doline covers 2808 m^2, the radius of the equivalent circle being r = 29.9 m. This density nearly equals the one established on Upper Cretaceous (352.5 per km^2), and differs from the one on Lower Cretaceous (212.2 per km^2) (F. Šušteršič, 1987, 79), in the same transect.

In order to understand the role of the dolines, two patterns are of paramount importance: their planar distribution, i.e the network of lines that they presumably lie on, and their coordination, visualized by the Voronoi diagram. Both the procedures rely upon the relations between points. If the dolines were spaced at greater distances, the question which non-dimesional point should represent the doline, would not be of great importance. However, in conditions when the dimensions of larger dolines exceed the radius of the average influence area it becomes crucial, especially if it is considered that the bottom points do not coincide with the ground plane gravity centres, and both of them with the equivalent cone apices, too. Until the roles of the three are not sufficiently cleared, this interesting question is put aside.

Sixteen dolines lie within the inner strip (Fig. 7) and they permit some insight into their spatial distribution. Among them, only three (SK-11, SK-15, SK-16) stand completely alone. The perimeters of the rest make contact in different ways. Dolines' SK-1 and SK-2, and SK-4 and SK-5 "bowls" cut one another. The intermediate terrain between the SK-6 and SK-7, and SK-3 and SK-4 does not differ from the surface further out from the dolines, but the whole contact lies within a general relief lowering. These two types are well known in literature. Opposingly, the one between the SK-12 od SK-13 which appear literaly intervolved, does not seem to have been encountered before. However, it may be either a single outcome of absolutely local circumstances, or, more seriously, an effect of incorrect definitions. The latter is the object of further study.

*

Dolines may be just the spots where local terrain lowering surpasses the general denudation rate, but there is no difference in the actual processes. If it is so, then it is rather risky to view them separately from the surrounding relief.

On the other hand, the mere existence of doline-generated surface processes which reflect in well determined "lip" suffices to accept the working hypothesis that dolines are genetically individuals, lying within a surface of different origin. In that case the "maternal" surface may be extrapolated over the dolines. In order to obtain it 220 spot elevations, mainly on the intermediate terain, and partly on the dolines perimeters were measured. Program Surfer[12] was used to obtain the contour lines (Fig. 7). Due to the lack of experience, all possible default values were retained.

Inspection of the figure is very instructive. The terrain which looked random at first

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[12] SURFER Access System Ver. 4.15, Copyright (C) Golden Software Inc. 1989.

sight is well organized in the Dinaric and South-North direction. Nearly all the dolines are gathered within the hypothetical terrain lowerings. Their bottom points lie in relative depression, below the computed 535 m contour, but avoid the extreme low positions.

If the surface shaping determines the dolines position this may mean that at some time - presumably in cold ages of Pleistocene - the surface was relatively impermeable, and that dolines were collectors of surface drainage. But, in that case dolines would occupy the very lowest parts, which is not the case.

On the other hand, if the occurence of dolines in a certain area brought about general lowering of neighbouring relief surface, one would expect that this area was shaped in some specific way. But inspection in the field did not reveal this, and well expressed "lips" imply that the surface development within dolines and outside of them go their own, different ways.

Their predominantly lateral, typically tectonically directioned positions possibly imply that the terrain lowering occurs where the parent rock is more fractured, and that dolines appear on the borders of these zones. The differences may be very tiny and might be revealed by minute tectonic analysis which has not been done yet.

The doline-less strip (noticeable also on Fig. 7), dividing the dolines in two groups approximately matches the dolomite layer. Idealized dolines (normative cones) were projected[13] on a vertical plane stretched in the dip direction (Fig. 8). It is evident that the approximate distance between the two groups fits the horizontal width of the dolomite layer reasonably well, but that they do not coincide. At the bottom the volumes of dolines are projected on the same plane, and further filtered by a cosine bell, as wide as the horizontal section of the dolomite layer. The gap between the two groups is expressed much clearer. It would overlap the dolomite stripe better if the surface were 15 m higher, that corresponds to 250 ka denudation (surface lowering), if taking in account its present rate (I. Gams, 1974, 71). Indications exist that the previously mentioned alluvium is approximatively the same age.

PARAMETRIC PRESENTATION

The following tables present some parametres provided by the program VRT[14]. The intention is primarily to give an impression about the dolines dimensions. However, some parameters, especially when inspected along with the other figures, give quite an insight into the formative processes.

In the first column there are doline labels, while in the first line there are parameter codes, explained at the bottom of the table. The units are metric.

[13] In fact, the bottom points were projected. The length of the normative cone axis (parameter 24) was used as the "depth", and inclination of its surface (parameter 25) was used as inclination of slopes. Fig. 8 is vertically exaggerated 4 times.

[14] The program is written in QBasic 4.5. The ASCII code or compiled version are available with the author or at the Karst Research Institute, ZRC SAZU, 66 230 Postojna, Titov trg 2, Slovenia.

Table 1

	5	6	8	9
SK-001	13.41	29.38	2.84	8.15
SK-002	17.57	33.52	2.94	8.80
SK-003	12.88	27.53	2.74	6.70
SK-004	7.48	17.69	2.20	5.18
SK-005	21.42	28.96	4.77	10.43
SK-006	12.81	29.93	3.06	9.03
SK-007	9.08	27.53	1.66	7.93
SK-008	6.89	23.55	0.56	5.20
SK-009	19.77	45.47	3.98	12.49
SK-010	12.82	26.65	2.60	6.68
SK-011	22.96	31.14	7.46	10.82
SK-012	10.32	32.32	2.04	8.23
SK-013	19.56	32.04	3.48	7.47
SK-014	18.27	32.26	5.53	7.33
SK-015	22.62	47.51	7.15	17.19
SK-016	13.78	28.80	5.16	9.54
SK-022	12.60	36.12	4.20	8.26

(5), (6) - the shortest and the longest radius
(8), (9) - the lowest and the highest elevation of the perimeter

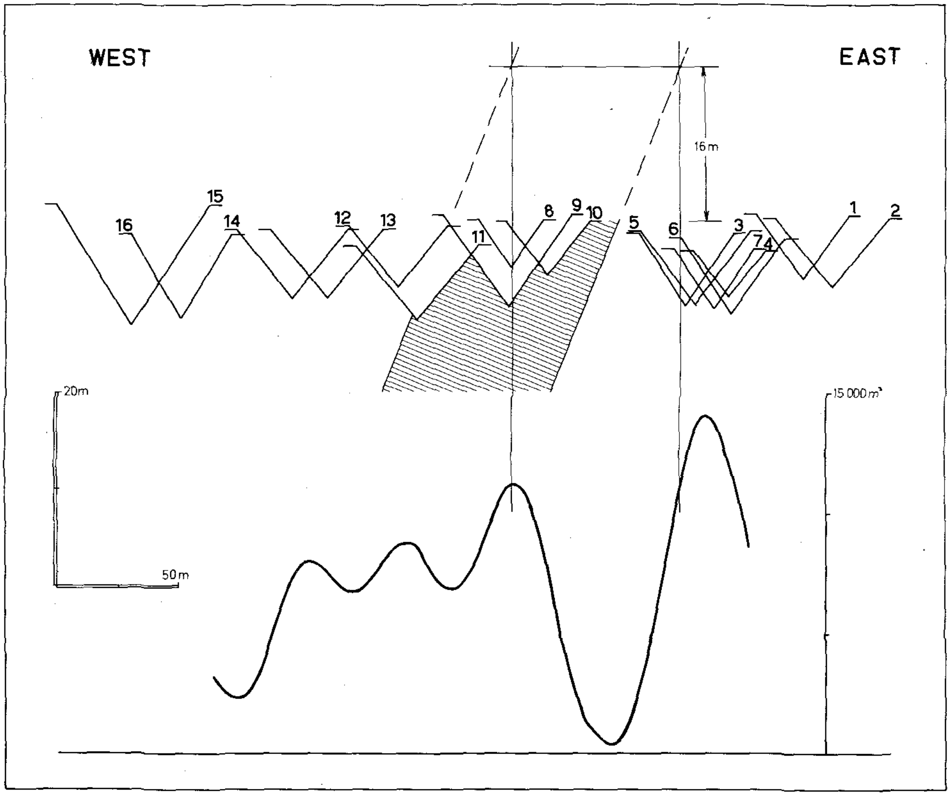
These parameters provide only information about the dolines size order. It is also evident that they are far from geometric regularity.

Table 2

0	10	11	V/A	24	25
SK-001	3351.33	1513.18	2.21	6.64	18.35
SK-002	4532.41	1947.35	2.33	6.98	17.00
SK-003	3146.03	1266.97	2.48	7.45	21.52
SK-004	979.37	632.25	1.55	4.65	21.20
SK-005	5379.75	2105.58	2.55	7.66	17.46
SK-006	4106.44	1544.47	2.66	7.98	20.61
SK-007	2062.63	979.06	2.11	6.32	22.57
SK-008	1290.12	780.76	1.65	4.96	19.60
SK-009	8616.05	2737.43	3.15	9.44	18.62
SK-010	2114.28	1161.52	1.82	5.46	16.24

SK-011	5486.18	2101.92	2.61	7.83	17.95
SK-012	3522.64	1649.21	2.14	6.41	17.83
SK-013	4603.63	1955.86	2.35	7.06	17.15
SK-014	4287.95	1805.59	2.37	7.12	17.54
SK-015	*16026.07*	*3835.63*	*4.18*	*12.53*	*20.26*
SK-016	4714.52	1627.57	2.90	8.69	22.22
SK-022	4414.83	1753.64	2.52	7.55	19.01

(10) - relative volume of the doline, (11) - planimetric area, (V/A) - relative lowering, (24) - length of the axis of the normative cone, (25) - inclination of the normative cone surface ( ).



Sl. 8: Zgoraj: normativni stožci izmerjenih vrtač in dolomitna skladovnica (črtkano), projicirani na navpično ravnino skozi padnico skladov. Štirikratno previšanje. Spodaj: Projekcija zbistrenih prostornin na isto ravnino (glej besedilo!).

Fig. 8: Top: normative cones of masured dolines and the dolomite layer (hatched), projected on a vertical plane running in the dip direction. 4 X vertical exageration. Bottom: Projection of filtered dolines volumes (See text!)

The volumes (10) and the planimetric areas (11) indicate primarly the size order of the dolines. Values of their quotients are predominantly 2.1 to 2.7. It follows that the relative surface lowering within the doline perimeter amounts to about 2.4 m in general (Fig. 9/a). The quotient is larger with the dolines SK-009, SK-015 and SK-016. Consequently, the mass removal has either been lasting longer, or it has been faster. Respective conclusions may be drawn concerning the dolines SK-004, SK-008 and SK-010 where relative lowering was smaller. It is interesting that the dolines of the smallest lowering rate are in touch with the ones with the greatest (especially the group SK-008, SK-009, and SK-010; also the group SK-003, SK-004, and SK-005). One may assume that higher inclination of slopes means faster mass removal, and that an estimate of the doline growth dynamism is given by inclinations of the cone surface (25). The angles range from 16.2° to 22.6°. A simple calculation shows that the volume of a cone increases for the factor 1.43 if its inclination changes within the mentioned range (Fig. 9/b). The plot of the V/A ratio against the inclination angle (Fif. 9/c) reveals very interesting relations. If the former assumption is fair then there exst dolines of large amount of denudation, and of great activity at the same time, too. But therea are no dolines of great activity at present, and large denudation at past (above the bold line). Thus, there exists a well defined time limit since when dolines have begun to appear. In the case of the Skalčen Kamen this conclusion is supported by other geomorphic facts, but this method might be applied also upon other localities where such an evidence is missing!

Table 3

0	20	21	22	23
SK-001	21.95	20.42	302.61	1.07
SK-002	28.10	21.34	18.00	1.32
SK-003	20.50	19.05	36.40	1.08
SK-004	15.29	12.53	79.09	1.22
SK-005	25.99	24.48	303.71	1.06
SK-006	23.91	19.82	60.89	1.21
SK-007	24.13	12.31	273.71	1.96
SK-008	15.81	14.30	289.84	1.11
SK-009	29.89	27.34	56.51	1.09
SK-010	20.77	18.11	36.96	1.15
SK-011	26.72	23.57	4.36	1.13
SK-012	26.74	18.55	7.51	1.44
SK-013	24.72	23.82	321.00	1.04
SK-014	26.85	20.14	6.04	1.33
SK-015	34.52	34.48	44.87	1.00
SK-016	23.60	20.69	24.04	1.14
SK-022	24.05	21.45	2.05	1.12

(20), (21) - lengths of the major and minor axis of the ellipse (22) - direction (azimuth) of the major axis of the ellipse (23) - elongation of the normative ellipse

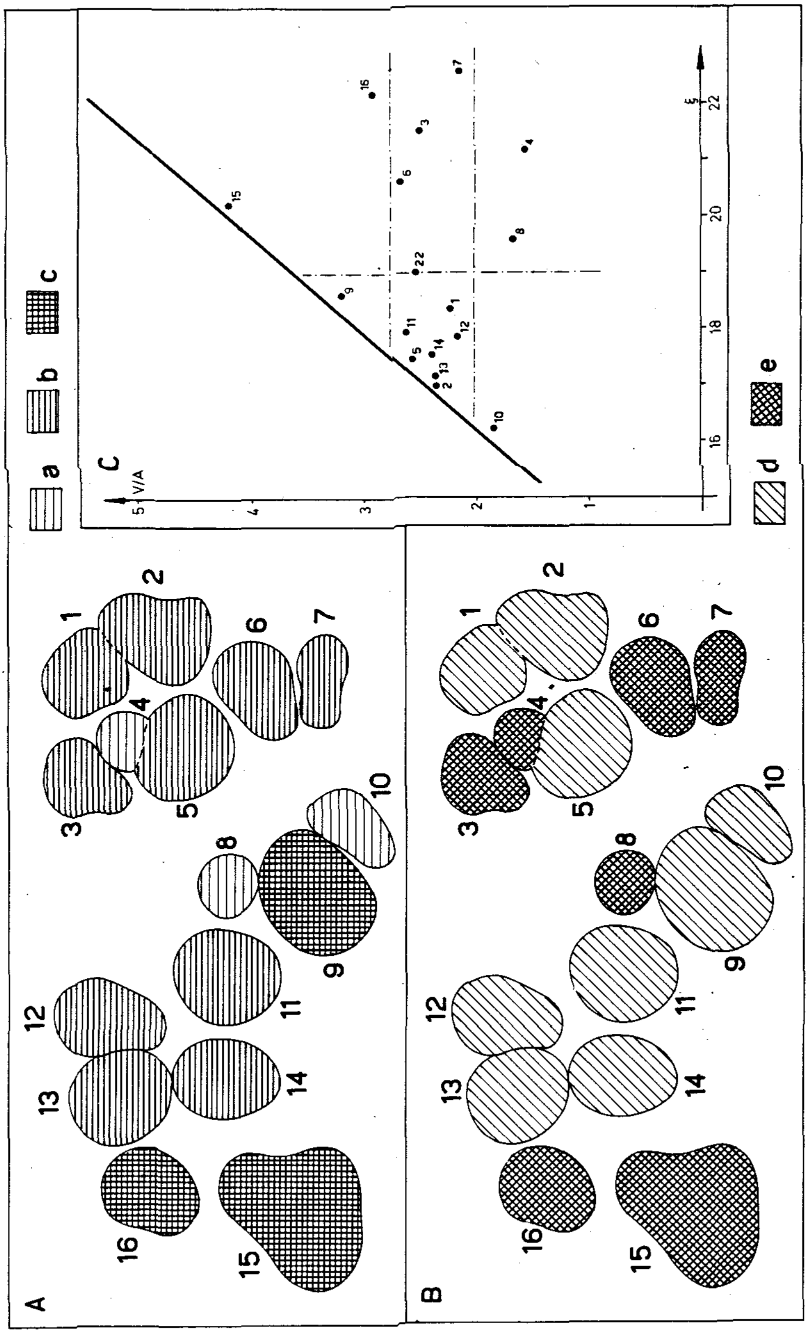


Fig. 9

The ellipses which fit the best the planimetric shapes of the dolines were computed. If the doline is reasonably regular, the axes of the ellipse is a fair estimator of the doline direction. However, if the ground plane of the doline is not regular, and even the idea of the direction loses its meaning, the ellipse longer axis still indicates the planar distribution of the negative mass. A rose diagram (Fig. 10) reveals that the preferred direction is the S-N.

Table 4

0	15	16	17	28	30	29
SK-001	8.53	25.85	0.2192	12.99	357.50	0.1753
SK-002	2.25	355.42	0.0509	10.28	258.41	0.2445
SK-003	4.54	53.85	0.1276	10.10	56.27	0.1564
SK-004	3.08	336.34	0.1225	9.70	318.03	0.2724
SK-005	1.22	240.75	0.0266	7.31	301.35	0.1480
SK-006	5.26	16.59	0.1339	10.92	43.39	0.1695
SK-007	4.43	89.29	0.1417	12.49	178.80	0.4224
SK-008	8.09	22.60	0.2897	10.45	55.04	0.2024
SK-009	12.72	232.80	0.2431	8.31	198.64	0.1429
SK-010	1.56	265.33	0.0456	4.43	2.39	0.1299
SK-011	3.44	351.98	0.0751	6.63	89.92	0.1719
SK-012	7.05	44.42	0.1737	11.52	324.13	0.3067
SK-013	5.15	296.38	0.1164	7.81	2.03	0.1667
SK-014	5.24	12.86	0.1234	13.94	354.06	0.2150
SK-015	6.24	256.55	0.1007	10.83	282.28	0.0948
SK-016	5.83	76.09	0.1446	2.70	333.52	0.1720
SK-022	10.42	344.63	0.2489	11.35	22.59	0.1704

(15) - shift of the gravity center, (16) - azimuth of the shift of the gravity center, (17) - normalized shift of the gravity center, (28) - shift of the apex, (30) - direction of the apex position, (29) - normalized shift of the apex

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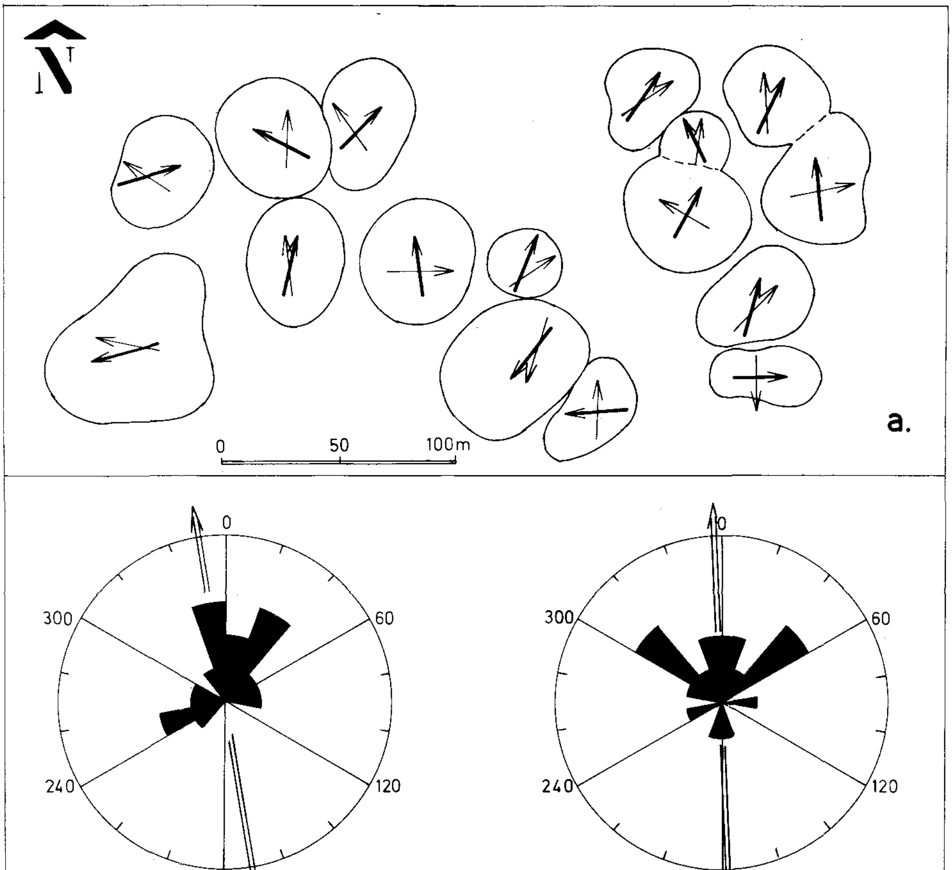
Sl. 9: Denudacija znotraj vrtač:
A: dejanski iznos = prostornina / ploščina. a/ < 2m, b/ 2m < 2.75m, c/ 2.75m <.
B: intenzivnost odnašanja = naklon plašča normativnega stožca (E). d/ < 19°, e/ < 18°.
C: Soodvisnost iznosa in intenzivnosti denudacije. Debela črta je približna meja "prepovedanega" (glej besedilo!) območja.
Fig. 9: Denudation within dolines: A: actual amount = volume divided by planimetric area. a/ < 2 m, b/ 2 m < 2.75 m, c/ 2.75m. B: intensity = inclination of the normative cone (E). d/ < 19°, e < 18°. C: Plot of the denudation against the intensity. Bold line is approximative limit of the "forbidden" area (See text!).

It is evident that the ground plane gravity centres, as well as the positions of the normative cone apexes, are shifted quite far from the bottom points. Though the directions seem scattered (Fig. 10), the directional statistics reveal coherent results. The average direction of the gravity centres shift is 351.6° (circular variance = 0.5358), and the apexes position 357.7° (circular variance = 0.5153). Differences, as well as scattering are due to



Sl. 10: a: Smeri odmikov težišč tlorisov (debelejša puščica) in vrhov normativnih stožcev (tanjša puščica). b: Rožni diagram smeri odmikov težišč tlorisov. c: Rožni diagram odmikov vrhov normativnih stožcev. Dvojni tanki črti s puščico sta povprečni smeri.
Fig. 10 a: Direction of shifts of the planar gravity centres (bold arrow) and the normative cone apices (thin arrow). b: Rose diagram of shifts of the planar gravity centres. c: Rose diagram of the normative cone apices (thin arrow). Double thin lines with pointer represent average directions.

uneven neigbouring terrain, but the general trend northwards is not negligible. In other words, this means that the deepest position of the doline lies towards the southern part of the ground plane. This may be the result of greater production of slope material on southward oriented slopes, and the creep of it towards south. Provided that the whole area has been predominantly forrested during the historical time, it is very likely that the displacement of the deepest position in the doline is due to Pleistocene subarctic conditions.

GEOMETRY

The first impression of the dolines one obtains when observing the map concerns their planar shape. As stressed in my previous work (F. Šušteršič, 1984, 1987), and also evident from A. Bondesan (& al., 1992, Figs. 14, 15), they are not as regular as many simple morphometric methods presume. Some of those irregularities are due to the roughness of the neighbouring terrain, and they do not imply irregularities of the "bowls" themselves. The others are probably due to the greater dynamism of the whole doline which does not permit the "bowl" to achieve the regular shape.

The research of the considered dolines further supports my previous observations (o.c.) that the "bowls" of the dolines are not symmetrical enough to permit classification which includes "a priori" symmetry. Consequently, the classical subdivision (Cvijić, 1893, D. C. Ford, Williams, P. W., 1989, 397) may serve as the first step of recognition only, and the semiprofiles remain the stepping stone to a more realistic classification and numeric taxonomy.

As a rule, within the perimeter, detailed morphometry revealed that the dolines geometry consists of three concentric areas.

- In the center there is a flat area, generally covered by soil. More rarely the soil is missing, and the center of the doline is occuppied by an inverted cone of loose boulders. Very exceptionally there appear the openings of vertical shafts[16]. The outer limit of this zone may usually be recognized by eye. On some infrequent occasions the border between the massive soil accumulation in the center, and relatively thin veneer of the soil on the solid slopes is virtually undistinguishable, and only detailed surveying or penetration would provide the proper information. If the soil deposit is somewhat more extensive, its surface is generally slightly inclined southwards.
- Then follows the ring of most inclined, and also the toughest slopes. They are the least weathered part in the whole doline. The surface may even be solid rock. More generally, it is reminiscent of the surface on hillslopes outside the dolines. It must be stressed that the inclination is not constant and the inflection point of the doline slopes is always within this zone.
- In the outer belt slopes are gentler, usually inclined at about a half of the maximum. They are evidently less stable than the ones within the itermediate belt. Somewhere clints

[15] The direction SE-NW is the direction of the main dinaric shear movements, while the N-S direction is the direction of the extension fissures of the same system.

[16] This was observed in quite an extent by Jennigs (J. N., 1975), without drawing further consequences.

stick out of the veneer of colluvium. The vertical extent of this zone does not exceed about 3 m, but it varies from doline to doline, even from place to place within a single doline. Its outer border is the perimeter of the doline, which it is marked by an abrupt change of the slope. In the case study the dolines had not been modified by human activity.

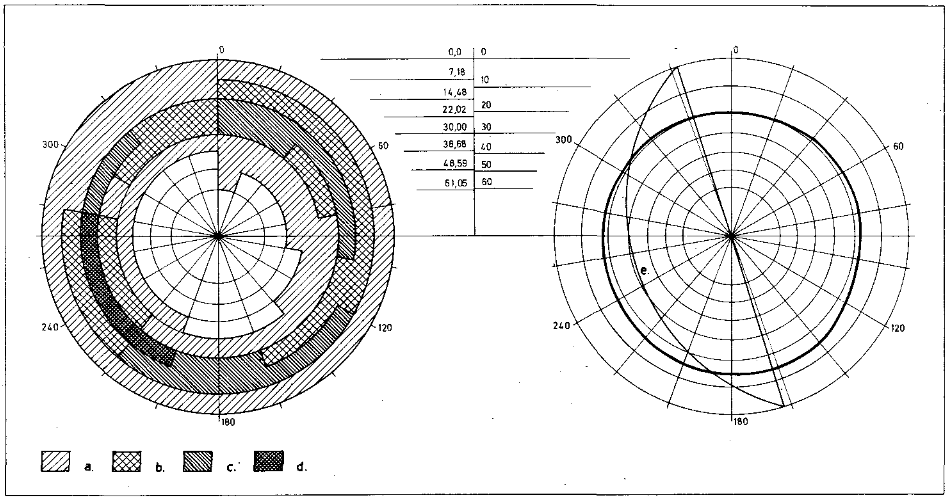
In the doline SK-022, the three zones are well evident from semiprofiles directioned 111.3° and 201.3° (Fig. 4). The inner belt is characterized by constant, linear increase of the slope angle. Thus, the slope is parabolic, which is a direct consequence of equilibration of the colluvium. The maximum slope is achieved in the intermediate belt, where slope angle changes according to the bell-like pattern. In the outer belt the slope angle tends to an approximate constant value. The slopes tend to be conical, which is an equilibrium reaction of an undercut, less stable layer. Other semiprofiles present more complex shapes, probably due to the reason that the "bottom point" has been shifted quite away from the center.

Though the three belts remain recognizeable in any direction, the slope angles generally change according to the direction of the slope. The doline SK-022 was scanned in 1 m intervals, and the aspect and the slope angles were computed. The results of the rough count of scores are presented in the following table:

Table 5

	0	5	10	15	20	25	30	35	40
0 - 19.9		5	18	8	6	9	11	-	-
20 - 39.9		1	16	15	12	13	2	-	-
40 - 59.9		-	9	23	14	7	-	-	-
60 - 79.9		-	6	47	8	-	-	-	-
80 - 99.9		-	12	55	7	-	-	-	-
100 - 119.9		-	25	46	42	-	-	-	-
120 - 139.9		1	37	50	60	4	-	-	-
140 - 159.9		1	38	59	49	31	-	-	-
160 - 179.9		1	58	58	44	44	-	-	-
180 - 199.9		1	28	59	42	46	-	-	-
200 - 219.9		1	8	49	41	44	-	-	-
220 - 239.9		2	4	17	60	36	-	-	-
240 - 259.9		1	2	4	57	27	-	-	-
260 - 279.9		-	1	1	38	17	4	-	-
280 - 299.9		-	-	1	30	10	10	-	-
300 - 319.9		-	-	1	13	13	9	-	-
320 - 339.9		-	-	-	3	23	36	3	-
340 - 359.9		-	5	6	8	7	24	9	-

Vertical classification: aspect angle
Horizontal classification: slope angle



Sl. 11: Levo: Frekvence smeri pobočij v vrtačah SK-001 do SK-016: a: 0 % - 1 %; b: 1 % - 2 %; c: 2 % - 3 %; d: 3 % <. Desno: Vpad skladov matične kamnine (lok) in smer najstrmejših pobočij (debela črta) - stereografska projekcija. Opomba: Slika prikazuje dejansko usmerjenost pobočij. Če želimo poudariti njihov položaj znotraj vrtač, moramo sliko zasukati na glavo.

Fig. 11 Left: Frequencies of the slope directions within the dolines SK-001 to SK-016: a/ 0% - 1%, b/ 1% - 2%, c/ 2% - 3%, d/ 3% <. Right: Dip of the parent rock (arch) and the line (bold) of the greatest inclination of slopes (stereographic projection). Note: The figure is oriented according to actual aspects of slopes. If intending to visualize their position within the dolines the figures must be turned up-side-down.

However, this arrangement is rather misleading because the areas of the spherical rectangles differ between parallel belts. In order to obtain fair statistics, the widths of the slope classes were changed to obtain equal areas. Additionaly, the data was changed to parts per mille:

Table 6

	0.00	7.18	14.48	22.02	30.00	38.68
0 - 19.9		9	9	6	9	-
20 - 39.9		5	12	10	7	-
40 - 59.9		1	17	14	1	-
60 - 79.9		-	30	5	-	-
80 - 99.9		1	35	7	-	-
100 - 119.9		2	36	27	-	-
120 - 139.9		2	45	39	-	-
140 - 159.9		1	51	50	-	-
160 - 179.9		1	60	51	4	-
180 - 199.9		2	47	41	11	-
200 - 219.9		2	27	42	10	-
220 - 239.9		2	7	58	1	-
240 - 259.9		1	2	44	4	-
260 - 279.9		-	1	25	9	-
280 - 299.9		-	1	19	9	-
300 - 319.9		-	1	10	10	-
320 - 339.9		-	-	6	30	1
340 - 359.9		1	5	5	19	5

Somewhat more comprehensive, but in essence the same picture displays the sumaric table for all the rest of the dolines at the Skalčen Kamen.

Table 7

	0.0	7.2	14.5	22.0	30.0	38.7	48.6	61.0
0 - 19.9	2.2	12.3	22.6	21.9	4.6	0.1	0.2	
20 - 39.9	2.7	14.0	21.6	20.0	1.8	0.2	-	
40 - 59.9	2.1	16.8	24.3	18.5	1.2	-	-	
60 - 79.9	4.0	18.5	27.9	11.7	2.4	0.9	-	
80 - 99.9	2.6	14.4	21.7	8.1	1.9	0.4	-	
100 - 119.9	2.2	15.8	14.6	9.1	2.0	-	-	
120 - 139.9	4.5	23.3	14.5	7.8	0.4	-	-	
140 - 159.9	4.8	25.6	17.1	3.2	-	-	-	
160 - 179.9	4.6	26.1	23.8	3.0	-	-	-	
180 - 199.9	5.5	24.3	26.4	6.8	-	-	-	
200 - 219.9	5.5	26.3	30.3	8.6	0.1	-	-	
220 - 239.9	4.1	16.7	32.3	10.1	0.3	-	-	
240 - 259.9	2.1	15.0	35.2	11.6	0.8	-	-	
260 - 279.9	2.4	12.1	33.1	12.2	1.6	-	-	
280 - 299.9	1.0	9.1	24.1	9.9	1.4	-	-	
300 - 319.9	1.4	6.5	21.1	10.2	1.4	-	-	
320 - 339.9	2.6	7.0	16.2	11.7	2.5	-	-	
340 - 359.9	2.1	8.3	17.9	14.5	3.5	-	-	
Total	56.4	292.3	424.9	199.0	25.7	1.5	0.3	

The slopes oriented southwards are the gentlest and the slopes oriented northwards are the steepest. However, the dip angle of parent rock influences the slope formation too and the former tables present the interplay of both (Fig. 11).

Combined with the previously discussed shift directions of the ground plane gravity centres and the normative cone apices towards the north, this is another hint that dolines had achieved most of their present form in cold periods of the pleistocene. At this times, exposition of slopes, and consequently, freeze and thaw oscilations were the most important factors controlling the slope formation. That the slopes feature forms of paralell slope retreat is so selfexplanatory.

Not ignoring an important detail: neither runnels or other traces of water streaming on the slopes, nor alluvial sedimentation at their feet were found. The only linear entrenchments, detected by computer analysis and hardly observable by naked eye are sutures, i.e. relative lowerings of tectonically crushed zones (F. Šušteršič, 1987, F. Šušteršič, 1988).

It is clear that the extent of the central portion depends exclusively of the accumulation of the products of the slope processes, and thus it is only temporary. Then, what is below? According to Cvijić's drawing (o.c.), and its numerous replicas, there should be a zone of weathered rock gradually passing to a number of small channels in solid rock. Anglo-saxon students would prefer the idea of a swallet, continuing to one tube or two tubes. P. W. Williams (1985, 465, Fig. 2) presented a somewhat different picture which is a compromise between the former two ideas.

Systematic examination of many dolines, especially in progressing faces of quarries, revealed that at least in this part of Slovenia, neither concept is fair. As dolines, cut by quarries (Fig. 12), as the relatively infrequent examples of completely empty dolines, display the same structure. The bottom of the "bowl" is of solid rock nearly to the actual center, where there appears an abrupt break into a vertical shaft. Sometimes, the edge is smoothed to some extent, but it is absolute clear that the transition is not gradual (Fig. 13). The diameters of the shafts are from 5 m 10m, while their depth is not known. No quarry face is high enough to cut the whole shaft. At the moment, the deepest accessible one is about 60m - but the apparent bottom is a boulder choke!

On the walls of the open shafts flowstone is quite usual. Shaping of their walls is typical for the pits, eroded by free falling water or by water films on the walls. In short, they are examples of the "ortovacua", defined by W. Maucci (1951/52). It appears that they match the "domepits" (W. B. White, 1988, Ford, D. C., Williams, P.W., 1989, 304, Fig. 7.38) in anglo-saxon literature.

The filling is predominantly loamy material, with loess or periglacial gravel mixed together. In many cases movement into the central shaft below is evident (Fig. 14) (also P. Habič, 1987). The sections in quarries, as well as minute study of dolines slopes reveal that in the vicinity there exist filled parallel shafts which are completely passive and do not perform any mass movement, much less any influence on the formation of the doline.

SOME DISCUSSION

If Cvijić's most cited object is not a doline, then another holotype must be determined. As mentioned before, the doline matched SK-022 was by no doubt implicitively referred to by Cvijić, within the group example of dolines at Skalčen Kamen. Besides, it features well the forms and processes, encountered in all the dolines of the area, and more general, it is also a good representative of millions of dolines in the Dinaric karst on the Balkans peninsula. Therefore, it is proposed that this should serve as the holotype of Cvijić's dolines, while the structure reproduced in his two books must be abandoned. The attribute "Cvijić's" is important because there is quite an evidence that the dolines, studied predominantly by the Anglo-saxon researchers (J.N. Jennings, 1975 is partly an exception) are not of the same kind.

*

Consequently, the role of the dolines in the karst surface must be reconsidered. This topic was extensively discussed by S. Bahun (1969); for our purpose his ideas might be simplified into three options:

1. Dolines are integral part of the karst surface. Due to local conditions lowering has been more extensive at some spots, but the processes are absolutely the same.

2. Dolines are specific phenomena of transition of the surface drainage into the underground one. Thus they are not just local lowerings, but they still play a role in the surface karstification.

3. Dolines are reproductions of the underground karst voids on the surface. The very act of intercourse is not a collapse, but denudation of the surface which is permanently opening the underlying caverns to surface. Having appeared on the surface these "negative masses" may have their own way of development, controlled by superficial processes.

It is evident that Cvijić has chosen the first option. However, a fundamental objection arises automatically. If the weak-points on the surface are geological structures, which are linear as a rule, then, why are dolines so very circular, even if ranged along tectonical lines, and clearly displaying these structures even in their internal form.

The second option is the one how Cvijić was predominantly understood. A number of the Anglo-saxon authors (M. Day: 1976, 1983, Ph. R. Kemmerly: 1976, 1982, 1986, P. W. Williams: 1985) support it more than enough. Even some rare examples from the karst of Slovenia might be best explained in this way.

The third option appears to fit best the dolines at Skalčen Kamen and its wider neighbourhood. Bahun (o.c.) did not pay great attention to the initial caverns, while C. D'Ambrosi (1960) explictively derived dolines from the Maucci's (1952) "ortovacua", i.e. vertical shafts. This best fits my observations of the dolines. It appears that some other researchers, especialy (J. N. Jennings, 1975, G. Benvenutti & U. Sauro, 1977, and A. Bondesan, M. Meneghel, and U. Sauro, 1992) deal with the same matter, though not being completely aware of all the consequences.

However, any further work depends greatly on our knowledge about the vertical shafts. At the moment, the classification of the vertical shafts is only rudimentary, and their origin has not been completely solved. It appears that only the domepits are prone to evolve into dolines, but the explanations of their origin diverge. In my experience, the explanation proposed by W. Maucci (o.c.), and further supported by A. Frumkin (1984, 1986) best fits the reality of the Classical karst.

The present shape of the dolines at the Skalčen Kamen is predominantly due to the Pleistocene gelifraction, and consequently, parallel slope retreat. Nevertheless, it does not mean that they are only passive concavities in the karst surface. Within them quite different rates of mass removal have been detected. Surprisingly, this process seems to be time constrained, though not simultaneous in all the population. Rather than the loamy filling in the central part of the dolines, the mass removal affects the coarse material deeper in the central shaft. In the section of the doline Renčelica near Sežana (P. Habič, 1987) it is clearly visible that the pleistocene gravel is sinking in the center of the doline (Fig. 15). A similar process has been established in some collapse dolines (F. Šušteršič, 1973), even if actually not connected with active caves.

It does not seem that the present dolines are any kind of catchment area. However, if the mass removal is so fast that the slopes can not cope with it, they will become steeper and steeper and the critical angle between vetical and superficial drainage is surpassed. In that case the second option of the doline interpretation becomes valid. In Pliestocene, when prmafrost appeared, this process might be quite widespread. However, the swallets formed in these conditions typically differ from the central shafts (dome pits).

*

Many dilemmas remain. Perhaps, the guideline for the future is the citation from W. B. White (1988, 20): "Dolines and pits have traditionally been discussed separately, ... they are closely related to the same processes of vertical solution and transport".

KLASIČNE VRTAČE KLASIČNEGA KRASA

Povzetek

Korenine

Del svojega Karsta (1893, 1895) je J. Cvijić posvetil zaprtim kraškim globelim srednjih izmer - vrtačam. Sto let nadalnjih raziskav je znanje o vrtačah bolj razširilo kot poenotilo. Zdi se, da raziskovalci uporabljamo isti besednjak, a ne govorimo vedno o istih naravnih pojavih. V takih primerih se samoumevno obračamo k koreninam in skušamo dognati, kaj so imeli v mislih pionirji, ki so postavili definicije.

Cvijić (o.c.) se sklicuje na opazovanja po celotnem ozemlju nekdanje Jugoslavije, vendar nudi en sam oprijemljiv primer vrtače. To je presekana globel v boku useka na železniški postaji Logatec. Slika tega prereza (J. Cvijić, 1893, 43; 1895, 63) je postala ena najbolj ponatiskovanih v vsej geomorfološki literaturi (Sl. 1). Današnje stanje tega prereza (Sl. 2) je zaradi širitve postaje precej drugačno, vsekakor pa je jasno, da ne gre za centralni presek vrtače, temveč za prečni prerez linearnega znižanja površja vzdolž zdrobljene cone (Sl. 3, krožec).

Napačno izbran primer je Cvijića in naslednike zapeljal k dedukciji, ki je daleč od realnosti. Vrtačo je razumel kot znižanje reliefa na tektonsko bolj poškodovanem mestu, pod njo pa je pričakoval množico drobnih kanalov v zdrobljeni kamnini. Ker v rabi izraza "ponor" ni dosleden, dojemajo predvsem anglosaški raziskovalci vrtačo (doline) kot stično točko med krajevnim površinskim in kraškim odvodnjavanjem (M. Day, M., 1976, 1983; Ph. R. Kemmerly, 1976, 1982, 1986; P. W. Williams, 1985). Njihova opazovanja takšno gledanje podpirajo - ne da pa se ga vskladiti z opazovanji vrtač na klasičnem krasu Slovenije oz. Dinarskega krasa. Da bi razčistil dilemo, sem podrobno obdelal 17 vrtač na lokaciji Skalčen Kamen 6 km jugovzhodno od Logatca, kjer Cvijić omenja lepe primere vrtač. Za v bodoče predlagam kot "holotip" vrtačo z delovno oznako SK-22.

Metoda

V nadalnjem so predstavljeni predvsem rezultati morfometrije. Znotraj preseka, definiranega v F. Šušteršič (1987), sem po metodah, opisanih v F. Šušteršič (1985 in 1989)

izmeril in obdelal vrtače na lokaciji Skalčen Kamen. S pomočjo računalniškega programa VRT je bilo izračunanih 30 parametrov, med njimi:

(5), (6) - Najkrajši in najdaljši tlorisni polmer vrtače glede na najnižjo točko.
(8), (9) - Največja in najmanjša višinska razlika med obodom in najnižjo točko.
(10) - Prostornina vrtače (zaprte globeli).
(11) - Ploščina znotraj oboda.
(15) - Premik težišča tlorisa glede na najglobljo točko.
(16) - Azimut premika težišča.
(17) - Normirani premik težišča (parameter 16 deljen s kvadratnim korenom tlorisne ploščine, deljene s pi).
(20), (21) - Najdaljša in najkraša os elipse, ki ima enako ploščino in enak vztrajnostni moment kot tloris vrtače (normativna elipsa).
(22) - Smer daljše osi normativne elipse.
(23) - Razmerje med daljšo in krajšo osjo normativne elipse.
(24) - Dolžina osi normativnega stožca. Vrtači je prirejen stožec z enako prostornino in tlorisno ploščino, presekan z ravnino, ki se najbolj prilega obodu. Ta parameter nadomešča intuitivno "globino".
(25) - Naklon plašča normativnega stožca. Ta parameter nadomešča intuitivni "povprečni" naklon pobočij.
(28) - Premik konice stožca glede na najglobljo točko vrtače.
(29) - Normirani premik konice. Podobno kot pri parametru (17).
(30) - Smer položaja konice glede na najglobljo točko.
(V/A) - Relativni iznos denudacije znoraj oboda vrtače.

Pri obdelavi je upoštevan samo "dolgovalovni paket", kar omogoča izločenje drobnih motenj v oblikovanosti vrtače. Tako dobimo "nemotene oblike" polrezov (Sl. 4). Geometrijo vrtače podajajo iznos (Sl. 5/a) in smer (Sl. 5/b) naklona pobočij. Pobočja se odklanjo od idealne smeri proti najglobljі točki, zato so kosinusi kotnih razlik cenilka skladnosti oblike realne vrtače z idealno (Sl. 5/c). Odkloni so pozitivni in negativni, zato obstojijo črte ničelnih odklonov, ki so privlačne ali odbojne (Sl. 5/d). Privlačne ničelne črte so mesta realativnega znižanja znotraj idealnega pobočja vrtače. Skupinski vzorec privlačnih ničelnih črt v vseh izmerjenih vrtačah (Sl. 6) spominja na škraplje v okolici, kar da misliti, da je podpovršinsko zakrasevanje zunaj vrtač in na pobočjih "sklede" v bistvu enako.

Vrtače pri Skalčnem Kamnu

Lokacija Skalčen kamen leži v osrednjem delu Begunjsko-Logaškega Ravnika. V širši okolici znaša povprečna gostota vrtač 356.1 na km^2. Vplivno območje posamezne vrtače pokriva 2808 m^2, kar da polmer r = 29.9 m. Njihovo prostorsko razporeditev na ožjem območju kaže Sl. 7. Na osnovi 220 merskih točk med njimi je bilo izračunano hipotetično površje, kamor so vrtače "vložene" (ista slika). Splošna organizacija površja "brez vrtač" je sorazmerno zelo pravilna, kaže pa značilne dirnarske smeri. Nobena vrtača ne leži v dnu izračunanih globeli, kar kaže, da niso odtoki krajevno zbrane deževnice.

Razviden je tudi pas brez vrtač, ki se približno krije z dolomitno skladovnico. Na navpično ravnino, ki poteka skozi padnico skladov, sem projiciral normativne stožce vrtač (Sl. 8, zgoraj) in njihove prostornine (spodaj). Približna širina dolomitnega pasu se ujema s širino pasu brez vrtač. Skladanje bi bilo popolno, če bi bilo površje 15 m višje, kar odgovarja 250 ka denudacije (po I. Gamsu, 1974, 71).

Prej našteti parametri so v več tabelah (1 do 4, glej angleško besedilo!) razporejeni v smiselne skupine, kar omogoča zanimive primerjave. Kvocienti med prostorninami in ploščinami so pretežno 2.1 to 2.7. Torej znaša relativno znižanje znotraj oboda v povprečju 2.4 m (Sl. 9/a). Kjer je večji, je bilo odnašanje mase hitrejše, ali pa je trajalo dlje. Večji naklon normativnega stožca (Sl. 9/b) lahko pomeni intenzivnejše odnašanje. Na sl. 9/c so nanešeni kvocienti V/A in naklonski koti. Torej obstojajo vrtače z visokim iznosom denudacije in veliko trenutno aktivnostjo, ni pa vrtač kjer bi bila denudacija velika v preteklosti, danes pa bi bila intenzivnost odnašanja nizka (nad krepko črto). Torej obstoji časovna meja, pred katero se vrtače niso pojavljale.

Iz povprečnih smeri odmikov težišča tlorisa (351.6°, cirkularna varianca = 0.5358) (Sl. 10/a) in konic normativnega stožca (357.7° (cirkularna varianca = 0.5153) (Sl. 10/b) je očitno, da so najgloblje točke vrtač bliže južnemu kot severnemu robu. Po vsej verjetnosti je to posledica pleistocenskih pobočnih procesov, ki so bili učinkovitejši na prisojnih, severnih pobočjih.

Meritve vrtač pri Skalčnem kamnu potrjujejo prejšnje ugotovitve (F. Šušteršič, 1984, 1987), da sestavljajo osnovni vzorec pobočij trije koncetrični pasovi, katerih nakloni seveda zavisijo tudi od osončenosti. V sredini je skoraj ravno območje ilovnatega polnila. Sledijo sorazmerno strma pobočja praktično v živi skali. Zunanji pas je položnejši - krije se z bolj preperelim, površini bližjim predelom matične kamnine. Ti pasovi so jasno razvidni s polrezov vrtače SK-022 (Sl. 4).

Sledeče tabele (5 - 7) prikazujejo statistiko naklonov pobočij v vseh vrtačah in posebej v vrtači SK-22. Potrjena je prejšnja ugotovitev, da na iznose naklonov močno vpliva osončenost, očiten pa je tudi vpliv vpada skladov (Sl. 11). Ponovno lahko ugotovimo, da kažejo pobočja izključno sledi pleistocenskih pobočnih procesov, nikakor pa ne fluvialnih.

Po vsej podobi se pod vrtačami nahajajo navpični jaški, zapolnjeni z ilovico in pleistocenskim materialom, kar kažejo tudi preseki v kamnolomih (Sl. 12). "Skleda" vrtače prehaja v jaške z jasnim pregibom, lahko pa te prehode minimalno zaobli (Sl. 13) v notranjost polzeči material (Sl. 14). Odkopavanja kažejo, da stene teh jaškov mnogokrat prekriva siga. Njihova globina ni znana - najglobljí (izpran) v Leskovi dolini je globok prek 60 m, v kamnolomih pa običajno sežjo preko višine celega čela. Kaže, da odgovarjajo "ortovakuolam", kot jih definiral W. Maucci (1951/52) in ki jih Anglosaksonci imenujejo "domepits".

Nekaj razprave

Ker smo odvrgli Cvijićevo tolmačenje vrtač in definirali nov holotip, moramo pretresti tudi vlogo vrtač v kraškem površju. Kaže, da je tematiko najbolje razčlenil S. Bahun (1969). Med različnimi možnostmi, ki jh ponuja, realnosti Skalčnega Kamna najbolj odgovarja tista, ki ima vrtače za preslikave kraških votlin na površje. Samo dejanje preslikave ni podor, temveč zniževanje površja, ki postopoma načenja prostore v globini. Po odprtju uberejo lastno razvojnoo pot, kjer se uveljavljajo površinski procesi.

Bahun (o.c.) ni bil posebej pozoren na izvor prvotnih votlin in je prezrl, da je C. *D'Ambrosi (1960) vrtače eksplictino izpeljal iz Mauccijevih (o.c.)* "ortovakuol", torej brezen. Ta kombinacija se najbolje sklada z mojimi opazovanji (o.c.), delno pa tudi z J. N. Jenningsom (1975), G. Benvenuttijem in U. Saurom (1977) in A. Bondesanom, M. Meneghelom in U. Saurom (1992). Globlje spoznanje vrtač v veliki meri zavisi od razumevanja navpičnih brezen. Kaže, da se v vrtače razvije samo en tip, tisti, ki sta ga doslej proučevala W. Maucci (o.c.) in A. Frumkin (1984, 1986).

Sedanja oblika vrtač je v veliki meri delo pleistocenskih pobočnih procesov. Ne znotraj vrtač, ne v okolici ni sledov fluvialnega oblikovanja. Ker se zdi slednje za vrtače Tennesseeja dokazano dovolj prepričljivo (Ph. Kemmerly, 1986), gre po vsej verjetnosti za dvoje različnih pojavov, ki ju obravnavamo pod istim imenom. Vodilo nadalnjim raziskavam naj bo W. B. Whitova (1988, 20) misel: "Iz navade vrtač in brezen ne obravnavamo skupaj ... toda .. oboje je tesno povezano z istimi procesi navpičnega raztapljanja in transporta."

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SOME THOUGHTS ON THE PULL-APART ORIGIN OF KARST POLJES ALONG THE IDRIJA STRIKE-SLIP FAULT ZONE IN SLOVENIA

NEKAJ MISLI O RAZPORNEM (PULL-APART) NASTANKU KRAŠKIH POLJ OB IDRIJSKEM ZMIČNEM PRELOMU

MARKO VRABEC

Abstract UDC 551.24 (497.12 Idrija)

Marko Vrabec: Some Thoughts on the Pull-Apart Origin of Karst Poljes along the Idrija Strike-Slip Fault Zone in Slovenia

There is still no satisfactory explanation of mechanisms for karst poljes formation. Some authors have recently assumed them to be pull-apart basins, yet they didn't provide convincing supporting evidence. This article takes into consideration detailed geological field maps, geophysical and borehole data and observations on geometry of poljes and surrounding lineaments. Regarding various published research describing pull-apart basins and their formation, it seems that poljes are not of pull-apart origin. However, depression in the central part of Cerkniško polje could be an early stage in pull-apart basin evolution, which would suggest that poljes are being deformed by current strike-slip activity in Idrija fault zone and are therefore of older origin. Still, more field evidence is required to substantiate this theory.

Key words: karst poljes, pull-apart tectonics, Idrija strike-slip fault

Izvleček UDK 551.24 (497.12 Idrija)

Marko Vrabec: Nekaj misli o razpornem (pull-apart) nastanku kraških polj ob idrijskem zmičnem prelomu

Za nastanek kraških polj še ne poznamo povsem zadovoljive razlage. Nekateri raziskovalci so v zadnjem času domnevali, da so polja ob idrijskem prelomu nastala z mehanizmi razporne (pull-apart) tektonike, vendar ugibanj niso podprli s prepričljivimi argumenti. V tem prispevku so upoštevani rezultati preteklih detajlnih geoloških kartiranj, geofizikalni podatki in podatki plitvega vrtanja ter opazovanje geometrije polj in okoliških lineamentov. Iz primerjave z raziskovalno literaturo, ki obravnava razporne bazene in njihov nastanek, se zdi, da polja niso razpornega nastanka. Špranjasta depresija v centralnem delu Cerkniškega polja bi lahko bila začetna stopnja v razvoju razpornega bazena, kar bi lahko pomenilo, da trenutna zmična aktivnost ob idrijskem prelomu polja deformira in so polja potemtakem starejšega izvora. Tudi ta domneva pa bi zahtevala še dodatnih terenskih dokazov.

Ključne besede: kraška polja, razporna (pull-apart) tektonika, idrijski prelom.

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INTRODUCTION

Neotectonic activity in the Slovenian teritory is generated by collisional/postcollisional processes between the Eurasian and African litospheric plates. Considering the physical nature of plate tectonic processes, we can assume broadly continuous tectonic activity over a large period of time rather than distinct episodes of "orogeny" and calm times. "Tectonic phases" should therefore be regarded as periods of different stress fields and strain rates, which can, as was found recently, change relatively fast over a geologically short period of time.

It is reasonable to expect that surface morphology (relief) of the Slovenian teritory is strongly determined by tectonic activity. However, the interesting question remains, especially in classical karst areas, to what extent this influence is active (relief produced by uplift and subsidence of tectonic blocks) and to what extent only passive (relief shaped by intensified weathering along mechanically weakened fault zones). In either case, in karst areas structurally produced relief forms mostly tend to be unmasked by mass transport processes, as the principal transport direction is downwards (see e.g. Šušteršič 1986).

The major Slovenian karst poljes lie along the Idrija strike-slip fault zone, which trends diagonally in the NW-SE direction across southwestern Slovenia. The question of their origin is nearly as old as karstology, the main dispute being over their tectonic vs. erosional/corrosional formation. Although many ideas developed in the last 100 years (see Gospodarič and Habič 1978, for a review) we do not find any of the proposed theories acceptable.

The theory of tectonic origin of poljes seems to be favoured by most geologists. Jevšenak (1986), for example, states that poljes are "neotectonic depressions (seismotectonic grabens)" without giving any further explanation or argumentation. In the search for an explanatory mechanism, some recent papers suggested the pull-apart origin of poljes (Poljak 1986, Verbič et al. 1992); however, they did not provide much supporting evidence.

The purpose of this work was to gather available field data in order to evaluate the feasibility of poljes pull-apart origin theory.

STRIKE-SLIP TECTONICS AND PULL-APART BASIN FORMATION

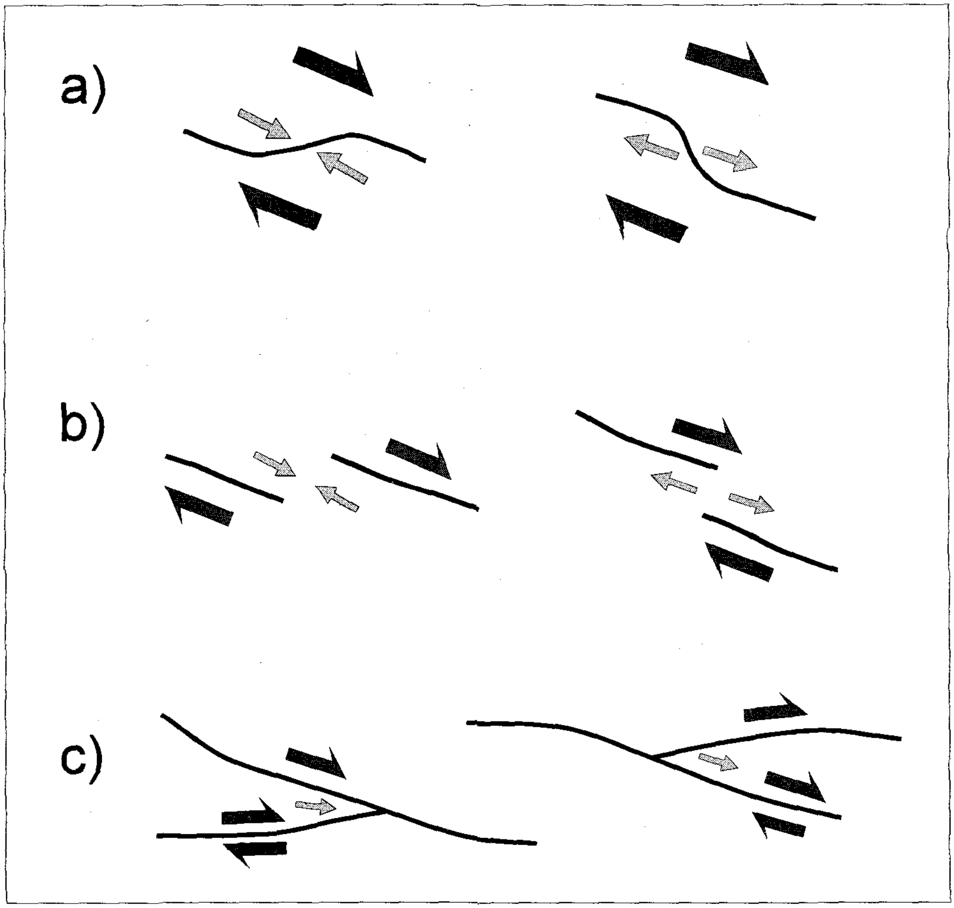

Fig. 1: Restraining (left side) and releasing geometries for right-lateral strike-slip fault. a) Fault bend. b) Overstep between en-echelon faults. c) Fault junction. Large arrows indicate relative movement of blocks, smaller arrows show sense and orientation of stress.
Sl. 1: Kompresijske=stiskajoče (na levi strani) in relaksacijske=sproščujoče geometrije poteka trase desnozmičnega preloma. a) Prevoj trase preloma. b) Prečni preskok med vzporednima (ešaloniranima) prelomoma. c) Stik dveh prelomov. Večje puščice kažejo smer relativnega premikanja blokov, manjše puščice pa smer in orientacijo mehanskih napetosti.

Strike-slip faults are defined as the faults along which predominantly horizontal displacement in the direction of the fault strike has taken place. Magnitude and obliquity of the slip can vary significantly along the same fault. Areas of convergent and divergent tectonic regimes also exist inside strike-slip zones and consequently produce associated structural phenomena such as folds, normal and reverse faults, thrusts and basins. Interested reader should turn to other sources for more in-depth treatment and further references (e.g. Sylvester 1984, Allen and Allen 1990, Twiss and Moores 1992).

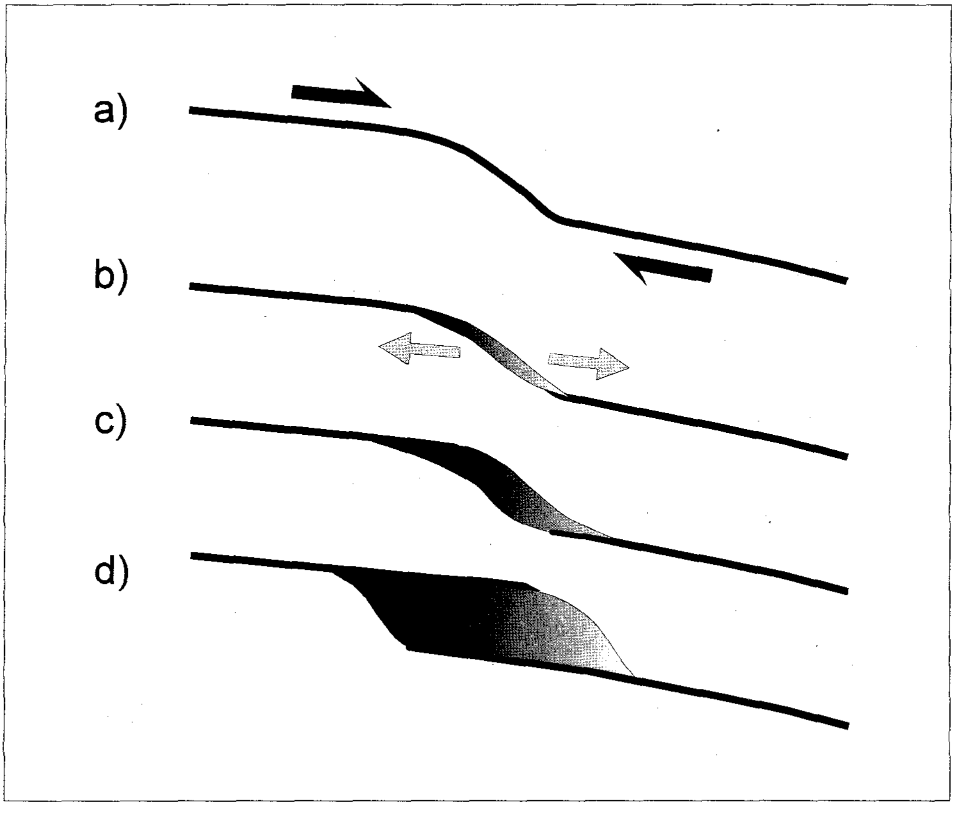

Fig. 2: Continous model of pull-apart basin development (Mann et. al., 1983). a) Right-lateral strike-slip fault with a releasing bend. b) Spindle-shaped basin (pull-apart basin initiation) c) Lazy-Z shaped stage d) Rhomboidal basin.
Faults bounding the basin are termed master faults. Secondary structural pattern inside the basin is not shown. Basin grows with progressing offset along the fault.
Sl. 2: Model zveznega razvoja razpornega bazena (po Mann et. al. 1983). a) Desnozmični prelom z relaksacijskim prevojem trase. b) Špranjasti bazen (začetek rasti razpornega bazena). c) Bazen oblike razpotegnjene črke "Z". d) Bazen romboidalne oblike. Preloma, ki omejujeta bazen, literatura imenuje glavna preloma. Sekundarne strukture znotraj bazena niso prikazane. Bazen raste s povečevanjem zmika ob glavnih prelomih.

It is known that structural patterns in strike-slip zones tend to be similar regardless of scale (Aydin and Nur 1982). On a local scale (several km to several 10km), extension and/or compression is mainly due to curvature of the fault trace, stepovers between en-echelon faults or due to stress at fault junctions (Fig. 1). Note that the fault geometry and the sense of slip determine the stress regime.

Pull-apart basins form in the zones of extension within the strike-slip zones. They are predominantly elongated and usually of rhomboidal shape. Their further characteristics include high subsidence rates, large total subsidence and therefore rapid sedimentation with thick sediment accumulations (Ballance and Reading 1980, Sylvester 1984, Christie-Blick and Biddle 1985, Allen and Allen 1990).

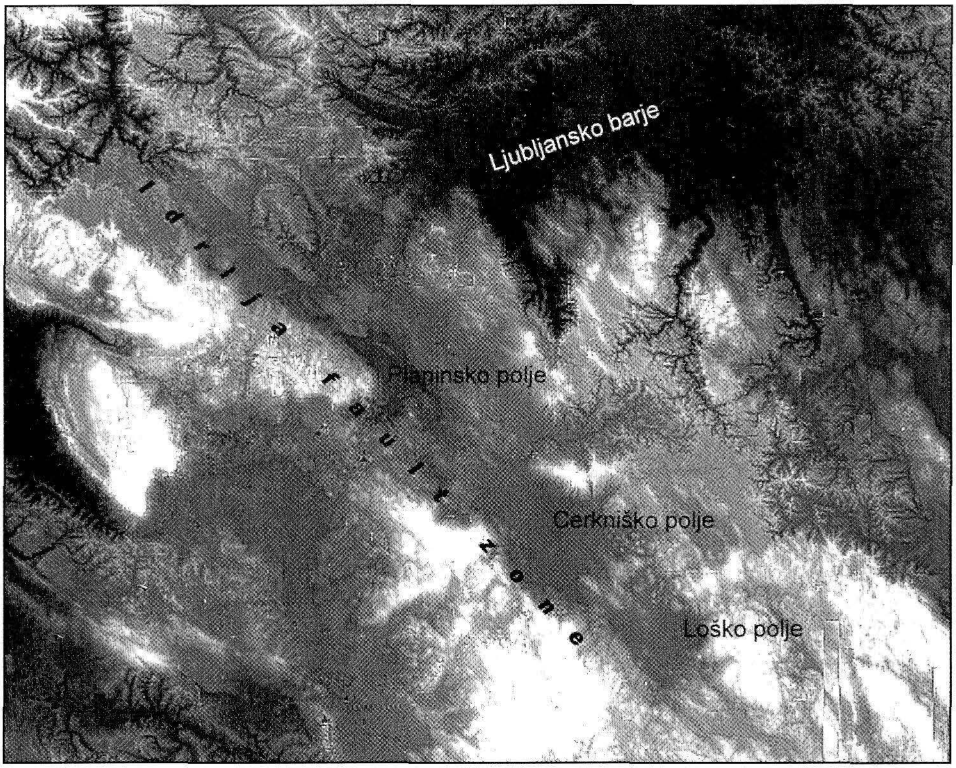

Fig. 3: View of the SW Slovenia showing the Idrija fault zone and major karst poljes. The Ljubljansko barje basin is a quaternary graben structure (Mencej, 1989). Image produced by edge enhacement (Laplacian method) of Digital Elevation Model data. Width of area shown is 60 km.

Sl. 3: Slika jugozahodne Slovenije prikazuje cono idrijskega preloma in večja kraška polja. Bazen Ljubljanskega barja je kvartarna tektonska udorina (Mencej 1989). Slika je izdelana z računalniško obdelavo (ojačanje robov po Laplacéovi metodi) digitalnega modela reliefa. Širina območja na sliki je 60 km.

Several models of pull-aparts evolution were proposed, based on field observations as well as numerical modelling and theoretical considerations (see Mann et al. 1983, for review). Of those, the continuous model of Mann et al. (1983) is most widely accepted (Fig. 2). This, however, is not the only known basin-forming mechanism in strike-slip settings (see e.g. fault-wedge basins in Crowell 1974).

IDRIJA STRIKE-SLIP FAULT ZONE

The Idrija fault is a right-lateral strike-slip fault extending diagonally in the NW-SE direction accross southwestern Slovenia (Fig. 3). Its trace can be well seen on satelite images and is therefore regarded as a structure of regional importance, although this aspect, to our knowledge, hasn't been fully studied yet. The fault was most thoroughly studied in the Idrija mercury mine area where plenty of surface and subsurface data was available (Placer 1982). The maximum horizontal slip has been determined to amount about 2500m (Placer 1982). The fault is highly active as recent movements of 1cm/year have been postulated from changed position of trigonometric points since the beginning of the century (after unpublished work of Vodušek, in Čar and Pišljar 1993).

Field data show that the Idrija fault is a zone of several parallel faults rather than a single fault. Detailed field maps are scarce, however, and cover only a minor portion of the entire zone (Placer 1982, Čar 1981, Čar and Gospodarič 1983, Šušteršič 1989). Lineaments observed on the computer image (Fig. 3) correspond well with larger faults that were determined (Fig. 4). Therefore it seems justified to use this image in the evaluation of the major structural patterns in the area.

Čar and Gospodarič (1983) have determined four generations of faults during their painstaking study of the area between Planinsko and Cerkniško polje. According to their observations the Idrija structures are the youngest as they cut and displace the older ones. The magnitude of the displacements seems to be quite small, which was also supposed by Placer (personal communication), who predicted the slip to be nearly vertical at Planinsko polje.

POLJES INSIDE THE IDRIJA FAULT ZONE

Within the Idrija strike-slip fault zone lie three large karst poljes: Planinsko, Cerkniško and Loško (Fig. 3). Their geometry seems to be strongly influenced by geological structures. Poljes are covered with thin (several m) sediment cover, ranging from clay to sand (Gospodarič and Habič 1978). Their limestone/dolomitic basement is more or less uniformly flat with many small scale irregularities due to various karstic forms, mostly dolines and shafts (Ravnik 1976, Gospodarič and Habič 1978).

If poljes are indeed of predominantly tectonic origin as many workers claim (see the Introduction), the model of their formation should be argumented as well. One of the possible explanations could be pull-apart processes. A definite answer cannot be given until a detailed geological mapping of the broader area including further geophysical investigations is carried out. Yet, the data gathered so far allow at least a feasibility evaluation of this theory.

Although at a first glance poljes, notably Planinsko, are geometricaly similar to pull-apart basins described elsewhere (see references in the Section 2 of this text), many inconsistencies with the classical pull-apart models exist.

1. The lenghth of poljes is greater than the total slip assumed at the Idrija fault zone, which contradicts observations of Mann et al. (1983), according to which pull-apart basins are generally much shorter.

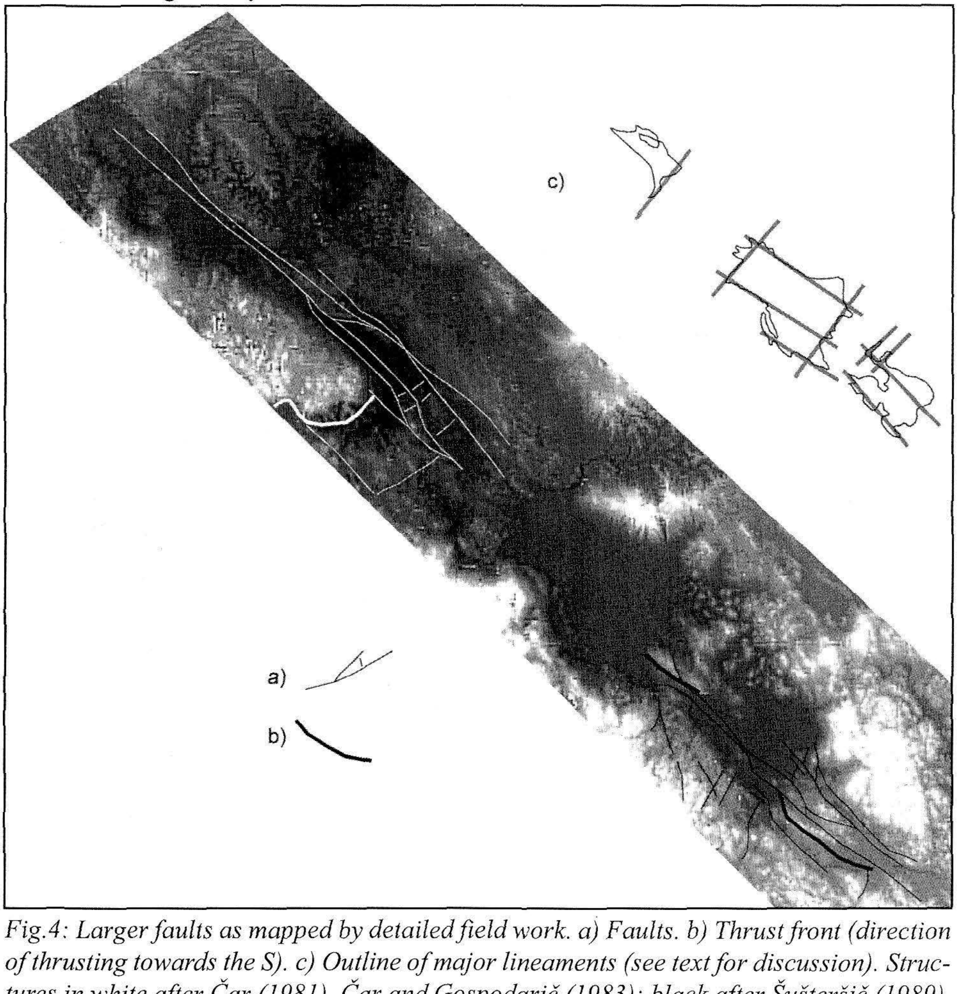

Fig.4: Larger faults as mapped by detailed field work. a) Faults. b) Thrust front (direction of thrusting towards the S). c) Outline of major lineaments (see text for discussion). Structures in white after Čar (1981), Čar and Gospodarič (1983); black after Šušteršič (1989).

Sl. 4: Potek pomembnejših prelomov, povzeto po rezultatih podrobnega geološkega kartiranja. a) Prelom. b) Narivno čelo (smer narivanja je proti jugu). c) Potek glavnih lineamentov (razlaga v besedilu). Strukture, izrisane v beli barvi po Čarju (1981), Čarju in Gospodariču (1983); strukture v črni barvi po Šušteršiču (1989).

2. Known field data and observation of lineaments on Figs. 3 and 4 indicate mostly parallel faults without significant releasing bends or en-echelon arrangement of fault segments, which usually generate pull-apart basins.
3. The rhomboidal shape of Planinsko polje is oriented opposite to the geometry necessary to produce divergence in the right-lateral slip environment. Therefore, if the northern edge of Planinsko polje was a fault bend or an overstep connecting parallel faults, right-lateral movement would cause a compression and not an extension (see Fig. 1).
4. If poljes are (or have been) active tectonic basins, we expect their basement would be segmented by secondary faults and differentialy subsided, which is not the case with poljes (see Mencej 1989, for comparsion, or Allen and Allen 1990, their Fig. 7.54, for examples from pull-apart environment). Borehole and geophysical data (Ravnik 1976, Gospodarič and Habič 1978) show flat and uniform basement, as already mentioned above.
5. Rapid subsidence, as generally observed in pull-apart basins, would undoubtedly produce more significant sediment accumulations than seen today in poljes, at least in the

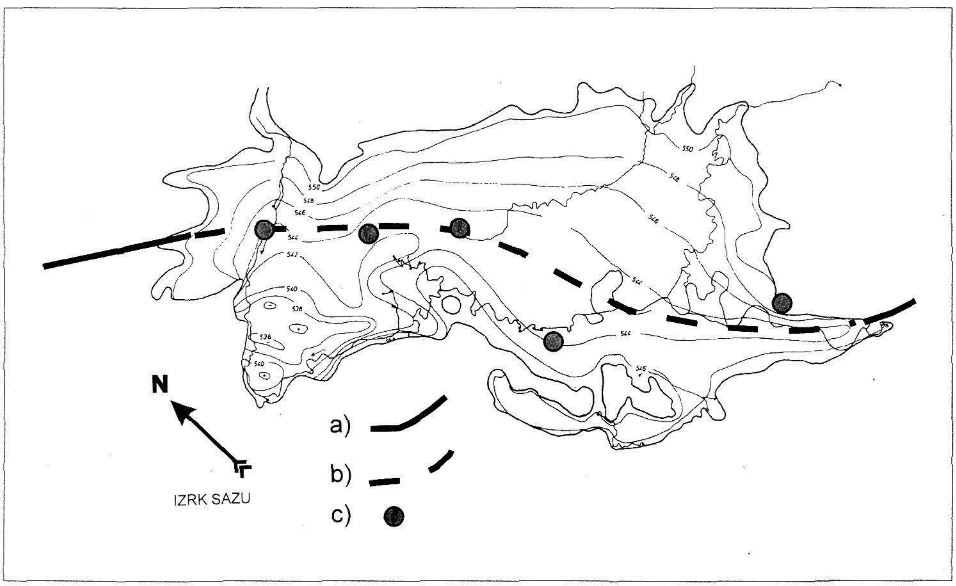

Fig. 5: Basement contours of Cerkniško polje (map after Gospodarič and Habič 1978), showing hypotetical spindle-shaped pull-apart basin. Contours at every 2m. a) Trace of major mapped fault. b) Hypotetical fault trace c) Earthquake epicenters after Jevšenak (1986).

Sl. 5: Oblika kameninske podlage Cerkniškega polja (karta po Gospodariču in Habiču 1978) s prikazanim hipotetičnim špranjastim razpornim bazenom. Izohipse na vsaka 2 metra. a) Potek pomembnejših prelomov (po objavljenih geoloških kartah). b) Hipotetični potek preloma. c) Epicentri potresov po Jevšenakovi (1986).

form of marginal talus and debris fans (the opposite view might be that the solutional lowering of poljes surroundings is rapid enough to compete with their subsidence).

6. The shape of Loško polje is highly irregular with height to width ratio well above the 3:1 average for pull-apart basins (Aydin and Nur 1982)

If the shape of Cerkniško polje is approximated by a pair of parallelograms, their longer axis is inclined for about 20 degrees to the Idrija fault zone (Fig. 4). The shorter sides of those parallelograms as well as some other lineaments from the area have approximately the same orientation as the first generation of faults mapped by ar and Gospodarič (1983). Those faults are reported to be very prominent with wide crumbled zones and are presumably significantly older than the fourth generation (Idrija) faults. Such correlation made on the base of lineaments seen on images is doubtful, however, until proven in the field.

A large number of boreholes was made on Cerkniško polje in order to determine thickness of Quaternary sediments. A basement map (Gospodarič and Habič 1978) shows a prominent elongated depression lying accross the polje (Fig. 5). Its ends trend towards two larger faults of the Idrija fault zone. The faults are most probably linked together, in which case there is a releasing bend or an overstep in between. According to Jevšenak (1986), several earthquake epicenters have been located along this inferred line. The depression could therefore be an initial stage of pull-apart basin development of Mann et al. (1983, see Fig. 2).

CONCLUSION

It seems that strike-slip faults of the Idrija fault zone cross and deform poljes, which, if tectonic origin is still assumed, are therefore of older origin. As already mentioned, extensive field work will be needed to substantiate this theory and borehole data from Cerkniško polje must be statictically re-evaluated to prove that the observed basement depth differences are significant.

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NEKAJ MISLI O RAZPORNEM (PULL-APART) NASTANKU KRAŠKIH POLJ OB IDRIJSKEM ZMIČNEM PRELOMU

Povzetek

Za nastanek kraških polj še ne poznamo povsem zadovoljive razlage. Nekateri raziskovalci so v zadnjem času domnevali, da so polja ob idrijskem prelomu nastala z mehanizmi razporne (pull-apart) tektonike, vendar ugibanj niso podprli s prepričljivimi argumenti. V tem prispevku so upoštevani rezultati preteklih detajlnih geoloških kartiranj, geofizikalni podatki in podatki plitvega vrtanja ter opazovanje geometrije polj in okoliških lineamentov. Iz primerjave z raziskovalno literaturo, ki obravnava razporne bazene in njihov nastanek, se zdi, da polja niso razpornega nastanka. Špranjasta depresija v centralnem delu Cerkniškega polja bi lahko bila začetna stopnja v razvoju razpornega bazena, kar bi lahko pomenilo, da trenutna zmična aktivnost ob idrijskem prelomu polja deformira in so polja potemtakem starejšega izvora. Tudi ta domneva pa bi zahtevala še dodatnih terenskih dokazov.

PAPERS PRESENTED AT INTERNATIONAL ROUND TABLE "E. A. MARTEL ET LE KARST SLOVENE", POSTOJNA, 12TH - 13TH NOVEMBER 1993

PRISPEVKI PREDSTAVLJENI NA MEDNARODNI OKROGLI MIZI "E. A. MARTEL IN SLOVENSKI KRAS", POSTOJNA, 12. - 13. NOVEMBER 1993

EDOUARD ALFRED MARTEL AND THE SLOVENE KARST

EDOUARD ALFRED MARTEL IN SLOVENSKI KRAS

ANDREJ KRANJC

Izvleček UDK 551.44 (497.12) : 929 Martel E.A.

Kranjc, Andrej: Edouard Alfred Martel in slovenski kras

Martel je trikrat obiskal kras na današnjem slovenskem ozemlju. Pokrajina Kras je po njem "prva pokrajina, kjer so resno in znanstveno preučevali podzemeljsko hidrologijo". Odtod tudi njegovo zanimanje za obisk tega krasa: najpomembnejša je bila njegova odprava med 8. septembrom in 24. oktobrom 1893. V tem času je premeril, skupaj z vodilnimi avstijskimi speleologi in postojnskimi jamarji, podzemeljsko Pivko in s tem je postala Postojnska jama najdaljša v Evropi.

Ključne besede: krasoslovje, speleologija, speleozgodovina, Martel E. A., Slovenija, Postojnska jama

Abstract UDC 551.44 (497.12) : 929 Martel E.A.

Kranjc, Andrej: Edouard Alfred Martel and Slovene Karst

Martel visited karst in nowadays Slovenia three times. Country Kras was, by his own words, "the first country where underground hydrology was seriously and scientificaly studied", hence his interest to visit it. The most serious were his investigation from 8th September to 24th October 1893. During this visit the survey of underground Pivka river was realized with the help of the leading Austrian speleologists and cavers from Postojna, and thus Postojnska jama cave became the longest one in Europe.

Key words: karstology, speleology, speleohistory, Martel E.A., Slovenia, Postojnska jama.

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E. A. Martel was born on 1st July, 1859 at Pontoise and died on 3rd June, 1938 at his castle La garde near Montbrison. According to the accessible documents he visited Austria four or five times: in 1866 (?), 1867, 1879, 1893, and 1896.

In October 6th, 1879 he visited with parents and five other Frenchmen Postojnska jama for the first time. He was deeply impressed, as he wrote afterwards: "les splendeurs de la caverne d'Adelsberg me firent envier les heureux pionniers souterrains..." (Casteret 1950; Martel 1894).

Before Martel came to Kranjska (= Carniola) he was known speleologist already and he wanted to see and to explore also the karst - to be exact "les pays calcaires" - out of France too. Here it has to be mentioned that he did not like "neologisms" and he did not used the words "karstification" and "phénomènes karstiques" but "phénomènes du calcaire" instead of. For him Austria was "la Terre classique des cavernes" and Kras itself "véritable terre des cavernes" (Martel 1894).

During the Martel's epoch the knowledge of the karst of Kranjska had long tradition already. I have to mention the earliest descriptions and investigations of caves and karst from 16th century on (Wernher, Kircher, Valvasor, Nagel, Steinberg, Hacquet, Gruber), cave tourism (Vilenica in 17th Cent., regular tourism in Postojnska and Škocjanske jame since 1819 on), and applied investigations (water supply, prevention of floods, tourism, etc.). These include deep potholes investigations on the Kras itself (Lindner - Labodnica or Trebiciano), Škocjanske jame (Svetina 1839), caverns of Notranjska and Kras (Schmidl about 1850), Škocjanske jame by Deutsche und österreichische Alpen Verein (from 1884 on). In Vienna the first speleological society "Verein für Höhlenkunde" was founded in 1879 and from 1889 at Postojna speleological society Anthron existed. Martel knew all this as may be seen also from his statements that the Kras "... c'est le premier sol ou l'on ait sérieusement et scientifiquement étudié l'hydrologie souterraine ..." and that it "possède des grottes et des rivières intérieures qui, pour la beauté et la puissance, se placent au premier rang parmi leurs semblables." (Martel 1894).

On the other hand Martel was well known to the Austrian speleologists with whom he had scientific relations too. Already before his speleological visit of Kranjska, on the August 17th 1890, a new discovered chamber in Škocjanske jame was named after him the "Martel Dom" (Pazze 1893).

One out of Martel's earlier and greater mission to the foreign karst was his visit to the Austrian karst in 1893 (from 8th September to 24th October 1893) during which he stayed at Postojna from 14th September to 24th September.

The preparations for his study voyage were exhaustive as usually. He turned for help directly to the Austrian government. In Vienna the karst of Kranjska was well known, regarding the fact that the Ministry of Agriculture was intensively occupied with the financing of the Notranjska karst investigations and floods prevention plans for the karst poljes. I am ignorant of Martel's proposals and arguments sent to Vienna, but I am sure they must exist in Vienna's archives.

In any case Martel's arguments were very good and he got the support from the highest court's and professional circles. Let Martel tell himself: "Par votre arreté en date du 16 Août 1893 vous avez bien voulu me confier une mission scientifique à l'effet d'étudier les grottes et rivières souterraines du Karst (Carniole, Istrie, Dalmatie, Bosnie, Herzégovine et Monténégro ..." (Martel 1893; Kranjc & Kranjc 1988). The Agriculture Minister Falkenhayn himself handed him recommandation letters for the civil and military authorities for the mentioned territories. And "... son Excellence le comte Falkenhayn, alors ministre d'Agriculture à Vienne, avait mis à ma disposition Mr Wilhelm Putick, inspecteur adjoint des forèts à Villach (Carinthie), ce dernier était, par ordre supérieur, chargé de me conduire dans les principales et les plus intéressantes des cavernes qu'il avait découvertes et explorées ..." (Martel 1893). Putick was specialist (Kranjc & Kranjc 1981) for the investigations of karst underground and karst waters in Kranjska. He became the leading Austrian speleologist, primarily as a field researcher. But Putick was not simply appointed to accompany Martel, the formalities were respected. "Hofrath" Salzer personally came from Vienna to Postojna to introduce Putick to Martel.

Martel's underground investigations executed between September 15th and 20th are well known, a lot was written already about them and they are described in details in the chapter "Karst" of his book Les Abîmes (Martel 1894).

For Carniola's karst the essential is Martel's underground navigation from Postojnska jama to Magdalena jama, thus the Postojnska jama system became the longest one in Europe, with the total lenght of about 10 km. And Martel's sentence published in Les Abîmes, that Postojnska jama is "maybe the most beautiful in the World" had great influence upon the francophone and even larger public.

For the history of our speleology the fact that this achievement was made by the help of Postojnska jama workers, of the members of Anthron Club, and of W. Putick and F. Kraus personally, is of the same importance as the underground adventure itself. Specially important is that Martel in Les Abîmes mentioned all the names of his assistants. Martel's book and his letters were the only source of our knowledge upon Anthron Club, and before we found the Anthron's Statute also the only direct proof of the existence of the club itself (Kranjc 1988; Kranjc 1990).

For Postojna as a town the meeting of, we can say, the most eminent speleologists of the period was extremely important. Minister Falkenhayn ordered that "Hofrath" Salzer came personally from Vienna to Postojna to introduce Putick to Martel, and for this occasions at Postojna beside mentioned Martel, Putick and Kraus gathered also Pazze, Marinitsch, Müller and Novak. I may say that we are a bit disappointed that municipality did not mark some of these events by a monument, a table, by a name of house or street.

The direct Martel's influence was felt at Postojna too: few years later Postojnska jama administration purchased the same type of boats that Martel had.

Martel visited also an important part of Notranjski kras and Kras in its strictest meaning; that is less known but nevertheless important and interesting for our speleohistory: for Rakov Škocjan and Zelške jame in particular he said "Je ne connais rien de plus bizarre que cette disposition"(Martel 1894), in Velika Karlovica he found safety exit (where Putick and his workers were trapped by sudden flood few years earlier), in the entrance pitch of Logarček (in that period called "Falkenhayn Höhle") the wooden ladders from 1887 were repaired by Putick's command, he made an experiment to measure the ceiling height in Škocjanske jame by the means of paper "mongolfier" running on hot air, etc., etc.

Less known and studied is the influence that had our karst and Martel's visit to it on Martel himself and on his later work. However it is well known that he published special articles talking about our karst, he mentioned and used the examples from our karst in his other works (specially as references and for comparation), he came back to Austrian karst, and he maintained the contacts with Austrian speleologists and organizations (Postojnska jama included), and maybe the best proof is the legacy of the copy of the Austrian cave register, made by Kraus, to Martel, to the Société de Spéléologie respectively.

Named after Martel, there are beside the Martel's Dom in the Škocjanske jame which was mentioned already, along the underground Pivka river the Martel's Hall and the Martel's Breakdown, and on the Trieste Kras there is the Fovea Martel (Kranjc 1993).

Translated by Maja Kranjc

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EDOUARD ALFRED MARTEL IN SLOVENSKI KRAS

Povzetek

Martel je trikrat obiskal kras na današnjem slovenskem ozemlju. Po njegovih lastnih besedah je Avstrija "klasična dežela jam", Kras sam pa "prava zemlja jam", kjer je bila "podzemeljska hidrologija prvič resno in znanstveno preučevana". Martel ni maral neologizmov in si je v svojih delih prizadeval, da ne bi uporabljali izrazov "kras" in "kraški", pač pa "apnenčev" ali "podzemeljski".

Njegova najpomembnejša odprava na naš kras je bila med 8. septembrom in 24. oktobrom 1893, med katero je bil deset dni (14.-24. septembra) v Postojni. Za ta obisk je dobil podporo in priporočila Kmetijskega ministrstva z Dunaja. Med 15. - 20. septembrom je Martel ob organizacijski pomoči V. Puticka in F. Krausa ter v spremstvu članov društva Anthron in vodnikov Postojnske jame preplul podzemeljsko Pivko od Velike dvorane v Postojnski jami do Magdalene jame. S tem je Postojnska jama dosegla dolžino okoli 10 km in postala najdaljša v Evropi.

Za Postojno je bilo gotovo velikega pomena, kar sicer ni ovrednoteno niti posebej obeleženo, da so se ob omenjeni priliki l. 1893 srečali v Postojni z Martelom takratni vodilni avstrijski speleologi Kraus, Marinitsch, Müller, Novak, Pazze, Putick in Salzer - največje priznanje tako Postojnski jami kot postojnskim jamarjem.

Obisk našega krasa je imel velik vpliv tudi na Martela in njegovo kasnejše delo:
- objavil je več prispevkov o našem krasu;
- v drugih svojih delih često omenja kras in jame z našega krasa;
- še večkrat je obiskal takratni avstrijski kras;
- ohranil je stike z avstrijskimi speleologi.

E. A. MARTEL IN BRIEFEN AN CARLO MARCHESETTI UND ERZHERZOG LUDWIG SALVATOR

PISMA E. A. MARTELA CARLU MARCHESETTIJU IN NADVOJVODI LUDWIGU SALVATORJU

BRIGITTA MADER

Izvleček UDK 044 : 929 Martel E.A.
551.44(091) : 929 Martel E.A.

Mader, Brigitta: Pisma E. A. Martela Carlu Marchesettiju in nadvojvodi Ludwigu Salvatorju

Avtorica objavlja pisma E. A. Martela botaniku, prazgodovinarju in direktorju Naravoslovnega muzeja v Trstu, Carlu Marchesettiju in avstrijskemu nadvojvodi Ludwigu Salvatorju, naravoslovcu in avtorju znanstvenih del. Nadvojvoda je povabil Martela naj razišče "Cuevas del Drach" na Mallorci, kar je razvidno tudi iz korespondence. Iz Martelovega pisma je opazen trud, da bi pridobil Marchesettija za sodelavca revije "La Nature", pa tudi Martelovo zanimanje za kras v današnji Sloveniji.

Ključne besede: zgodovina, speleologija, speleozgodovina, Martel E. A., Marchesetti C., Ludwig Salvator Erzherzog.

Abstract UDC044 : 929 Martel E.A.
551.44(091) : 929 Martel E.A.

Mader, Brigitta: E. A. Martel's letters to Carlo Marchesetti and Erzherzog Ludwig Salvator

The author is publishing the letters of E.A. Martel to the botanist, prehistorian, and director of Natural History Museum in Triest, Carlo Marchesetti and to the Austrian Erzherzog Ludwig Salvator, natural history scientist and author of scientific works. Erzherzog invited Martel to explore "Cuevas del Drach" on Mallorca, which can be seen from the correspondence too. From Martel's letter may be seen his wish Marchesetti to be the author for the "La Nature" review, as well as his interest for the karst in nowadays Slovenia.

Key words: history, speleology, speleohistory, Martel E. A., Marchesetti C., Ludwig Salvator Erzherzog.

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Im Goldenen Buch des Naturhistorischen Museums von Triest[1] findet sich am 16. Oktober des Jahres 1893 die folgende Eintragung: E. A. Martel avocat à Paris avec Madame.

Auch Carlo Marchesetti, unter dessen Direktion das Museum von 1876 - 1921 stand, vermerkte den Besuch Martels in den Jahresberichten[2].

Marchesettis Kontakte zu Martel beschränkten sich jedoch nicht nur auf die üblichen Pflichten des Hausherrn, sondern erstreckten sich, wie zwei Briefe aus der reichen Korrespondenz Marchesettis mit Gelehrten aus aller Welt, die im Diplomatischen Archiv der Städtischen Bibliothek Triest[3] aufbewahrt wird, bezeugen, auch über das gemeinsame Arbeitsgebiet der Karst- und Höhlenforschung.

Besonders interessant und aufschlußreich ist in Hinblick auf den wissenschaftlichen Austausch Martels Brief vom 10. Dezember 1907 an Marchesetti[4]. Marchesettis Schreiben vom 5. Dezember 1918 oder 1919[5] - die beiden letzten Ziffern sind übereinander geschrieben - , das nur als Konzept vorliegt, gibt hingegen in erster Linie der Freude über den beendeten Ersten Weltkrieg und die wiedergewonnene Freiheit sowie der Hoffnung auf eine Wiederaufnahme der alten, freundschaftlichen Beziehungen zu Martel Ausdruck.

Paris
le 10 dec. 1907

23, RUE D'AUMALE IX.
TEL. 120 . 68

Cher Monsieur

La poste m'a bien remis les 24 h. 30.

Puisque vous ne voulez pas accepter
cette modique somme de retribution[6], je
le remettrai de votre part au secrétaire

---

[1] Albo d'oro, Museo Civico di Storia Naturale di Trieste

[2] C. Marchesetti, Atti del Museo Civico di Storia Naturale di Trieste Ix (S. N. III), 1895, S. 24

[3] Archivio Diplomatico - Biblioteca Civica di Trieste, R. P. MS. Misc. 88/F/16 und 88/O/A-F und 88/P/G-O und 88/Q/P-Z

[4] Archivio Diplomatico - Biblioteca Civica di Trieste, R. P. MS. Misc. 88/P/G-O: M2

[5] Archivio Diplomatico - Biblioteca Civica di Trieste, R. P. MS. Misc. 88/F/16

[6] Wahrscheinlich handelt es sich um das Honorar für Marchesettis Beitrag "La necropole

qui a, un peu (très peu) arrangé
votre texte.

Mais une autre fois veuillez bein
garder ce léger honoraire qui est adressé
non pas par moi, mais par les éditeurs:
ils paient un tarif général de
0 fr. 15 la ligne, qui est bien faible,
mais les dépenses pour les gravures
(que nous soignons de notre mieux)
sont toujours grosses.

Quant aux 50 numéros,
nous vous les offrons avec grand
plaisir, à cause de l'intérét special
de votre article, qui a eu grand succès.

Il en est de même du service
gratuit de la Nature, que nous
offrons aussi à une cinquantaine
de correspondants en France ou à
l'étranger en échange des documents
ou sujets qu'ils peuvent nous fournir.

Lorsque vous penserez qu'un
article peut nous intéresser, proposez nous
le avant de le rédiger pour que nous
vous disions s'il nous convient: aussi
vos nouvelles recherches sur l'homme
préhistorique du Karst sont tres curi-
= euses, mais ne conviendraient pas à
notre revue. En revanche une notice
sur les Castelli Preistorici[7] nous serait
agréable; nous pourrions empreindre
quelques vues et plans à votre volume
de 1903, et si vous en aviez de nou-
= veaux cela serait excellent.

préhistorique de Santa Lucia (Autriche)", erschienen in der Zeitschrift "La Nature" (Revue des sciences et de leurs applications aux arts et a l'industrie.) Jg. 35, Nr. 1799 (16.11.1907).

[7] Martel bezieht sich auf Marchesettis Werk "I Castellieri preistorici di Trieste e della Regione Giulia". Trieste 1903.

De meme les objets suivants
seraient les bienvenus.:
1 Le Meereschwinde du Teufelsbrunnen
pres Abbazia, mentioné dans
la Höhlenkunde de Von Knebel
(1906, p. 107)
2 Les travaux de dessechement du
lac Cepič (s'ils sont terminés)[8]
3 L'amélioration des Ponors et
Polje de Croatie, Bosnie,
Dalmatie, Herzegovine
4 La grotte bleue de l'ile Busi[9]
5 L'origine et les variations de la
cascade source de la Save (Wochein
Terglou)[10]
6 L'état actuel des mines d'Idria[11]
7 Les nouvelles études sur la faune
souterraine du Karst (ou est
l'affaire de. M. Valle, un de M.
Apfelbeck)
etc, etc, etc, et autres analogues.

Tous ces sujets avec photographies.

Vous voyez che vous pouvez nous
rendre largement service.

Un résumé sur la civilisation
d'Hallstadt, - un autre sur le

[8] Der nunmehr gänzlich trockengelegte Čepić-See befand sich im Nordosten Istriens, heute erinnern die Toponyme Čepić un Čepić polje nördlich von Plomin an die einstige Lage des Sees. Vgl.: Zepitscher See in J. W. Valvasor, Die Ehre des Herzogthums Krain, III. Bd. XI. Buch Seite S. 660 f. (mit Abb.), Laibach-Nüherberg 16892

[9] Gemeint ist die "Blaue Grotte", heute "Modra spilja", eine durch einen Kanal vom Meer her zugängliche Höhle auf der Insel Biševo (ital. Busa), der Nachbarinsel von Vis (ital. Lissa), in Mitteldalmatien. Die Grotte ist ein seit jeher belibtes Touristenziel, vor allem wegen des besonderen Farbenspiels. Vgl. Grieben Reiseführer - Dalamtien. Bd. 161, Berlin 1930, S. 150.

[10] Wochein = Bohinj
Terglou = Triglav
Gemeint sind der Wasserfall der Savica aus dem letzten Triglav=see und der Oberlauf der Save (Bohinjsko jezero und Sava Bohinjka)

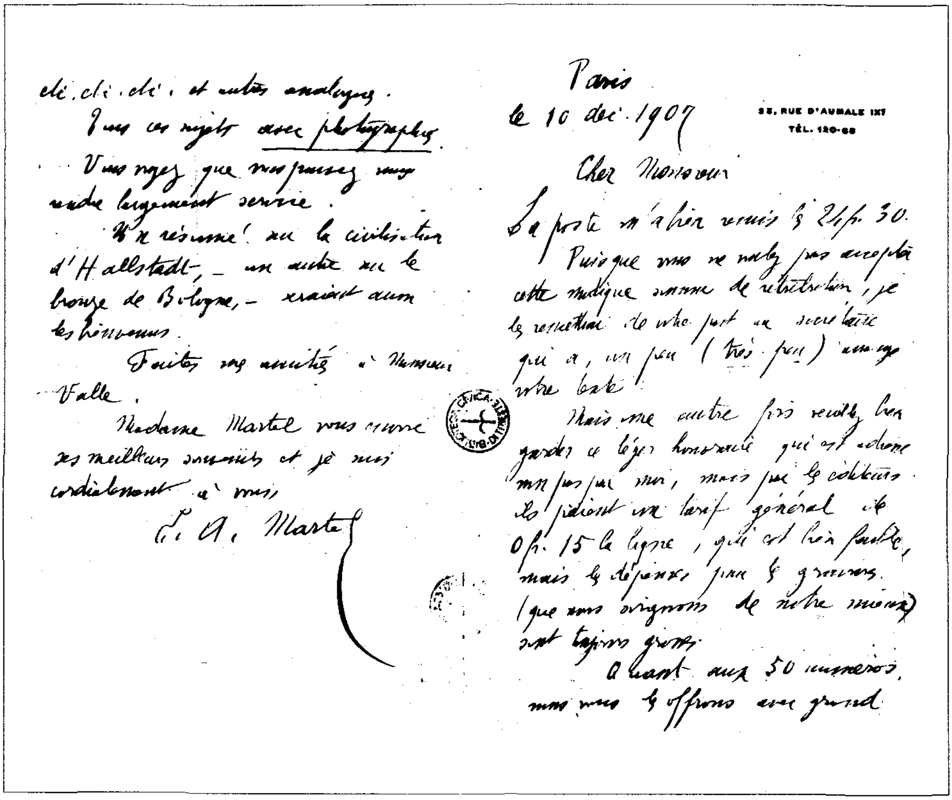
[11] Quecksilberminen von Idrija in Slowenien

bronze de Bologne, - seraient aussi les bienvenus.

Faites mes amitiés a Monsieur Valle[12].

Madame Martel vous aussi ses meilleurs souvenirs et je suis cordialment a vous

E. A. Martel


etc. etc. etc. et autres analogues.
Tous ces sujets avec photographies.
Vous voyez que vous pouvez nous rendre largement service.
Un résumé sur la civilisation d'Hallstadt, – un autre sur le bronze de Bologne, – seraient aussi les bienvenus.
Faites mes amitiés à Monsieur Valle.
Madame Martel vous envoie ses meilleurs souvenirs et je suis cordialement à vous
E. A. Martel

Paris
le 10 déc. 1907
23, RUE D'AUMALE IXe
TÉL. 120-68
Cher Monsieur
La poste m'a hier remis les 24 f. 30.
Puisque vous ne voulez pas accepter cette modique somme de rétribution, je la remettrai de votre part au secrétaire qui a, un peu (très peu) [illegible] votre tâche.
Mais une autre fois veuillez bien garder ce léger honoraire qui est alloué non pas par moi, mais par les éditeurs qui paient un tarif général de 0 f. 15 la ligne, qui est bien faible, mais les dépenses pour les gravures (que nous soignons de notre mieux) sont toujours grosses.
Quant aux 50 numéros, nous vous les offrons avec grand

Fig. 1: Facsimile of Martel's letter to C. Marchesetti (10.12.1907).
Sl. 1: Faksimile Martelovega pisma Marchesettiju (10.12.1907).

[12] A. Valle war unter Marchesetti Konservator am Naturhistorischen Museum, er war auch Vizesekretär des "Bolletino della Societa Adriatica di Scienze Naturali in Trieste" sowie Mitarbeiter der Societa di Pesca e Piscicoltura marina in Triest.

Paris
10. Dezember 1907 *23, Rue d'Aumale 9.*
Tel. 120.68

Werter Herr

Die Post wurde mir rasch zugesandt, 24h 30.

Da Sie diese bescheidene Summe als Bezahlung[6] *nicht annehmen wollen, werde ich Ihren Teil dem Sekretär über geben, der Ihren Text ein wenig (zu wenig) eingerichtet hat.*

Aber ein anderes Mal werden Sie dieses unbedutende Honorar, das durchaus nich durch mich, sondern durch die Herausgeber ergeht, wohl annehmen wollen: sie zahlen einen Einheitstarif von 0 F. 15 pro Zeile, was recht gering ist, aber die Kosten für den Druck (den wir bestens besorgen) sind immer hoch.

Was die 50 Nummern anbetrifft, su überlassen wir sie Ihnen mit großen Vergnügen aufgraund des speziellen Interesses Ihres Artikels, der großen Erfolg hatte!

Es ist ebenfalls ein kostenloses Service von La Nature, das uns auch für ca. 50 Korrispondenten in Frankreich oder im Ausland im Austausch von Unterlagen und Aufsätzen, die uns jene liefern können, geboten wird.

Wenn Sie meinen, daß uns ein Artikel interessieren könnte, schlagen Sie ihn uns ehe Sie ihn verfassen vor, damit wir Ihnen miteilen können, ob er uns recht ist: auch neue Forschungen über den prähistorischen Menschen im Karst sind bemerkenswert, passen aber nicht in unsere Zeitschrift. Stattdessen käme uns ein kurzer Bericht über die "Castelli Preistorici"[7] *gelegen: wir könnten einige Ansichten und Pläne zu Ihrem Buch von 1903 abdrucken und wenn Sie noch neue hätten, so wäre das ausgezeichnet.*

Folgende Themen wären gleichfalls willkommen:

1 Die Meeresschwinde von Teufelsbrunnen bei Abbazia, erwähnt in der Höhlenkunde von Von Knebel (1906, S. 107)

2 Die Trockenlegungsarbeiten des Čepić - Sees[8] *(ob sie schon beendet sind)*

3 Die Melioration der Ponore und Polje in Kroatien, Bosnien, Dalmatien, Herzegovina

4 Die Blaue Grotte auf der Insel Busi[9]

5 Ursprung und Variationen des Quellflusses mit Wasserfall der Save (Wochein - Terglou)[10]

6 Der aktuelle Zustand des Bergwerks von Idrija

7 Die neuen Studien über die unterirdische Fauna des Karstes (wo ist die Sache von Hrn. Valle, jene von Hrn. Apfelbeck)

etc., etc., etc. und ähnliche andere.

All diese Themen mit Photographien.

Sie sehne, daß Sie uns einen großen Dienst erweisen können.

Eine Zusammenfassung über die Hallstatt - Kultur, - eine andere über die Bronzezeit von Bologna, - wären auch willkommen.

Grüßen Sie mir Herrn Valle[12].

Mit den besten Empfehlungen auch von Madame Martell verbleibe ich herzlichst Ihr

E. A. Martel

Briefkonzept: Marchesetti an Martel

Martel *Parigi 5/12 18 oder 19*

Cedute finalmente le barriere che si isolavano completamente dal resto del mondo civile, invio dalla nostra Trieste redenta nell'amplesso d'Italia un caloroso entusiastico saluto, a Lei vanto e gloria della eroica Francia liberata anch'essa delle onde barbariche che per un lungo tempo la straziavano crudelmente. Evviva la liberta! Evviva il trionfo della giustizia e della civilta! Sperando che Ella e la sua distinta Signora stiano bene e che riannodermo le antiche amichevoli relazioni

Nachdem endlich die Barrieren gefallen sind, durch die wir vom Rest der zivilisierten Welt vollkommen abgeschnitten waren, sende ich aus unserem in Italiens Umarmung erlösten Triest einen herzlichen, enthusistischen Gruß, Ihnen Ruhn und Glorie des heroischen Frankreich, das nun ebenfalls befreit ist von den barbarischen Gewalten, die es für lange Zeit grausam peinigten. Es lebe die Freiheit! Es lebe der Triumph der Gerechtigkeit und der Kultur! In der Hoffnung, daß Sie und Ihre geschätze Gattin wohlauf sind und wir die alten, freundschaftlichen Beziehungen wieder aufnehmen werden

Von Martel spricht aber auch Erzherzog Ludwig Salvator[13] in einem Brief an Marchesetti[14]. Ludwig Salvator, selbst Naturforscher und Autor zahlreicher Werke wissenschaftlichen Charakters, weilte häufig auf seinem Landgut in Zindis unweit von Triest un stand über Jahrzehnte mit Marchesetti in freundschaftlichem Kontakt[15]. Am 11. September 1895 dankt er Marchesetti aus Venedig für dessen Arbeiten und meint weiter:

Venezia 11. Settembre 1895.

... I suoi studi sulle grotte[16] potrebbero forse gettare importante luce anche su quelle delle Baleari, le quali per tale scopo si propone Martel d'investigare secondo varie lettere che mi ha scritto, ma che non ha potuto fino adesso levare a capo causa le molteplici occupazioni...

---

[13] Ludwig Salvator von Toskana, Erzherzog von Österreich, Sohn des Großerzogs Leopold II. von Toscana und der Maria Antonia von Sizilien.

[14] Archivio Diplomatico - Biblioteca Civica di Trieste, R. P. MS. Misc. 88/P/G-O: L"

[15] F. De Farolfi, Un grande dimenticato. Atti e Memorie della Societa Istriana di Archeologia e Storia Patria. XX-XXI N. S., (LXXII-LXXIII della Raccolta), Trieste 1972-73, 335 ff., 349 f. und 369 f.

B. Mader, Signor dottor Carlo de Marchesetti-Museo di Storia Naturale in Trieste-Austria. I rapporti di Marchesetti con Vienna attraverso la sua corrispondenza. Atti della giornata internazionale di studi "Carlo Marchesetti a cent'anni dalla pubblicazione di "Scavi nella necropoli di S. Lucia presso Tolmino", Trieste 1993. in Druck

[16] Da Ludwig Salvator für die in den "Atti" del Museo Civico di des Naturhistorischen Nuseums

... Ihre Studien über die Höhlen[16] *könnten vielleicht auch wichtin und aufschlußreich für jene der Balearen sein, deren Erforschung Martel, mehreren briefen, die er mir schrieb, zufolge, vorhat, womit er jedoch bis jetzt wegen mehrfacher Beschäftigungen noch nicht beginnen konnte...*

Ein Jahr später schließlich kam es zur Realisierung des langgehegten Projektes. Anfang September 1896[17] begann Martel auf Mallorca mit der Erforschung der "Cuevas del Drach", die zuvor schon Ludwig Salvator in seinem mehrbändigen Werk über die Balearen ausführlich beschrieb. Er fügte auch einen genauen Plan des Höhlensystems sowie mehrere Abbildungen bei, bezeichnete die Höhle als "Hauptanziehungspunkt von Manacor" und meinte, daß sie "...wenn auch nicht an Großartigkeit, doch an Schönheit der Cova de Artá gleichkommt, ja sie sogar nach Meinung einiger übertrifft..."[18].

Noch in selben Jahr veröffentlichte Martel die Ergebnisse seiner Forschungen im Jahrbuch des Französichen Alpenvereins[19]. Der Abschluß dieser Arbeiten bedeutete aber keineswegs auch das Ende der Kontakte[20] zwischen Martel und Ludwig Salvator, der höchstwahrscheinlich Martel noch gerne zur Erforschung weiterer der so zahlreich auf Mallorca befindlichen Höhlen bewegt hätte.

Wie aus den folgenden zwei in Österreichischen Haus-, Hof- und Staatsarchiv in Wien aufbewahrten briefen Martels an Ludwig Salvator aus den Jahren 1913 und 1914[21] hervorgeht, standen die beiden noch lange Jahre in briefkontakt, tauschten ihre Werke aus und Martel plante (1914) sogar eine neuerliche Reise nach Mallorca, wo er den Erzherzog zu sehen hoffte.

Nur Höhlen wollte der damals 55 jährige Martel aus Altersgründen nicht mehr bogehen. Trotzdem aber überlebte er Ludwig Salvator, der im Oktober des darauffolgenden Jahres verstarb, um vieles[22].

Triest erschieneen Arbeiten dankt, beziehen sich die "Studien über die Höhlen" höchstwahrscheinlich auf folgende Arbeiten Marchesettis:

La grotta azzura di Samatorza, Atti del Museo Civico di Storia Naturale di Trieste IX (N. S. III), 1895, S. 249-255

L'ursus ligusticus iss. nelle Alpe Giulie, ebendort S. 265-271.

[17] H. Schwendinger, Erzherzog Ludwig Salvator. Der Wissenschaftler aus dem Kaiserhaus. Wien-München 1991. S. 213.

[18] Ludwig Salvator, Die Balearen in Wort und Bild geschildert. Bd. V/2, Die eigentlichen Balearen. Leipzig 1884. S. 496 ff (mit Abbn.)

Der Höhenplan befindet sich in Anschluß an Seite 496 und trägt die Aufschrift: Plano de la Cueva del Drach situado en el predio Son Moro/Manacor, Isla de Mallorca propriedad del Sr. Dn. Jose Jgnazio Moragues. Maßstab 1:500.

[19] Les grottes du Crach. Annuaire de Club Alpine Francaise. Bd. 23, 1896.

[20] Bei H. Schwendinger, wie Anm. 17, S. 218 ist vom Ende des Briefwechsels mit 1910 die Rede. Wo sich die betreffenden Briefe befinden, ist nich angeführt.

[21] Österreichisches Staatsarchiv Wien, Abteilung: Haus-, Hof- und Staatsarchiv. Habsburger Familienarchiv, Ludwig Salvator 3 (Brief vom 29.V.1914) und 7a (Brief vom 25.VIII.1913).

[22] Ludwig Salvator stirbt am 12. Oktober 1915 in Brandeis im Alter von 68 Jahren. Martel Stirbt 23 Jahre später 1938 in Paris.

Der tod Ludwig Salvators, vor allem jedoch der Ausbruch des Ersten Weltkrieges - ein Monat nachdem Martel seinen Besuch auf Mallorca angekündigt hatte, erfolgte die Ermordung des österreichischen Thronfolgers - scheint den Schluß nahe zu legen, daß wir es hier mit einem der allerletzten, vielleicht sogar dem letzten Brief Martels an Ludwig Salvator zu tun haben. Es ist auch anzunehmen, daß Martels Reise infolge der Kriegserignisse nicht mehr zustande kam.

Paris
25 août 1913

23, RUE D'AUMALE IX^{E}.
TEL. 120.68

Monseigneur,

Depuis bien longtemps, - plus
d'un an je crois, - je me reproche
de ne pas m'être rapellé a votre
excellent et haut souvenir.

J'ai en beaucoup d'occupations
et de soucis pendant ce délai:
il y a en d'abord d'aout à
octobre 1912 un voyage de trois
mois que j'ai fait aux Etats-Unis
d'Amérique; - ensuite depuis six
mois ma mère a eté fort malade
et se trouve actuellement paralysée
dans un état très attristant.
J'ai été bien touché de voir
que cependant vous ne m'oubliiez
pas; car en novembre 1912 j'ai
reçu de l'editeur le très bel album
des Skizzen aus Miramar[23].

Excusez-moi de ne pas vous
en avoir remercié plus tôt.

Au printemps de 1912, je
crois, je vous avais envoyé moi-
-mème un paquet de mes
derniers mémoires: il est revenu

[23] "Miramar" war der Name des Wohnsitzes von Ludwig Salvator auf Mallorca.

à Paris avec l'adresse déchirée
et tout ouvert. Je n'ai pas pu savoir
pourquoi il n'était pas arrivé à
destination.

Si cette lettre vous parvient
et si vous daignez me donner votre
adresse, je me ferai un devori
de vous refaire cet envoi.

Je n'oublierai jamis les belles
journees que j'ai passées à Miramar
et à Majorque, par votre haute
protection et estime; c'est un des
plus jolis souvenirs de mes voyages.

Madame Martel se joint à
moi pour vous prier d'accepter,
Monseigneur, nos plus respectueux
et sympathiques hommages,

E. A. Martel

Paris
25. August 1913 — *23, Rue d'Aumale 9.*
Tel. 120.68

Monseigneur,

Seit recht langer Zeit - mehr als einem Jahr glaube ich - mache ich mir Vorwürfe mich nicht Ihres vortrefflichen und hohen Geschenks erinnert zu haben.

Ich war die inzwischen verstrichene Zeit über sehr beschäftigt und hatte Sorgen: Zuerst gab es von August bis Oktober 1912 eine dreimonatige Reise, die ich in die Vereinigten Staaten von Amerika unternommen habe, - sodann litt meine Mutter 6 Monate an einer schweren Krankheit und befindet sich derzeit nunmehr gelähmt in sehr betrüblichem Zustand.

Ich war sehr gerührt zu sehen, daß Sie mich unterdessen nich vergessen haben, denn im November 1912 habe ich vom Verleger das wunderschöne Album der Skizzen aus Miramar[23] *erhalten.*

Entschulding Sie, daß ich Ihnen nich früher dafür gedankt habe.

Im Frühjahr 1912, glaube ich, habe ich selbst Ihnen ein Paket mit meinen letzten

Abhandlungen geschickt: es ist offen und mit zerissener Adresse nach Paris zurückgekommen. Ich konnte nich erfahren, warum es nicht am Bestimmungsort angekommen ist.

Wenn Sie diser Brief erreicht und Sie geruhen würden mir Ihre Adresse zu geben, werde ich es mir eine Pflicht sein lassen Ihnen diese Sendung erneut zu schicken.

Ich werde niemals die schönen Tage, die ich durch Ihre hohe Gunst und Wertschätzung in Miramar und Malorca verbracht habe, vergessen. Sie gehören zu meinen schönsten Reiseerinnerungen.

Madame Martel schließt sich mir an, Sie Monseigneur, zu bitten unsere hochachtungsvollsten und wohlgefäfflisten Ehrerbietungen entgegenzunehmen

E. A. Martel

23, RUE D'AUMALE IX.
TEL. 120.68

PARIS
29. V. 14

Monseigneur,

Une fois de plus je reçus
de vous un intéressant volume
sur Porto Pi,[24] *qui me*
rappelle d'heureux souvenirs
dans un bien beau pays.

En vous remerciant bien
sincèrement j'ai le plaisir
de vous dire que nous avons
le projet de retourner a Ma-
= jorque en septembre prochain,
si nul événement ne nous
en empoche.

Nous avons un vif désir de
revoir encore l'ile magnifique
et ravissante!

Et je serais bien heureux
si nous avions à cette époque

---

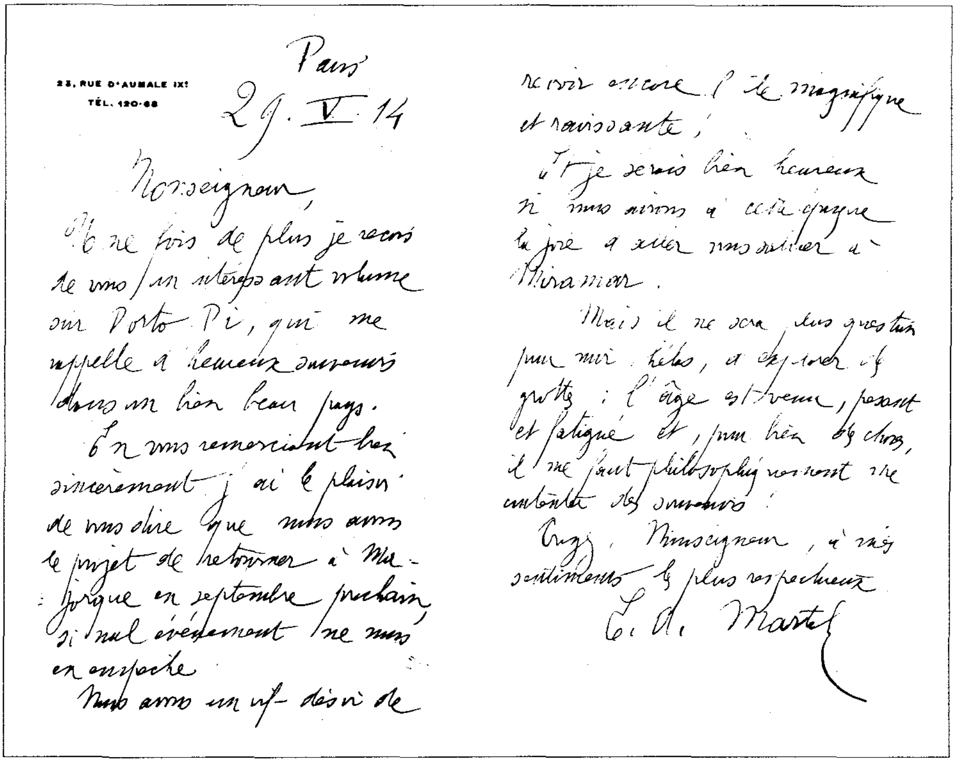
[24] Ludwig Salvator, Porto Pi - In der Bucht von Palma de Mallorca. Prag 1914.

la joie d'aller vous saluer à Miramar.

Mais il ne sera plus question pour moi, hélas, d'explorer des grottes; l'âge est venu, pesant et fatigué et, pour bien des choses, il me faut philosophiquement me contenter des souvenirs!

Croyez, Monseigneur, à mes sentiments les plus respectueux

E. A. Martel



23, RUE D'AUMALE IX°
TÉL. 120-68

Paris 29. V. 14

Monseigneur,

Une fois de plus je reçois de vous un intéressant volume sur Porto Pi, qui me rappelle d'heureux souvenirs dans un bien beau pays.

En vous remerciant bien sincèrement j'ai le plaisir de vous dire que nous avons le projet de retourner à Majorque en septembre prochain si nul événement ne nous en empêche.

Nous avons un vif désir de revoir encore l'île magnifique et ravissante;

et je serais bien heureux si nous avions à cette époque la joie d'aller vous saluer à Miramar.

Mais il ne sera plus question pour moi, hélas, d'explorer des grottes; l'âge est venu, pesant et fatigué et, pour bien des choses, il me faut philosophiquement me contenter des souvenirs!

Croyez, Monseigneur, à mes sentiments les plus respectueux

E. A. Martel

Fig. 2: Facsimile of Martel's letter to Ludwig Salvator (29.5.1914).
Sl. 2: Faksimile Martelovega pisma Ludwigu Salvatorju (29.5.1914).

23, Rue d'Aumale 9.
tel. 120.68 *Paris*
29. V. 14

Monseigneur,

Wieder einmal habe ich von Ihnen einen interessanten Band über Porto Pi[24] *erhalten, der in mir glückliche Erinnerungen an eine sehr schöne Gegend wachruft.*

Ich danke Ihnen ganz aufrichting und freue mich Ihnen gleichzeitg mitzuteilen, daß wir, falls uns nichts dazwischen kommt, vorhaben, im nächsten September wieder nach Mallorca zu kommen.

Wir haben den lebhaften Wunsch die wunderschöne und zauberhafte Insel noch einmal zu sehen. Und ich wäre sehr glücklich, wenn wir in dieser Zeit das Vergnügen hätten Sie in Miramar zu begrüßen.

Leider, aber, wird es für mich nicht mehr in Frage kommen Höhlen zu erforschen: das Alter ist gekommen, schwer und müde, und ich muß mich daher in vielem auf philosophische Weise mit Erinnerungen begnügen!

Seien Sie, Monseigneur, meiner größten Hochachtung versichert

E. A. Martel

PISMA E. A. MARTELA CARLU MARCHESETTIJU IN NADVOJVODI LUDWIGU SALVATORJU

Povzetek

V pričujočem prispevku predstavi avtorica tri pisma E. A. Martela botaniku, prazgodovinarju in od 1876 do 1921 direktorju naravoslovnega muzeja v Trstu, Carlu Marchesettiju, kot tudi avstrijskemu nadvojvodi Ludwigu Salvatorju, naravoslovcu in avtorju številnih znanstvenih del (1847 -1915). Na pobudo Ludwiga Salvatorja je Martel prevzel raziskavo "Cuevas del Drach" na Mallorci v letu 1896. Napotke za v tem času pripravljenemu, sicer že dalj časa planiranemu projektu, najdemo v pisanju Ludwiga Salvatorja Carlu Marchesettiju (1895).

Martelova pisma Ludwigu Salvatorju, ki so shranjena v avstrijskem družinskem, dvornem in državnem arhivu na Dunaju, izvirajo iz let 1913 in 1914 in pričajo o mnogo let trajajočem sodelovanju in znanstveni izmenjavi.

V bogati korespondenci Marchesettija z učenjaki vsega sveta je zgolj eno samo Martelovo pismo, ki se nanaša predvsem na Marchesettijevo sodelovanje pri francoskem časopisu "La Nature", vendar pa kaže tudi Martelovo veliko zanimanje za Slovenijo, tedanjo avstrijsko Primorsko in Dalmacijo. V konceptu pisma iz leta 1918 ali 1919 izraža Marchesetti veliko veselje nad koncem prve svetovne vojne in upa na obnovo prijateljstva z Martelom. Obe omenjeni pisanji, kot tudi omenjeno pismo Ludwiga Salvatorja Marchesettiju, so v diplomatskem arhivu mestne knjižnice v Trstu.

KRAUS UND MARTEL - EINE VERBINDENDE ACHSE IN SACHE KARST

KRAUS AND MARTEL - AN AUSTRIAN-FRENCH CONNECTION IN KARST RESEARCH

KARL MAIS

Izvleček UDK 551.44(497.12) : 929 Martel E.A.
551.44(497.12) : 929 Kraus F.

Mais, Karl: Kraus in Martel - avstrijsko-francoska povezava pri raziskovanju krasa.

Kraus (1834-1897) in Martel (1859-1938) sta osebnosti, ki sta močno vplivali na razvoj krasoslovja konec 19. stol. Oba sta pričela raziskovati iz osebnih nagibov, njune kasnejše raziskave pa so imele pomemben znanstveni in tudi javni pomen. Kraus je ustanovitelj prvega speleološkega društva (Dunaj 1879), raziskoval je kras v okolici Postojne, kjer se je udejstvoval tudi Martel (1893). Medsebojno sodelovanje the dveh speleologov je imelo velik pomen za razvoj speleologije v Evropi.

Ključne besede: speleologija, speleozgodovina, Kraus F., Martel E. A.

Abstract UDC 551.44(497.12) : 929 Martel E.A.
551.44(497.12) : 929 Kraus F.

Mais, Karl: Kraus and Martel - an Austrian-French connection in karst research..

Kraus (1834-1897) and Martel (1859-1938) were the personalities having great influence upon the development of karstology at the end of 19th Century. Both started to investigate from their personal interest, later on their investigations became of great scientific and public interest. Kraus founded first speleological society (Vienna 1879), he investigated the karst in the vicinity of Postojna, where Martel (1893) was active too. Connection between those two speleologists had great influence upon the further development of cave science in Europe.

Key words: speleology, speleohistory, Kraus F., Martel E.A.

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Messeplatz 1, Stiege 10
A - 1070 Wien, Austria

ZU FRANZ KRAUS, 1834 - 1897

Der 1834 in Wien zur Welt gekommene Franz KRAUS erfuhr eine, für den väterlichen Betrieb entsprechend sorgfältige kaufmännische Ausgebildung, indem er nach der Schul- und Lehrzeit in Wien seine weitere kaufmännische Ausbildung bei Geschäftspartnern in Cette in Frankreich und Barcelona in Spanien erweiteren konnte. Die merkantilen Erfahrungen erweiterte er durch Reisen nach Nordafrika und Italien und setzte die Erfahrungen mit fremden Völkern, Sprachen und Landschaften gut um, besonders für seine allgemein naturwissenschaftlichen Interessen.

Er übernahm schließlich das väterliche Unterehmen, führte es jedoch nur wenig über das Jahr 1872 hinaus fort und zog sich dann, etwa 40jährig ins "Privatleben" zurück. So konnte er sich seinen erdwissenschaftlichen Interessen widmen, zuerst vertiefte er sich in die Gebiete Mineralogie und Geologie. Er wurde auch Mitglied bei wissenschaftlichen Gesellschaften. Bei einigen Vereinigungen fungierte er als gründendes Mitglied, wie beim "Wissenschaftlichen Klub" in Wien (1876). In diesen naturwissenschaftlichen Kreisen nahm er regen Anteil am fachlichen Leben und war ein kompetenter Motor für viele Aktivitäten. Das machte ihn zum geschätzten Freund. Unter anderen Persönlichkeiten dieser Zeit pflegte er etwa mit dem Direktor der k.k. Geologischen Reichsanstalt im Wien, Hofrat von HAUER und dem Intendanten des Naturhistorischen Museums Wien, Ferdinand v. HOCHSTETTER enge Kontakte. Mit diesen kam es im Jahre 1879 zur Gründung des "Verein für Höhlenkunde" in Wien, um ein Gremium für ihr spezielles Interessensgebiet zu schaffen.

HÖHLENFORSCHUNG UND DAS ÖFFENTLICHE INTERESSE

Zuerst befaßte sich Franz KRAUS mit den Höhlen alpiner Regionen von Oberösterreich, Salzburg und der Steiermark. Über diese erschienen ab 1878 verschiedenste Beiträge von ihm. In zunehmendem Maße fesselten ihn jedoch die karstdynamischen und großräumig verfolgbaren Phänomene der "Kesseltälern" Krains. Er war bemüht das bereits erarbeiteten Wissen über die Zusammenhänge der unterirdischen Entwässerung, für die agrarische Nutzung der Karstgebiete Krains auszuwerten, sowie durch gezielte Forschungen zu erweitern. Dadurch gelang es ihm, die gesellschaftsrelevate Bedeutung der Speläologie hervorzukehren und das Interesse staatlicher Stellen, insbesondere des k.k. Ackerbauministeriums an diesem Fachgebiet wach zu halten.

Im renomierten Österreichischen Touristenklub, zu dessen Mitgliedern Prominenz aus

Wissenschaft und Gesellschaft gehörten, initiierte Franz KRAUS die Gründung eines eigenen "Karst-Comités". Zu dessen Mitgliedern als Präsident der Intendant des naturhistorischen Hofmuseums Franz Ritter von HAUER zählte, weiters der Initiator des Comités Franz KRAUS, Josef SZOMBATHY, aber auch der Reichtagsabgeordnete Fürst Ernst WINDISCHGRÄTZ, der Abgeordnete und Geologe Prof. Eduard SUESS und zahlreiche andere fachlich kompetente Persönlichkeiten. Das Comité hatte sich zu Beginn des Jahres 1885 etablierte und nahm bereits im Sommer des selben Jahres die Arbeit im Bereich Adelsberg - Pivka auf (HAUER 1986). Diese Untersuchungen verblieben nicht im privaten Kreise, sondern erfolgten im allgemein nutzbringenden Interesse, unter Einbindung des k.k. Ackerbauministeriums in Wien und der Landesregierung der Kronlandes Krain in Laibach.

Franz KRAUS richtete am 4. April 1885 ein Schreiben an die Stadt Triest, in dem er für die Wasserversorgung der Stadt ein Projekt zur "subterranen Hydrographie des Karstes" im Hinterland von Triest detailiert und mit einer auch für heutige Verhältnisse umfassenden Methodik, unter Einschluß von Tracerversuchen, darstellte (ILMING & TRIMMEL 1983). Die Anregung zur Wiederaufnahme einer intensiven karstkundlichen Erforschung des triestiner Karstes fand jedoch auch nach einem weiteren Brief aus dem Jahr 1888 keinen direkten Widerhall. Erst 1892 unternahm die Societá Alpina delle Giulie mit ihrer Commissione Grotte, deren Gründung auf das Jahr 1883 zurückgeht, einen Tracerversuch mit Fluoreszein. Diese Untersuchungen entsprachen zwar durchaus den seinerzeitigen Vorstellungen von KRAUS, erfolgten jedoch ohne den Rahmen der damals vorgeschlagenen systematischen Begleituntersuchungen.

Im innerkrainer Karst hingegen waren die Projekte des "Comité" gerne angenommen und brachten erfolgreiche Ergebnisse. Der Forstassistent Wilhelm PUTICK leitete dabei, ab 1886 die Vermessungen und Untersuchungen vor Ort, wobei er von Ing. V. HRASKY unterstützt war (HAUER 1887: 60-61; 1889). Wegen seiner Verdienste um die Karst-Melioration, speziell die Eindämmung der Überflutungen des Planinsko - Poljes wurde Franz KRAUS zum Ehrenbürger von Planina ernannt, eine Anerkennung, auf die er sehr stolz war.

Neben dem Karst-Comité arbeiteten im engeren und weiteren Gebiet des klassischen Karstes auch die obgenannte Commissione Grotte, sowie auch die "Abtheilung für Grottenforschung der Section Küstenland" des Alpenvereins (gegründet 1883). Das Arbeitsgebiet der Section Küstenland mit den Herrn A. HANKE, J. MARINITSCH, Fr. MÜLLER und P.A. PAZZE lag vornehmlich im Bereich der Reka bei St. Kanzian und hatte einerseits den Ausbau der Höhle für den öffentlichen Besuch und andererseits die Verfolgung des unterirdischen Verlaufes der Reka gegen die Trinkwasserquellen bei Aurisina und des Timavo zum Ziele. Die Berichte über diese speläologischen Forschungen sind in vielen Veröffentlichungen festgehalten.

ZUR "HÖHLENKUNDE" UND "LES ABIMES"

Seit dem Beginn der 80er Jahre hatte Franz KRAUS eine Zusammenfassung der lokalen Ergebnisse aus der alpinen und außeralpinen Höhlenforschung, sowie ihre überregionale Bedeutung systematisch verfolgt und dabei auch die entsprechenden Ergebnisse aus aller Welt verarbeitet. Als 1894 seine "Höhlenkunde" als erstes zusammenfassendes Handbuch auf diesem Gebiet erschien, bezog er sich vielfach auch auf einen französischen Forscher: auf Edouard Alfred MARTEL, mit dem er bereits seit längerer Zeit einem sehr freundschaftlichen Kontakt gepflegt hatte.

Der französiche Advokat Edouard Alfred MARTEL war ebensowie der Geschäftsmann Franz KRAUS sehr am Alpinismus und den Geowissenschaften, besonders aber an der Höhlenkunde interessiert, vielleicht mehr, als an seiner direkten beruflichen Basis. Beide verfügten über eine umfassende Bildung und unstillbare Wißbegierde. Ihre solide finanzielle Grundlage, sowie die gesellschaftliche Stellung gewährte ihnen den für ihre Geländearbeiten nötigen Rückhalt. Dadurch besaßen die Ergebnisse ihrer Forschungen eine entsprechende Akzeptanz in den wissenschaftlichen und politischen Gremien ihrer Länder.

Beide hatten sich in bergsteigerischen Kreisen einen guten Namen geschaffen und eine weitgehende Literaturkenntnis auf ihrem Fachgebiet erarbeitet. Franz KRAUS durch den Aufbau seiner Literaturkartei, die zum "Literatur-Anzeiger" des Vereins für Höhlenkunde in Wien, 1879 - 1880, führte (MAIS 1984) und die er konsequent ergänzte; E.A. MARTEL durch die Betreuung der "Chronique et bibliographie des montagnes" des Club Alpine Francaise, ab 1884. Über die höhlenkundliche Literatur ergab sich ein entsprechend zunehmendes Verhältnis der Beiden.

Franz KRAUS schätzte die Arbeiten seines um 25 Jahre jüngeren Kollegen sehr, was deutlich daran zu erkennen ist, daß er die Ergebnisse des forscherischen Elan ab 1890 immer wieder in angesehenen Zeitschriften referrierte und in den Titeln den Forscher auch selbst nannte. Etwa 1893: "E.A. Martels Höhlenfahrten in Krain." in der Zeitschrift Gaea (Leipzig) und 1895: "E.A. Martels Höhlenforschungen." ebendort. Franz KRAUS baute an vielen Stellen seines 1894 erscheinenden Buches "Höhlenkunde" Forschungsergebnisse MARTELs ein. 33 Nennungen erfolgtem in verschiedenen Zusammenhängen im Text, 9 Bilder und Pläne MARTELs fanden als Illustration Verwendung.

Unter den Abbildungsvorlagen und zusätzlichem Material für die "Höhlenkunde", welche am Naturhistorischen Museum Wien verwahrt werden, befinden sich Spirituskopien von Handskizzen, die offenbar MARTEL für die Umzeichnung durch den Graphiker angefertigt hatte (Abb. 1), sowie Bürstenabzüge von Höhlenplänen des ebenso 1894 im Druck erscheinenden Werkes "Les Abimes". Franz KRAUS hatte diese Entwürfe von seinem Freund zur Information und freien Verfügung erhalten. Ein Bürstenabzug einer Tafel über den "unterirdischen Lauf des Poik Flusses bei Adelsberg in Krain" für Petermann's Mitteilungen mit den von MARTEL zusammengestellten Entdeckungsphasen stellt eine geringe Umarbeitung von MARTELs Entwurf dar. Für die Übersichtstafel in der "Höhlenkunde" generalisierte jedoch KRAUS die Abbildung deutlich, ohne den Charakter wesentlich zu ändern. So haben beide Autoren nach der gleichen Grundlage gearbeitet, sie jedoch in anderer graphischer Bearbeitung ihren Werken beigegeben. Siehe Abb. 2.

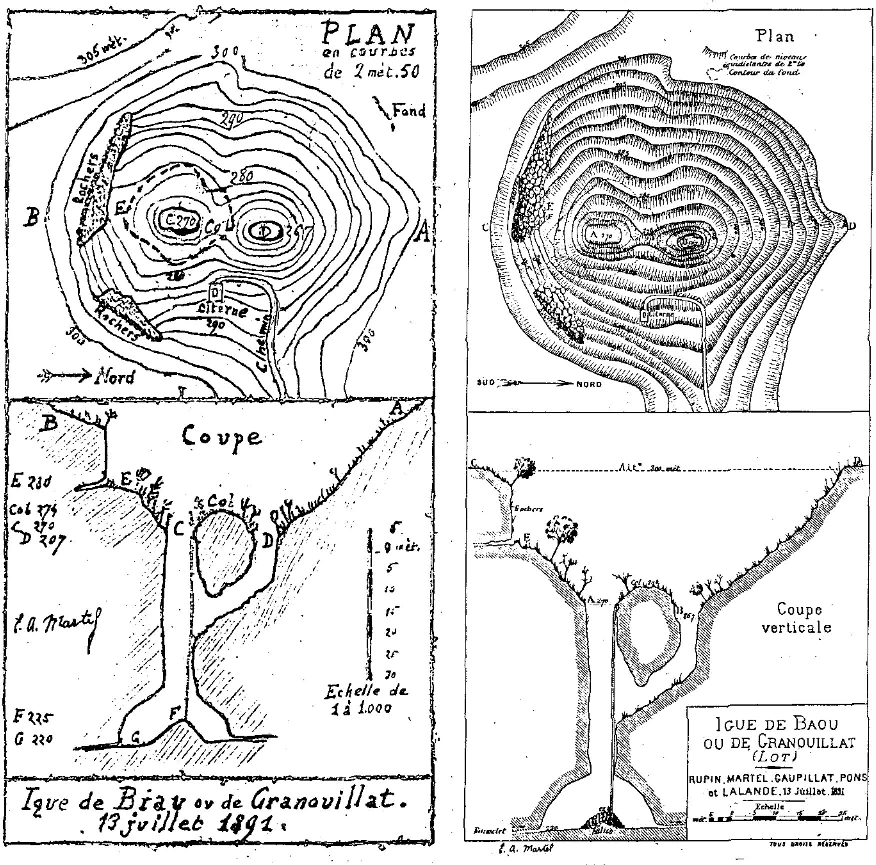
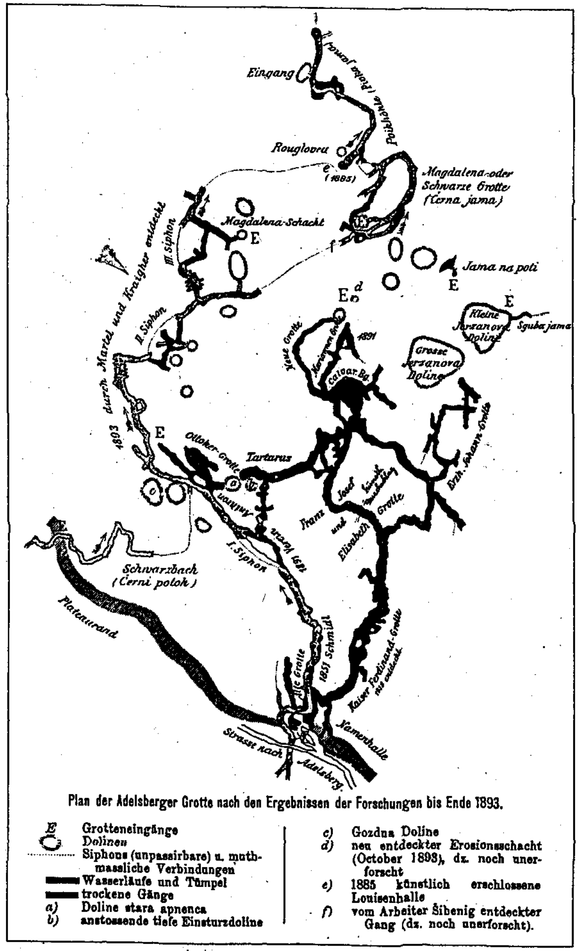
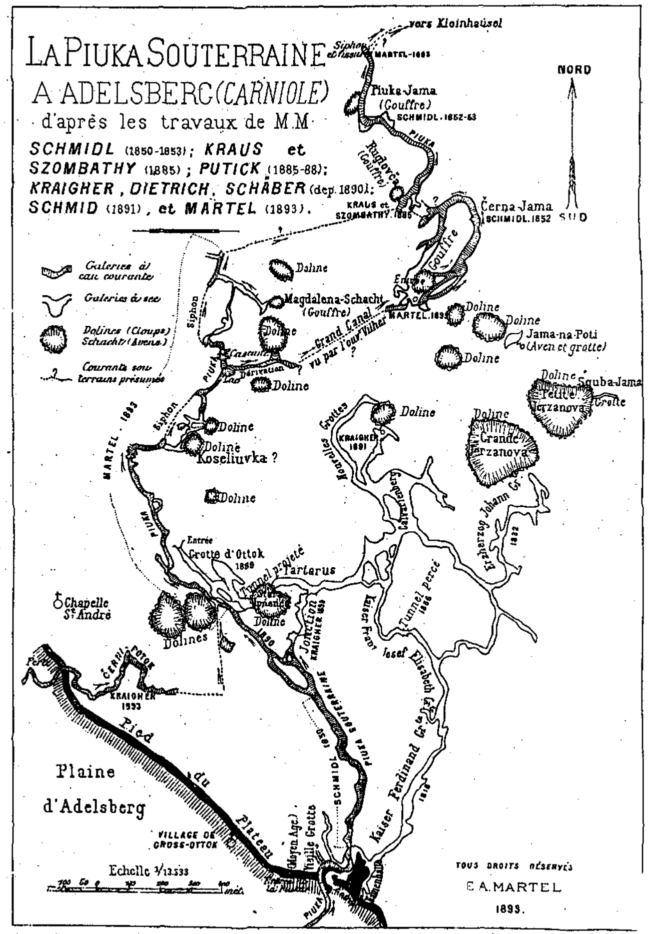


Abb. 1.: Beispiel für den Informationsfluß zwischen MARTEL und KRAUS: Links: Spirituskopie eines Höhlenplanes den MARTEL als Vorlage für den Grafiker anfertigte und zur Vor-Information an Franz KRAUS schickte. Rechts: Grafische Umsetzung der Vorlage, aus "Les Abimes" Seite 302.

Abb. 2.: Plan der Adelsberger Grotte / La Piuka Souterraine nach F. KRAUS 1894: und MARTEL (1894 b: 440) als Beispiel für die unterschiedliche Endfassung einer identen Plangrundlage. Bei KRAUS sind die Höhlengänge färbig hervorgehoben (wasserführend oder trocken). Bei MARTEL sind weit mehr Hinweise auf die Erforschung enthalten. Bei den Entdeckungen von 1893 steht jedoch nur MARTEL; bei KRAUS sind als Entdecker MARTEL und KRAIGHER vermerkt.

Fig. 2


Eingang
Rougloveu
Magdalena-oder Schwarze Grotte (Černa jama)
Magdalena-Schacht
Jama na poti
Kleine Jersanova Doline
Grosse Jersanova Doline
Sguba jama
Tartarus
Ottoker-Grotte
Franz Josef und Elisabeth Grotte
Erzh. Johann-Grotte
Kaiser Ferdinand-Grotte
Alte Grotte
Schwarzbach (Černi potok)
Plateaurand
Strasse nach Adelsberg
Namenhalle
Plan der Adelsberger Grotte nach den Ergebnissen der Forschungen bis Ende 1893.
E Grotteneingänge
Dolinen
Siphons (unpassirbare) u. muthmassliche Verbindungen
Wasserläufe und Tümpel
trockene Gänge
a) Doline stara apnenca
b) anstossende tiefe Einsturzdoline
c) Gozdna Doline
d) neu entdeckter Erosionsschacht (October 1893), dz. noch unerforscht
e) 1885 künstlich erschlossene Louisenhalle
f) vom Arbeiter Šibenig entdeckter Gang (dz. noch unerforscht).


LA PIUKA SOUTERRAINE
A ADELSBERG (CARNIOLE)
d'après les travaux de MM.
SCHMIDL (1850-1853); KRAUS et SZOMBATHY (1885); PUTICK (1885-88); KRAIGHER, DIETRICH, SCHÄBER (dep. 1890); SCHMID (1891), et MARTEL (1893).
Galeries à eau courante
Galeries à sec
Dolines (Cloups) Schacht (Avens)
Courants sou-terrains présumés
vers Kleinhäusel
Piuka-Jama (Gouffre)
Černa-Jama
NORD
SUD
Magdalena-Schacht (Gouffre)
Jama-na-Poti (Aven et grotte)
Sguba-Jama
Petite Jerzanova
Grande Jerzanova
Koseliuvka ?
Grotte d'Ottok
Tartarus
Chapelle St André
Dolines
Plaine d'Adelsberg
Pied du Plateau
VILLAGE DE GROSS-OTTOK
Echelle 1/13.533
TOUS DROITS RÉSERVÉS
E. A. MARTEL
1893.

KRAUS geht zu Beginn seines Werkes auf die verschiedenen Höhlenbildungstheorien ein, die es im Laufe der Zeit gegeben hat, aber auch auf zeitgenössiche Ansichten, wo widment er sich auch den Ansichten E.A. MARTELs. Hiebei erscheint für die biographische Seite wesentlich, was er auf Seite 30/31 schreibt :

"Unter den französichen Forschern steht MARTEL daher der deutschen Schule am nächsten. Inwieweit seine Forschungen am österreichischen Karste, die er im Herbst 1893 angestellt hat, seine Ansichten beeinflußt haben, wird sein neuestes Werk "Les Abimés" lehren, von dem bei Schluß dieses Buches erst einige Correcturbogen vorlagen, aus denen aber schon ersichtlich war, daß er zum mindesten für weichere Kalke den Einsturzerscheinungen einen weit höheren Einfluß einräumt als früher.

Mit großer Begeisterung schildert da MARTEL die Naturwunder des Karst und insbesondere die interirdischen Wasserläufe in der Adelsberger Grotte, in den Rekahöhlen und in den Rakbachöhlen. Die Umgebung der Naturbrücken (im Rakbachthale) nennt er das lehrreichste Terrain, welches er je gesehen hat, und das will viel sagen, denn Herr MARTEL hat seine Untersuchungen über den wesentlichsten Theil von Frankreich und über die Karstländer nördlich und östlich des Adriatischen Meeres ausgedehnt, bis Griechenland hinab.

Herr MARTEL ist Advocat in Paris und zählt als Naturforscher daher nicht unter die zünftige Gelehrtenwelt. Seine zahlreichen wissenschaftlichen Arbeiten berechtigen ihn aber, einen Platz unter denselben zu beanspruchen /hier weist der Autor auf seine Arbeit "Die Höhlenforschung in Frankreich" in Petermann`s Geographischen Monatsheften 1892(4) hin/. Seit dem Auftreten MARTEL's hat die Höhlenforschung in Frankreich einen großen Aufschwung erhalten. Dieses Verdienst wird auch allgemein anerkannt..."

Das gegenseitige Verhältnis der Beiden wird auch dadurch deutlich, daß Franz KRAUS als gründendes Mitglied der "Societé de Spéléologie" aufscheint, die nach der vorbereitenden Organisation von E.A. MARTEL im Jahre 1895 in Paris ihre Tätigkeit aufnimmt. Für die danach erscheinende Zeitschrift "Spelunca" liefern KRAUS, FUGGER und andere Österreicher in der Folge verschiedene speläologische Beiträge. Von Franz KRAUS erschienen nur zwei Beiträge.

Die weitere Entwicklung verlief jedoch ohne ihn, er verstarb am 12. Jänner 1897 an einem schwere Krebsleiden im 63. Lebensjahr. E.A. MARTEL war damals noch nicht einmal 40 Jahre und hatte noch 40 schaffensreiche Jahre vor sich.

ZU EDOUARD ALFRED MARTEL, 1859 - 1938

Edouard Alfred MARTEL machte bereits als Fünfjähriger seine entscheidende Höhlenerfahrung in einer Gletscherhöhle des Mont Blanc Massiv bei Chamonix (SHAW 1986) und blieb der Faszination der Höhlen zeitlebens verhaftet.

In seinen Veröffentlichungen und Berichten scheinen anfangs bemerkenswerterweise immer wieder "österreichische" Themen auf. Etwa ein Beitrag über die österreichischen Alpen im Jahrbuch des französichen Alpenklub, den er mit rund 23 Jahren geschrieben hatte, weitere über die Ostalpen, die Tauern, österreichische Kartenwerke, über

Publikationsreihen touristischer Vereine, aber auch über die Persönlichkeit von Karl von SONKLAR. Beiträge aus, bzw. über den "Karst" bereiteten im Laufe der Jahre die bemerkenswerte "Expedition" des Jahres 1893 in den Raum von Adelsberg Postojna vor.

Im großzügig ausgestatteten Werk "Les Abimes" widmet sich MARTEL nicht nur einzelnen Karstgebieten mit ihern Phänomenen, sondern er behandelt praktisch alle Punkte, die in einem speläologischen Handbuch zu suchen wären und berücksichtigt die bestehende Literatur in oft erstaunlich umfassender Art. So etwa zur Höhlenforschung in den Ländern der Donau-Monarchie, wobei er sowohl auf die wichtigen Autoren, als auch die historische Entwicklung der Forschung jener Zonen einging, die er in seiner 1893-Expedition besuchte. So gab MARTEL durch sein Werk der französisch - romanischen Fachwelt einen einwandfreien und umfassenden Einblick in den Stand und die Entwicklung der Höhlenforschung im damaligen Österreich und damit eine Übersicht über die

Abb. 3.: Unterirdischer Partie der Pivka, beim ersten Siphon; Holzstich nach einer Photographie, aus MARTEL 1894 a: 11.

Karsterscheinungen der Gebiete des heutigen Slowenien, Kroatien und der südöstlich anschließenden Länder anhand von Literatur und eigenen Feldforschungen.

Die Entdeckungen MARTELs schließen im innerkrainer, triestiner und istrischen Karst direkt an jene der Forschungen des Vereins Anthron (Gründung 1889, Adelsberg), der Abteilung für Grottenforschung der Alpenvereins-Sektion Küstenland und der Commissione Grotte an und werden vielfach unter Begleitung von Mitgliedern dieser Vereine unternommen (KRANJC 1988). Sowohl KRAUS als auch MARTEL erwähnen in ihren Berichten (MARTEL 1994 a) und Werken die Mitwirkung von W. PUTICK und A. KRAIGHER und anderer Höhlenforscher bei ihren Unternehmungen. Dies ist in "Les Abimes" (p.434) gut dokumentiert und in der "Höhlenkunde" klar zu ersehen.

In den Plänen MARTELs, die alle signiert sind, tritt eine gewisse Dominanz hervor. So sind in "Les Abimes" (S. 440) die im Verlauf der unterirdischen Pivka von ihm 1893 entdeckten Partien als "MARTEL 1893" gekennzeichnet, während bei KRAUS diese Strecke den Hinweis "1893 durch Martel und Kraigher entdeckt" trägt. KRAUS dokumentiert dadurch, daß diese Entdeckung nicht als Einzelleistung, sondern doch als Teamarbeit erreicht wurde. Franz KRAUS dürfte weit bescheidener gewesen sein, als sein jüngerer Freund aus Frankreich, da bei ihm mehrfach Hinweise auf die eigene Person fehlen.

Beide verwendeten in ihren Arbeiten Bildvorlagen des selben Photographen, von M. SCHÄBER aus Postojna, der auch ein erfolgreicher Höhlenforscher war. MARTEL illustriert "Les Abimes" auch mit einigen der dynamischen Zeichnungen HEJLMANNs, verzichtet aber auf ebenfalls eindrucksvolle Holzstiche, die nach Fotos gefertigt in seinem Forschungsbericht über 1893 erschienen sind (MARTEL 1894 a), Abb. 3.

Bei den Höhlennamen hält sich MARTEL an die ortsüblichen und gebräuchlichen Bezeichnungen der Gegend, die er bisweilen übersetzt. So schreibt er etwa "Coupe de la Magdalena Schacht", "Piuka Jama", "Jama na poti (Grotte de décollement)", "Vodny-Dol (Wasser-loch, trou à eau)" usw., wobei er auch Hinweise zur Aussprache beigibt, etwa "Cerna Jama (prononcez Tcherna-iama)". Daraus ist zu erkennen, welche Wertschätzung MARTEL den Forschern und Bewohnern der besuchten Karstgebiete entgegenbrachte und dem Leser seines Werkes reales Wissen und ordentliche Kenntnisse vermitteln wollte. Leider besitzen nur wenige Forschergruppen, die heute in fremden Gegenden arbeiten mur selten eine solche Einstellung. Sie erforschen im "Kollonialstil" die Höhlengebiete, ohne die "Eingeborenen" zu informieren, ohne auf deren bisherige Forschung zu achten und ohne sich um deren Namengebung zu kümmern; dafür gibt es etwa in Österreich immer wieder traurige Beispiele.

MARTEL befaßt sich in seinen theoretischen Arbeiten auch mit der ihm gut bekannten deutschsprachigen (=österreichischen) Terminologie, die er aus der Literatur und von der Verwendung im Gelände gut kannte. In den "Applications géologiques de la Spéléologie" (1896) geht er auf die unterschiedlichen, typisierenden Benennungen in verschiedenen Sprachen ein und diskutiert die Begriffe und ihre Verwandbarkeit; etwa "les bassins femes (du Jura), les Kesselthäler (d'Autriche), les Polje (de Dalmatie, Bosnie, etc.)". Bei der Verwendung von Ausdrücken stützt er sich oftmals auf die "Höhlenkunde" und zieht bei Vergleichen immer wieder Karsterscheinungen des klassichen Karstes heran, wodurch dieser eine entsprechende Bekanntheit im französichen Sprachraum erhielt.

DIE KARST-CONNECTION KRAUS - MARTEL

"Les Abimes" und die "Höhlenkunde" stellen zwei Werke dar, die lohnen, auch nach hundert Jahren in die Hand genommen zu werden. Wegen ihrer fachlichen Aussagen, der wissenschaftsgeschichtlichen Dokumentation, aber auch wegen der menschlichen Qualitäten ihrer Autoren besitzen sie heute noch eine wesentliche Bedeutung. Der Franzose Edouard Alfred MARTEL und der Österreicher Franz KRAUS haben durch ihren fachlich freundschaftlichen Kontakt zum Ende des 19. Jahrhunderts eine Brücke zwischen der Karstforschung im Westen Europas mit jener Mittteleuropas geschlagen. Sie haben somit eine verbindende Achse in Sachen Karst, eine Karst-Connection hergestellt.

BEMERKUNGEN ZU GEGENWÄRTIGEN BIOGRAPHISCHEN ARBEITEN

Eine speläohistorisch biographische Aufarbeitung solcher Ereignisse, wie sie die Karst-Connection KRAUS - MARTEL darstellt, muß die veröffentlichten Arbeiten als sachliche Fakten ansehen, welche oft nur kurz gefaßten Forschungsergebnisse beinhalten. Vom Wesen der Autoren kann dort kaum mehr als eine persönlich sachliche Stellungnahme enthalten sein, wodurch sie vielfach ohne biographischer Bedeutung und nur von wissenschaftsgeschichtem Wert sind. Demnach erschöpfen sich meist Forscher-Biographien im rein sachlichen Bereich der Werke, gehen aber nicht auf das Wesentliche, den Forscher als Menschen ein. Hiefür fehlen bei "trockenen" Naturwissenschaftlern oftmals die Unterlagen. Im gegenständlichen Fall wird im Archiv des Naturhistorischen Museums zwar das Vorlagenmaterial für die Abbildungen der "Höhlenkunde" von Franz KRAUS sorgfältig verwahrt, der Briefverkehr und andere Unterlagen sind jedoch nicht greifbar. Möglicherweise sind sie noch in anderen Verwahrungseinheiten vorhanden, möglicherweise waren sie aber nie aus dem Privatbereich von KRAUS hinausgegangen. Wo sich heute der bei der Familie verbliebene Nachlaß befindet, entzieht sich der allgemeinen Kenntnis.

Die Karst- und Höhlenabteilung am Naturhistorischen Museum besitzt noch wenige Unterlagen, da sie erst seit rund 15 Jahren als Musealabteilung besteht, sie bemüht sich aber um die Akquirierung derartiger biographischer Materialien und ist für alle Hinweise auf Bestände dankbar. Es werden alle Arten von Material: Originale, Abschriften, Kopien, Reproduktionen usw gesammelt, soweit sie einen Bezug zur speläologischen Forschung besitzen.

Im Sinne der speläohistorische Forschung sollen alle Anstrengungen unternommen werden, noch nicht allgemein bekannte Materialien zur Geschichte der Höhlenforschung aufzutreiben, durch Abgabe von Kopien zu sichern und bei spezifischen Symposien aufgearbeitete Unterlagen zu Präsentieren.

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ZUSAMMENFASSUNG

Zwei außergewöhnliche Persönlichkeiten haben gegen Ende des 19. Jahrhunderts der Speläologie entscheidende Impulse verliehen. Es waren dies der Kaufmann Franz KRAUS und der Advokat Edouard Alfred MARTEL, die nicht nur für die jeweils lokal und national ausgerichtete Höhlenforschung gearbeitet haben, sondern auch für die überregionale und

internationale Akzeptanz des karst- und höhlenkundlichen Fachgebietes. Dies konnten sie umsomehr, als sie von der Kenntnis lokaler Höhlengebiete ausgehend, die allgemeine Bedeutung ihrer Ergebnisse erkannten und sich von ihren persönlichen Erfahrungen ausgehend mit der Phänomenologie der benachbarten und ähnlichen, vergleichbaren Gebieten befaßten.

Franz KRAUS hat seinen naturwissenschaftlichen Interessen nach, mit Gleichgesinnten den "Verein für Höhlenkunde" 1879 in Wien gegründet und 1885 die Einrichtung eines Karst-Comités erreicht, dessen Ziel in der intensiven Karstforschung mit Augenmerk auf die ökonomische und agrarische Nutzung des klassichen Karstes gelegen war. Diese Forschungen waren erfolgreich und durch lokale Höhlenforscher und Höhlenvereine unterstützt. Im Jahr 1893 unternahm E.A. MARTEL eine Forschungskampagne in dieses Gebiet und war dabei von KRAUS und dessen Mitarbeitern entsprechend unterstützt.

KRAUS und MARTEL standen zu diesem Zeitpunkt bereits seit längerer Zeit in fachlicher Verbindung, was sich in den 1894 erschienenen Werken "Höhlenkunde" von Franz KRAUS und "Les Abimes" von E.A. MARTEL deutlich zeigt. Diese gegenseitige Anerkennung hat zu einer entsprechenden Übernahme von Forschungsergebnissen in den jeweils anderen Sprachkreis geführt, in den diese ansonsten kaum eingedrungen wären.

Aus einigen Details der genannten Veröffentlichungen lassen sich bemerkenswerte Schlüsse auf die unterschiedlichen Persönlichkeiten dieser Forscher ziehen.

SUMMARY

On the end of the 19th century two extraordinary persons had great importance for the developing karst and cave science: Franz KRAUS, 1834-1897, an Austrian merchant in Vienna, and E.A. MARTEL, 1859-1938, an advokat in France. Both made resarch first only by their local and personal interest, later on by their perception for the public importance of their doing, not only for pure science in caves and karst regions.

Franz KRAUS founded with his great interest on geoscinece in 1879 the first caving club in Vienna (Verein für Höhlenkunde), subsequent in 1885 a "Karst-Comité" for karst and cave research in the region of the classical karst, in neighbourhood of Adelsberg/Postojna. The "Comité", with F. KRAUS and W. PUTIK had great success in their fieldwork and ware supported by lokal cavers and members of caving clubs of Postojna and Trieste. In 1893 E.A. MARTEL started fieldwork in the former Austrian countries and had also very good results in the region of Postojna, assisted by the colaboraters of KRAUS and himself.

KRAUS and MARTEL had for long years a close scientifical connection, long before their meeting at the 1893 fieldwork. Therefore they took a lot of ideas and examples from each other into their scientific works, KRAUS for his spelological textbook "Höhlekunde" (Wien, 1894) and MARTEL for his reperesentative book "Les Abimes" (Paris, 1894) and later publications. The speleological connection betwen this two speleologists had great influence for the further developement of cave science in Europe. Remarks are made on details for their special individualities.

KRAUS IN MARTEL - AVSTRIJSKO-FRANCOSKA POVEZAVA PRI RAZISKOVANJU KRASA

Povzetek

Konec 19. stol. sta imeli dve izjemni osebnosti velik vpliv na razvoj znanosti o krasu: Franc Kraus (1834-1897), avstrijski trgovec z Dunaja, in E. A. Martel (1859-1938), francoski advokat. Oba sta se lotila raziskovanja iz lokalnih in osebnih nagibov, kasneje pa sta spoznala splošni pomen njunega dela, ne le za čisto znanost o jamah in kraškem svetu.

Zaradi velkega zanimanja za vede o Zemlji je Franz Kraus 1879 ustanovil prvo jamarsko društvo na Dunaju (Verein für Höhlenkunde), ki mu je sledil 1885 "Karst-Comité" za raziskave krasa in jam na območju klasičnega krasa v okolici Postojne. Comité je bil, ob sodelovanju F. Krausa in V. Puticka, zelo uspešen pri terenskih raziskavah in so ga podpirali lokalni jamarji in člani jamarskih društev iz Postojne in Trsta. 1893 se je Martel lotil terenskih raziskav v nekdanjih avstrijskih deželah, posebno uspešen je bil na postojnskem, kjer so mu pomagali Krausovi sodelavci in tudi Kraus sam.

Kraus in Martel sta imela tesne znanstvene stike že dolgo preden sta se srečala pri terenskem delu 1893. Zato sta za svoje znanstveno delo uporabljala veliko zamisli in primerov drug od drugega, Kraus za svoj speleološki učbenik "Höhlenkunde" (Dunaj 1894) in Martel za svojo reprezentativno knjigo "Les Abîmes" (Paris 1894), kot tudi za kasnejše objave. Povezava med tema dvema speleologoma v okviru speleologije je imela velik vpliv na njen nadaljnji razvoj v Evropi. Članek vsebuje tudi podrobnosti o njunih posebnih osebnostnih značilnostih.

THE MARTEL'S CHAMBER IN ŠKOCJANSKE JAME

MARTELOVA DVORANA V ŠKOCJANSKIH JAMAH

ANDREJ MIHEVC

Izvleček UDK 551.442 (497.12 Škocjan)

Mihevc, Andrej: Martelova dvorana v Škocjanskih jamah

Predstavljene so raziskave in najnovejše meritve Martelove dvorane v Škocjanskih jamah, ki je z volumnom 2.100.000 m^3 največja dvorana na Krasu. Dolga je 308 m, široka 123 m, v povprečju 89 m. Jamski strop je visok v povprečju 106 m, na najvišjem delu pa 146 m. Najnižja točka v jami leži 214 m nad morjem.

Ključne besede: speleologija, speleomorfologija, Kras, Škocjanske jame, Martelova dvorana

Abstract UDC 551.442 (497.12 Škocjan)

Mihevc, Andrej: The Martel's Chamber in Škocjanske jame

The explorations and the most recent surveys of the Martel's Chamber in Škocjanske jame which is, in terms of its volume - 2.100.000 m^3 - the largest chamber on Kras are described. It is 308 m long, 123 m wide and 89 m wide on an average. The cave ceiling is 106 m high on an average, on the highest point it is 146 m high. The lowest point in the chamber lies at 214 m a.s.l.

Key words: speleology, speleomorphology, Kras, Škocjanske jame, Martel's Chamber

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INTRODUCTION

Without doubt E.A. Martel is one of the most important karstologists from the transition of the 19th to 20th century. This is the reason that numerous caves or parts of caves were named by his name (Casteret 1943, 218), five out of them lying on Kras.

By Martel's name are called Martel's Chamber and Martel's Breakdown in Postojnska jama in remembrance to his visit at Postojna, when his guide was W. Putick and together they explored 2 km of new passages. A. Perko named Jama na Pauli vrh cave near Prosek Fovea Martel (VG 144). It is 114 m deep pothole where the discovery of the underground Reka flow was expected.

At the discovery in 1890 already the Martel's Chamber and Lake in Škocjanske jame were named by him. On the occasion of the centennary of the discovery and Martel's visit the inner parts of Škocjanske jame were resurveyed. These surveys provide a more accurate idea of the chamber itself and correct the essential errors regarding the depth of the cave and the location of the chamber.

ŠKOCJANSKE JAME EXPLORATIONS AND THE DISCOVERY OF THE MARTEL'S CHAMBER

The first cave explorations are recorded since the first half of the 19th century. The most important explorers of the time were Svetina and A. Schmidl. In 1884 at Triest was set up the Littoral Section of DÖAV, it rented the cave and its vicinity and started the intensive explorations. In the same year they bridged the 6th waterfall in the Svetina's Chamber which was till then the biggest obstacle while exploring the cave downstream. In August 1890 they reached the largest space in the cave and called it Martel's Chamber and in October 5th of the same year the outflow siphon at the end of the Marchesetti's Chamber which is now known as the Dead Lake (Müller 1891; Pazze 1893).

According to the habit of the time the parts of the cave were named by various donators, well known or cave explorers of merit. The last are A. Hanke, man of merit for Škocjanske jame, W. Putick, the explorer of the caves at Notranjska and world famous speleologist E.A. Martel by whom the largest chamber was named.

In the following years some other passages were discovered in Škocjanske jame but all of them closer to the entrance. The continuation in the downstream direction was impracticable. The first new discovery in this direction succeeded to cave divers not earlier than in

September 15, 1991 when Janko Brajnik found the continuation and swam across the sump in Marchesetti's Lake. The explorations are still going on (Morel 1991; Sancin 1991).

The first explorers equipped the newly discovered passages and chambers by the inscription tablets. In the Martel's Chamber there are two such tablets put together.

The upper one is the tablet of thank to the explorers working in the cave mostly in 1890 and who discovered the chamber: Anton Hanke, Friedrich Müller, Joseph Marinitsch and the local workers Paul Antoncich, Joseph and Juri Cerkvenik, Janes Delles and Franz Sniderсich.

Below it lies a tablet usual for the cave, denoting the name of this part of the cave, in this case "Martel Dom", the society, the explorers and the date of discovery. Unfortunately most of other such tablets were removed after the First World War.

MARTEL'S VISIT TO ŠKOCJANSKE JAME

Martel never visited the chamber named by him. During his visit to Kras, in September 23, 1893 this part of the cave was not accessible due to high waters of Reka river.

Martel was guided into the cave by Marinitsch, Müller, Pazze and Putick but they reached the Rinaldini's Chamber only. They have taken with them the paper baloon working on warm air "mongolfière en papier" in order to establish the ceiling height. The baloon raised for 45 m but did not reach the ceiling, it did not work due to humid air. The visit to the cave is described in detail by Martel in his book Les Abîmes (1896, 468).

MAPPING OF ŠKOCJANSKE JAME AND MARTEL'S CHAMBER

Parallel to explorations and penetrations down the Reka stream the explorers, in particular A. Hanke, surveyed and made the sketches, cross sections and cave plan. A. Hanke surveyed by the mining compass the final part of the cave and by aneroid he estimated the altitude of the last lake to approximatively 205 m. His plan of this part of the cave was published by Müller (1891, 130). All the Hanke's maps were later combined, somewhere a bit corrected but the cave survey remained generally the same.

The first such plan was not published until 1924 by Oedl and later the groundplan and cross sections were used by Bertarelli & Boegan 1926, Boegan 1938, XXVI and other later explorers. According to it the cave was 5000 m long, 253 m deep, the outflow sump at 173 m. Later only the show parts were resurveyed, the most demanding part of the cave, the underground canyon through the Hanke's Channel up to Martel's Chamber and further on to the Dead Lake was not resurveyed.

After the discovery of the underground Reka flow downstream in Kačna jama in 1972, according to caving compass measurements it was shown that the depth of Škocjanske jame was exaggerated (Petkovšek & Kenda 1974). The survey of Kačna jama up to Brzice in 1982 (Mihevc 1984) confirmed this statement as the inflow siphon in Kačna jama lies at

Fig. 1: Tablet of thank to the most meritorious explorers of Škocjanske jame in the past century (up) and the tablet denoting the Martel's Chamber.
Sl. 1: Zahvalna tabla najznamenitejšim raziskovalcem Škocjanskih jam v prejšnjem stoletju (zgoraj) in tabla, ki označuje Martelovo dvorano.

182 m a.s.l., hence higher than the outflow siphon in Škocjanske jame according to Oedl's plan.

All these facts required a new survey of Škocjanske jame. The Karst Research Institute approached to this work in 1980's. Classical, theodolite and compass surveys with the metal tape were not precise enough this is why the cave was resurveyed by electro-optical theodolite for measuring the angles and distances (Nikon DTM A10 LG).

The points of the basic polygon were fixed to the floor. These are rounded bronze tablets, 5 cm of diameter labelled by consecutive numbers. The points of the detail are not specially marked. But the instrument could not measure the ceiling height. Later we used the laser beam projecting on the unaccessible walls and ceiling the points which were then defined trigonometrically.

We continued with measuring the ceiling height helped by AMT profiler. With its help we measured 22 profiles between the Martel's Chamber and the entrance into Hanke's Channel. The first measurements were not successful due to extreme humidity, a layer of mist respectively in the cave. On the layer of mist the beam was disintegrated in such a manner that no reflection was obtained from the walls. When we continued these measurements during the winter at low waters, when the air in the cave is relatively dry and cool, the results were satisfactory in spite of problems posed by a layer of mist about 80 to 100 m above the floor. The measurements of the ceiling and walls distances were stored into computer and later the profile surfaces were calculated and the profile designed in the scale 1:500. By the help of these measurements the dimensions and forms of the Martel's Chamber may be much better described.

During the measurements we met with numerous problems which did not exist in other caves. The roaring of Reka, f.i. enabled the understanding among the surveyers and the radio communication was obligatory, high waters were frequent or else, a thick mist appeared at particular weather situations. This is the reason that in spite of great efforts done in the cave it is not yet completely surveyed.

SOME MEASUREMENT RESULTS

The measurements have indicated several mistakes existing on older plans. The above sea level of Martel's Lake is according to Hanke's aneroid measurements at 205 m, according to later citations (Bertarelli & Boegan 1926; Boegan 1938) 173 m. The new measured altitude is 214 m. The second mistake was done on the ground plan. According to old plan the cave is directed from the Hanke's Channel in the same direction towards NW. But new measurements have shown that the passage at the Rinaldini' s Chamber turns for about 30^0 and is oriented almost towards the north. Thus the final part of the cave, the Dead Lake, lies 350 m towards northeast. The measurements have indicated more precise forms of the chamber and the Reka channel.

THE SURVEY OF MARTEL'S CHAMBER

The Martel's Chamber is widened part of the gravitation passage shaped by the Reka sinking flow. In front of the chamber the Reka flows through narrow, 10 to 30 m wide and 80 to 95 m high Hanke's Channel. The Reka riverbed almost entirely occupies its bottom. On some places the channel widens, and these parts were named f.e. Putick's Chamber or Shadeloock's Chamber. The last one passes without any distinctive limit into Martel's Chamber.

The beginning of the Martel's Chamber was placed below the 22 nd waterfall to the polygon point 55, where the Hanke's Channel extremely widens and the ceiling height increases as well. The cave bottom is here 25 m wide occupied mostly by the Reka riverbed. The layout plan of the channel is 66 m wide.

Below the waterfall on the eastern side at the beginning narrow and later wider bank appears. The bottom of the chamber raises from the Reka riverbed towards the walls. In the first part the bank lies on the right, eastern side of the Reka and on its highest point it is 30 m above the riverbed. In the northern side of the chamber the Reka flows at the eastern wall, the chamber's bottom raises towards the western wall for 47 m.

The bottom is covered by huge breakdown blocks, on their lower parts the gravel was laid down, higher there are sand and fine-grained sediments. All over the sandy beach, in particular at point 57 there is a lot of deposited wood and plastics left by the Reka flood waters.

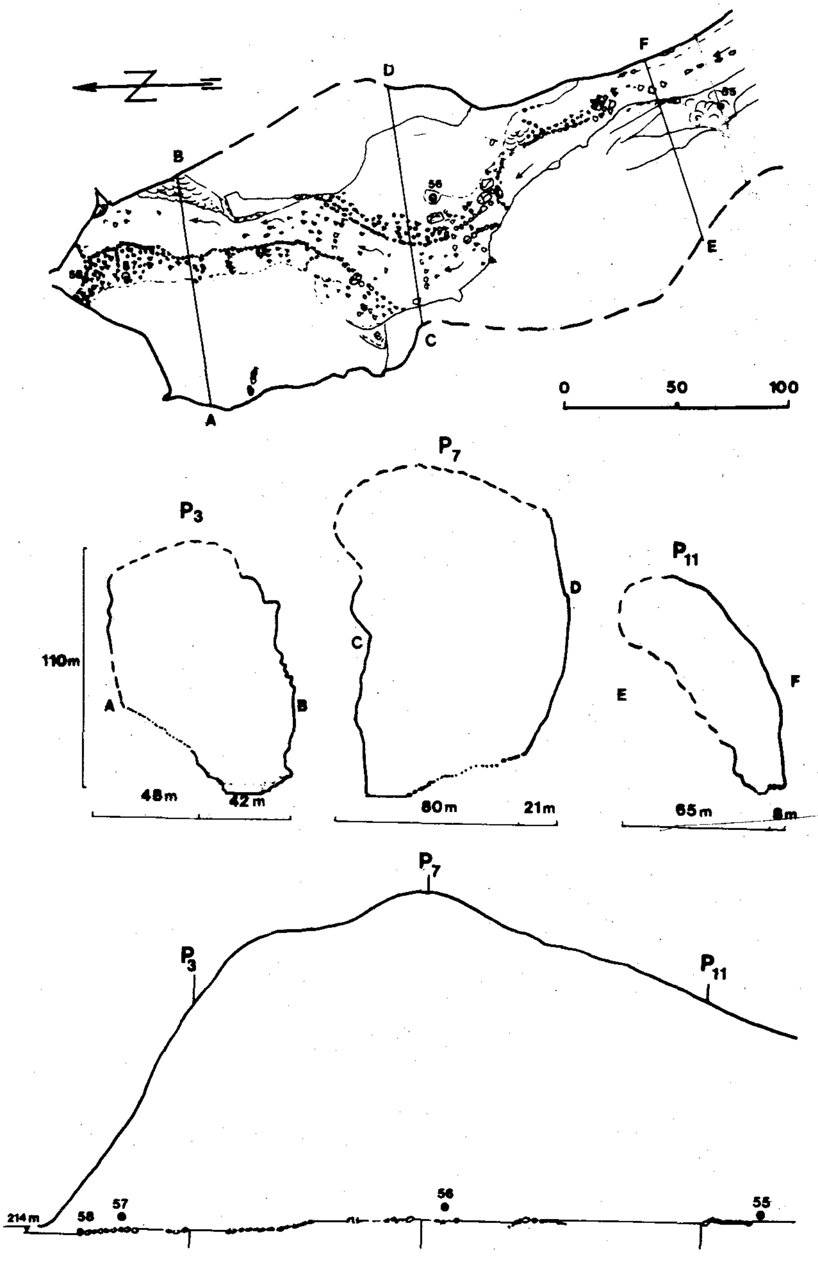
At the right side of the chamber in front of the point 56 there are on the wall fixed the mentioned memorial tablets. They are on the place where the pathway lowers from the right side and enabled the visit of this part of the cave during high waters even as it is built 10 to 20 m above the Reka riverbed mostly. The pathway later continues by the right side and reaches the Martel's Lake and goes further on towards the Marchesetti's Chamber.

At the point 57 the chamber narrows, the cascades calm down into Martel's Lake and from there passage, 1,5 m high and 9 m wide only, leads into next, the Marchesetti's Chamber. Between this place and the point 55, where the Martel's Chamber starts, there are 308 m of the distance.

The bottom of the chamber lowers from 233 m at the point 55 to 227 m at the 22nd waterfall and further on by several cascades to 214 m at the Martel's Lake. The ceiling height raises from the initial 81 m to the utmost 146 m in the profile 7 at the point 56, the average chamber's ceiling height is 106 m. The ceiling lies at 300-370 m, the surface at 430 to 445 m.

The widest is the chamber within the profile 6 where it is 123 m wide, the average width is 89 m. The figure shows three characteristical profiles of the Martel's Chamber.

Out of totally 10 profiles, measured in the chamber one may calculate the volume rather accurately. The profiles were taken on 30 m on an average. The biggest profile 6 has the surface of 11.740 m^2, the average profile 6694 m^2. Hence the volume of the Chamber is 2,100 000 m^3.



F
D
B
E
C
A
0
50
100
P7
P3
P11
110m
A
B
C
D
E
F
48m
42m
80m
21m
65m
8m
P7
P3
P11
214m
58
57
56
55

Fig. 2

CONCLUSION

Out of respect for the eminent speleologist the explorers of the then the largest cave on Kras have named its biggest chamber by E.A. Martel. The chamber having the volume of 2,100 000 m^3 is the biggest chamber on Kras and in Slovenia.

New measurements with electronic theodolite and laser profiler by which 10 cross sections were surveyed enabled a precise calculation of the location and dimension of the chamber and corrected the mistakes that occurred at the first surveys of the cave.

The chamber is 308 m long, on the widest place 123 m wide, on an average 89 m wide. The chamber's ceiling is on an average 106 m high, on the highest place the ceiling is 146 m high. The volume of the chamber is 2.100 000 m^3. The bottom of the chamber lies from 233 m where the Reka flows into the chamber to 214 m, where is the lowest point of the chamber, the level of Martel's Lake respectively.

Translated by Maja Kranjc

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Sl. 2: Tloris in profili (profili p3, p7 in p11) Martelove dvorane v Škocjanskih jamah.
Fig. 2: Groundplan and profiles (profiles p3, p7, p11) of the Martel's Chamber at Škocjanske jame.

MARTELOVA DVORANA V ŠKOCJANSKIH JAMAH

Povzetek

V znak spoštovanja do uglednega speleologa so raziskovalci tedaj največje jame na Krasu poimenovali njeno največjo dvorano po E.A. Martelu. Dvorana je z 2.100.000 m^3 prostornine največja dvorana na Matičnem krasu in v Sloveniji.

Nove meritve z elektronskim teodolitom ter z laserskim profilerjem, s katerim smo v dvorani izmerili 10 prečnih profilov, so omogočile natančen izračun lege in dimenzij dvorane, ter popravile napake, ki so nastale pri prvih meritvah jame.

Dvorana je dolga 308 m, široka pa na najširšem mestu 123 m, s poprečno širino 89 m. Strop dvorane je v poprečju visok 106 m, na najvišjem mestu pa je dvorana visoka 146 m. Volumen dvorane je 2.100.000 m^3. Dno dvorane leži v višinah med 233 m, kjer Reka priteče v dvorano, najnižja točka dvorane oziroma gladina Martelovega jezera pa je v nadmorski višini 214 m.

ŠKOCJANSKI JAMSKI SPLET AND E. A. MARTEL'S "LES ABIMES"

ŠKOCJANSKI JAMSKI SPLET IN MARTELOVA KNJIGA "LES ABIMES"

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Rojšek, Daniel: Škocjanski jamski splet in Martelova knjiga Les Abîmes

Avtor predstavlja vlogo Škocjanskih jam v monografiji E.A. Martela Les Abîmes. Poudarjena sta svetovni pomen jamskega sistema in monografije.

Ključne besede: E.A.Martel, Les Abîmes, Škocjanski jamski splet, Slovenija.

Abstract UDC 551.442 (497.12 Škocjan)

Daniel Rojšek: Škocjanski jamski splet and E.A. Martel's Les Abîmes

The role of Škocjanski jamski splet in E. A. Martel's monograph Les abîmes is illuminated by author's interpretation. The world importance of the System and a meaning of the monograph is emphasized.

Key words: E. A. Martel, Les Abîmes, Škocjan Cave System, Slovenia.

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INTRODUCTION

The speleology is placed in the last position of extremely rich E. A. Matrel's monograph Les abîmes headline, nevertheless in the first chapter explanations of terms, purposes, programmes of works in underground and techniques of spelaeology are published in 1894.

In the same chapter photographs of the first Velika voda - Reka ponor and of Miklov skedenj cave entrance with the highest waterfall in the Škocjan Cave System (as an example of karst spring) are published.

I was very surprised seeing the photos in pages four and six of the monograph, twenty years ago. My first thought was, that the author had decided to accent the world importance of the System by publishing the photos in the early beginning of the book, already at the end of the last century.

LES ABIMES AND ŠKOCJANSKI JAMSKI SPLET

At the end of the 19th century started a dividing of speleology in two human activities: - spelaeology as a science of underground karst phenomena and - caving as discovering and description of accessible karst caverns by amateurs of nature.

Les Abîmes is undoubtly one of the most important scientifical works of that time, but it is also a manifest of modern caving with a review of the most important caves of France and other parts of Europe and even of continents Africa, Asia and both Americas.

Author tried to ask questions of karst and speleological terminology using active local names of karst phenomena in different countries of the Earth.

Les Abîmes is outfited by 60 reproductions of photographs, 47 copperplates, many very illustrative cave plans with profiles and cross-sections of karst regions.

ŠKOCJANSKI JAMSKI SPLET IN THE MONOGRAPH

Klasični kras - classical karst or Karst propre called by E. A. Martel represents central object of the 27th chapter entitled Le Karst, where the System is partly overshadowed by Postojnski jamski splet - the Postojna Cave System. Namely, E. A. Martel was one of the discoverers of the active Pivka river channels of the Postojna System. A reason for the statement is supposingly psychologic, everyone who discovers something new is emotionally bound to that thing and put it on the first place.

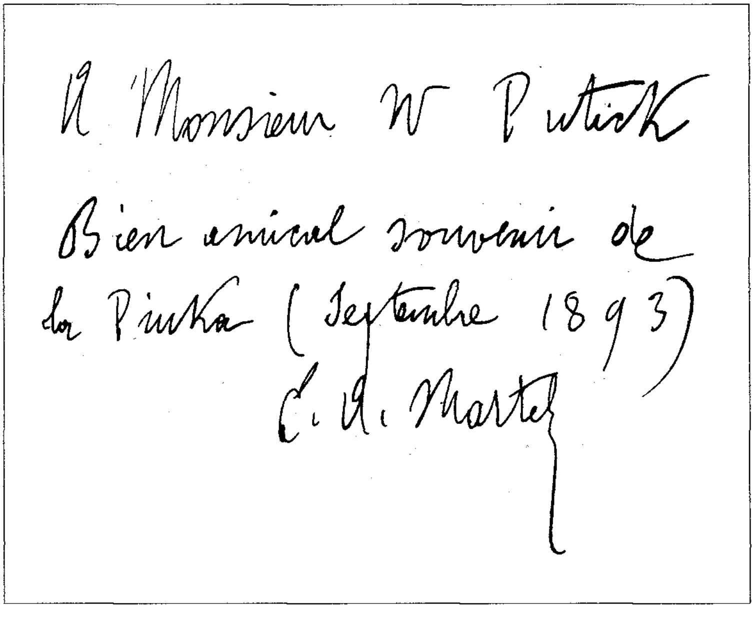
In the 32nd page of the 27th chapter (pp 364) the Kras region and the Škocjan Cave System designations begin. Austrian official toponyms (in German language) are used in the book, mostly with Slovene names cited in parenthesis, but somewhere only Slovene and even Italian toponyms are quoted.

The Velika voda - Reka river is denoted as the most important karst river.

A discourse about name Recca or Reka and quotations of six "Rekas" from Dinaric orographic system have amazed me, like publishing of comparative terminology of six karstological phenomena in five languages (Franch, German, Slovene (from Carniola), Serb (from Montenegro and Serbia), and Czech (from Moravia); pp 433).

After presentation of the Škocjan Cave System hydrogeological situation of Velika voda-Reka is discussed (pp 467 - 471). Historical and geogaphical role of the river is accentuated by citation (pp 470) of a part of Roman poem Aeneis by Virgilius, where the Timavus springs are mentioned.

The Cave System is introduced very clearly and particularly in five pages. The most important is starting statement, that the System should be the most gigantic among existents. Descriptions of karst features with precise estimations of lengths, widths, heights and depths are based on printed and manuscripted reports of explorers, members of German-Austrian Alpine Club - Coastal Section of Triest. Existent bibliography review is presented, too.



Sl. 1: Martelovo posvetilo Puticku v knjigi Les Abîmes
Fig. 1: Martel's dedication to Putick in his book Les Abîmes

The System is graphically illustrated by three reproductions of photographs, seven copperplates and by longitudinal cross- section of the System, other speleological objects and the Kras region.

The first and the second photographs are mentioned in the introduction of this paper, the third one is reproduction of postcard, showing rimstone pools or gours in the Dvorana Ponvic - the Hall of Rimstone Pools (pp 84). The author published it as example of big rimstone pools to illustrate bigger or giant's gours in Grotte de Saint-Marcel-d'Ardèche. The copperplates are reprints of F. Müller (1987), the cross-section is based on austrian topographic maps and cave maps published by members of German-Austrian Alpine Club-Coastal Section (F. Müller 1891).

The final illustration of Le Karst chapter is plan and cross-section of side hole above Müllerjeva dvorana - Müller Chamber called Grotto of Jubilee, discovered on the 21 st of January 1894. Monograph brings discoveries of 1888 to 1893, but with mentioned plan of the Grotto the book was current like a magazine.

CONCLUSION

Škocjanski jamski splet is presented in Les abîmes as cave system of world importance and as beginning of the Velika voda - Reka drainage zone in the Kras region with immense karst holes connected by the water, as an example of ponor cave and of karst spring cave, and by ten illustrations (three photographs and seven copperplates), which present aproximately 10 % of the book's graphic material.

Les Abîmes is also a manifest of modern caving.

Discovering technics of protected paths (cutted steps into rocks protected by steel ropes of Alpine standards from that times), leading down- and upwards in the System are important contribution to caving technics in the World.

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ŠKOCJANSKI JAMSKI SPLET IN MARTELOVA KNJIGA "LES ABIMES"

Povzetek

V Martelovem delu Les Abîmes je Škocjanski jamski splet predstavljen kot jamski sistem svetovnega pomena, kot pričetek podzemeljskega odtoka Velike vode - Reke v podzemlje Krasa z ogromnimi votlinami ob podzemeljskih vodah, kot primer ponorne jame in izvirne jame. *Ti primeri so podkrepljeni z desetimi ilustracijami (tri fotografije in sedem* bakrotiskov), kar predstavlja okoli 10 % vsega grafičnega gradiva celotne knjige.

Les Abîmes je tudi odraz moderne speleologije. Tehnika odkrivanja in nadelavanja zavarovanih poti (v skalo vklesane stopnje, zavarovane z jeklenimi vrvmi po standardih takratnega planinstva), ki vodijo gor in dol po sistemu Škocjanskih jam so pomemben prispevek k svetovni jamarski tehniki.

THE WIDER PURPOSE OF MARTEL'S VISITS ABROAD

RAZLOGI MARTELOVIH OBISKOV TUJEGA KRASA

TREVOR R. SHAW

Izvleček UDK 551.44(091) : Martel E.A.

Shaw, Trevor R.: Razlogi Martelovih obiskov tujega krasa

V članku so podana razmerja inozemskih članov v Société de Spéléologie in njihovih objav v Spelunci, kakor tudi Martelovi obiski in članki v inozemstvu. Zlasti v Sloveniji in Angliji so objave neposredno sledile Martelovim obiskom.

Ključne besede: Martel, speleologija, zgodovina, objave, društva, Francija, Slovenija, Velika Britanija

Abstract UDC 551.44(091) : Martel E.A.

Shaw, Trevor R.: The wider Purpose of Martel's Visits Abroad

The proportions of foreign members in the Société de Spéléologie and of their writings in Spelunca are presented, together with Martel's visits and publications abroad. In some countries, notably Slovenia and England, such activity followed directly on Martel's visits there.

Keywords: Martel, speleology, history, publications, societies, France, Slovenia, Great Britain

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Martel's visits to regions outside France were not made solely for new exploration and to advance his own knowledge of caves and karst. Their purpose was also to inspire and encourage cave work by others throughout the world.

There can be no doubt about the extent of Martel's links with speleology in other countries. Of his 26 annual "campaigns" of exploration, 19 went outside France in what are now 20 countries and in addition he made lecture tours and other visits abroad.

At least 61 of his publications on caves appeared in other countries in his lifetime. Many of these were papers presented to learned societies, and there were also popular articles and the texts of public lectures. In addition, some items were simply translations or reprints of work already published in France, showing the interest with which it was regarded abroad.

FOREIGN MEMBERSHIP OF THE SOCIÉTÉ DE SPÉLÉOLOGIE

The Société de Spéléologie, which Martel founded in Paris in 1895, enjoyed high scientific standing from the outset and it was one of the means by which he contrived the extension of cave study into an international subject. Foreign membership of the Society was remarkably high. 21 % of the founder members lived outside France, indicating the close links already existing before 1895. Between 1895 and 1904 the proportion rose to 29 %; in addition three foreign cave societies were members. Membership for each country is listed in Table I, which excludes those who were probably French citizens living abroad.

Many papers by foreign contributors, most of them members, were published in the Society's journal, Spelunca. Table II shows that they comprised between 14 % and 50 % of papers printed in individual years. In the first six years of Spelunca's existence short news reports, "informations", were also printed, some of them summarized from published sources and others contributed by individuals. Of the latter, up to 25 % in any one year were sent in by foreigners.

French authors also wrote in Spelunca about caves in other lands. The Society exchanged its publications with foreign journals, and the many long primary bibliographies in Spelunca included literature from all over the world.

In some cases, no doubt, foreign authors wrote for Spelunca to achieve wider dissemination of their work in a specialist journal. Of these, many will have been inspired by personal contact with Martel. In other cases material was actively solicited by him, as will be seen later in this paper.

It was not only reports that Martel encouraged. In Spain he caused a cave section to be formed within the Associacio d' Excursion Catalana (Martel 1897b, p. 399), and he instigated and set up a group of cave explorers in Mallorca (Casteret 1943, p. 211). He recommended to the minister in Wien and to the management of Postojnska jama that they should support the Anthron caving club at Postojna as much as possible (letters of 9 Nov. 1893 and 26 Jan. 1894) *His encouragement of cave study in England is described later.*

FOREIGN VISITS, MEMBERSHIP AND PUBLICATION

In Table III the various aspects of foreign relationship (Martel's visits and publication abroad, foreign membership of the Société de Spéléologie and foreign contributions to Spelunca) are listed region by region. The visits include those listed by Casteret (1943, p. 230) and some additional ones. His publications abroad include those given by Chabert and

Table 1 - Foreign individual membership of the Société de Spéléologie, excluding French nationals living abroad (derived from Anon., 1895a, 1904,1909b)

	Founder members (before 1 Jan 1895)	*1 May 1895*	*1 Sept. 1904*	*1 Oct. 1909*
Algeria	-	-	1	1
Austria*	4	6	4	3
Belgium	2	2	6	6
Bohemia	-	-	1	1
Bosnia	-	-	1	1
Bulgaria	-	-	1	-
Croatia	-	-	1	1
England	1	3	7	4
Germany	3	3	5	4
Greece	1	1	1	1
Hungary	-	1	1	1
Ireland	-	1	1	1
Italy (except Trieste)	-	1	4	2
Mallorca	1	1	-	-
Moravia	-	-	1	1
Serbia	1	1	1	-
Slovenia	1	1	2	2
Trieste	5	5	6	4
Spain	2	2	2	2
Switzerland	3	3	-	-
U.S.A.	-	-	5	3
Venezuela	-	-	-	2
total foreign membership	24	31	51	40
total membership	116	140	174	138
% membership foreign	21	22	29	29

* The present day boundaries of Austria are used in this table
† Slovenia and Trieste are shown together as members explored in the same region

Courval (1971) plus others. Foreign membership again excludes those who were probably French nationals living abroad. The year columns include the years for which Spelunca fascicules were issued, which were not nesessarily the same as the years of publication. Trieste, which was then in Austria, is shown separately and next to Slovenia where most of its members' exploration was being done.

Perhaps it may be possible to find out more about Martel's direct influence on these international relationships by examining the pattern and sequence of events. Did the memberships and publications follow some identifiable activity of Martel such as a visit?

In some cases this was clearly not so. There were no known visits to Algeria, Bulgaria, Laos and Serbia. Although he travelled to Portugal, Sardinia, Slovakia and Turkey, no Society memberships or publications followed. In USA, where there were several members and much publication, Martel's only known visit took place some 20 years after the relationship began. It is, of course, always possible that earlier, undetected, visits had occurred in some countries.

Belgium received so many visits and is so close to Paris that it is not possible to relate cause and effect. In contrast, the area of present-day Austria was the subject of no major "campaigns" at all. Perhaps this is not so surprising after all, for cave study had been well established there since the time of Schmidl in the 1850s, leaving less opportunity for new exploration and less for encouragement.

In Bosnia, Croatia and Greece visits were indeed followed quite soon by membership and sometimes authorship, but the single member in each case, however distinguished, cannot form a pattern.

In contrast to the lack of clear pattern seen in any of the above cases, Martel's visits to Slovenia in 1893 and to England and Ireland in 1895 do seem to have been followed by very significant and continuing association by membership, publication and further visits.

Whether the reasons for this were the same in the two cases is doubtful. Cave studies in

Table II - Papers and notes contributed to Spelunca by foreigners

	1895	*1896*	*1897*	*1898*	*1899*	*1900*	*1901*	*1902*	*1903*	*1904*	*1905*	*1906*	*1907*	*1908*	*1909*	*1910*	*1911*	*1912*	*1913*
Foreign papers	3	5	10	5	6	2	0	0	0	3	0	0	1	2	3	0	1	0	1
Foreign contributed notes	3	1	5	7	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Foreign contributions (papers & contributed notes)	6	6	15	12	9	5	0	0	0	3	0	0	1	2	3	0	1	0	1
Total papers	13	24	25	22	15	14				9			4	4	11		3		4
Total contributed notes	22	26	34	34	19	12				0			0	0	1		0		0
Total papers & contributed notes	35	50	59	56	34	26				9			4	4	12		3		4
Foreign papers as %	23	21	40	23	40	14				33			25	50	27		33		25
Foreign contributed notes as %	14	4	15	20	16	25													
Foreign contributions (papers and contributed notes) as %	17	12	25	21	26	19				33			25	50	25		33		25

Slovenia had already taken place for more than 200 years; technically difficult explorations had been in progress for at least ten years, undertaken by organized cave societies that published their results; and geographers and professional engineers such as Kraus and Putick were associated with karst work. In Great Britain, on the other hand, although occasional cave descents had been made before 1892 and more frequently since the foundation of the Yorkshire Ramblers' Club in that year, it was all rather amateur and localized and there was scope for Martel's stimulation and encouragement.

With that brief contrast between the state of speleological development in the two areas where Martel's visits were followed by closer association with France, little more will be said here about Slovenia which is being examined in detail in this two-day meeting. Within seven years of Martel's visit there in 1893, Slovenia (together with the neighbouring city of Trieste from which so many of its cave workers came at that time) produced nine members of the Society and published eight papers and eight notes in Spelunca.

Table III - Martel's visits and publications abroad, foreign membership of the Société de Spéléologie, and foreign publication in Spelunca

	1888	1889	1890	1891	1892	1893	1894	1895	1896	1897	1898	1899	1900
ALGERIA										▼		○	
AUSTRIA	★	★					▼▼▼▼	▼▼▼▼		■□	■■		■
BELGIUM		★	[visit]			★★	▼▼		★★ ▼	★ ■	[visit] ★★★★ ★★★● ▼▼▼▼○		
BOHEMIA & MORAVIA								▼			[visit]		
BOSNIA						[visit]		□		▼			
BULGARIA									▼		■		
CORSICA													
CROATIA						[visit]		▼					
ENGLAND							★★★	[visit] ▼▼▼ ●	★★▼	★ ▼▼ ●	★	■	
GERMANY							▼▼▼	▼			[visit] ▼▼	▼	
GREECE				[visit]			▼						
HUNGARY								▼			[visit] ■		■
IRELAND								[visit] ▼▼	★	□			
ITALY except Trieste								▼	▼	▼	▼		
LAOS													
MALLORCA								▼	[visit]		●	●●	●
MONTENEGRO						[visit]							
NORWAY							[visit]						
PORTUGAL													
RUSSIA													
SARDINIA													
SERBIA							▼	■	■	■			
SLOVAKIA											[visit]		
SLOVENIA						[visit]	▼	▼	[visit]				
TRIESTE							▼▼▼▼▼	▼ ■ ●●	■■■ ○	■□□ ●	●●	■	▼ ●●
SPAIN			★				▼	▼	[visit]	○○	★★ ▼ ●	■	
SWITZERLAND							▼▼▼			[visit]	[visit] ○○		[visit]
TURKEY													
U.S.A.						★★★	★	▼	★★ ▼ ■	▼ ■■○	▼ ■	■■■	▼
VENEZUELA													

	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914
ALGERIA														
AUSTRIA														
BELGIUM		[visit] ★★★	[visit] ★★★ ★★★		[visit] ★★	★	★★	▼ □	★★ □	★★				
BOHEMIA & MORAVIA		▼▼												
BOSNIA														
BULGARIA														
CORSICA								[visit]						
CROATIA														
ENGLAND		▼		[visit] □	[visit] ★			★						
GERMANY							▼							
GREECE											■			
HUNGARY									■					
IRELAND														
ITALY except Trieste			[visit] ★	▼								★		★
LAOS								□						
MALLORCA	[visit]													
MONTENEGRO														
NORWAY														
PORTUGAL					[visit]									
RUSSIA			[visit]				□							
SARDINIA								[visit]						
SERBIA														
SLOVAKIA														
SLOVENIA														
TRIESTE				■										
SPAIN					[visit]	[visit]								
SWITZERLAND		[visit]												
TURKEY										[visit]				
U.S.A.				★ ■		★			★ ■			[visit]	■	
VENEZUELA							▼▼							

[visit] Martel visit
★ Martel publication
▼ member joined
■ paper by member
□ paper by other
● note by member
○ note by other

The case of England and Ireland will be studied in some detail because it does demonstrate the way in which Martel deliberately developed cave study into an international subject. Great Britain was suitable ground for such efforts at that time for it already had some interest in the subject but was in need of the wider outlook and experience that Martel brought - in short it needed the "professional" approach already existing in France, Austria and Slovenia.

ENGLAND AND IRELAND, 1895

Martel visited Great Britain in July and August, 1895. In addition to his celebrated first descent of the 100 m deep shaft of Gaping Gill (Anon, 1895b), he visited several well-known caves in Derbyshire to study any regional characteristics they might possess, and also some less easy caves in Ireland (Martel 1896a-g, 1897a-c). In the course of the visit he also delivered a lecture on caves at the International Geographical Congress in London (Martel, 1896h).

As the translators of the Derbyshire section (Martel, 1914) of his Irlande et caverns anglaises (1897a) pointed out 17 years later, "It is perhaps difficult to realise that the only comprehensive work on English and Irish caves has not been written in the English tongue". He had "obtained from the French Government... a scientific mission in the name of the Minister of Public Instruction to make a comparison between the grottoes and subterranean waters of Great Britain and those which I had already examined in France, Belgium, Austria [i.e. Slovenia] and Greece" (Martel, 1897c, p. 500).

Ever seeking to arouse and encourage cave research wherever he went, he wrote (1897c, p. 500): "The principal aim... was to attract the attention of English scientific men and tourists to all that still remains to be done and to be found in the natural caves of Great Britain." Also "I wish that cave-hunting may be now energetically resumed there by English investigators, to the great benefit of human knowledge and curiosity." (Martel, 1897c).

Table III shows the ensuing group of new members joining the Société de Spéléologie, with a few British papers and notes in Spelunca and Martel's continuing use of British publications for his own writing. Baker (1904) acknowledged Martel's success in stimulating cave interest among the British: "Since 1895 cave-exploring has become a more popular pursuit, thanks largely to the example and enthusiasm of M. Martel. Clubs and societies have taken up the work, and both the scientific and the sporting attractions of cave-exploring have received general acknowledgement."

ENGLAND, 1904

In 1904 he visited the caves of the Mendip area for a few days (Martel, 1904, 1905; Shaw, 1988). H. E. Balch, E. A. Baker and others took him into the tourist caves at Cheddar and Wookey Hole on June 15th, and showed him the entrances of Eastwater Swallet and

Swildon's Hole, then being explored. There were only two days of cave visiting and he apparently did not remain in England afterwards.

It is clear that he did not set out to make any new explorations in the Mendip area; indeed he did very little exploring at all. What then did he aim to do and what did he achieve? There seem to have been two objectives: (a) to broaden his own experience; (b) to create and encourage another international link in the cave world.

It was Martel's practice not only to explore caves but to study them and their associated karst hydrology. Just as in 1895 he had visited tourist caves in Derbyshire, so in 1904 he studied the characteristics of the Mendip karst. He was particularly interested in the effect of the soluble Dolomitic Conglomerate (which in places covers the limestone) on the major risings.

Although Balch, the dominant Mendip cave explorer of the time, never became a member of the Société de Spéléologie, he did write a paper "On the caves and underground watercourses of the Mendip Hills... (explorations 1901 - 1904)" which appeared in French (Balch, 1904b). It was not published in English at the time but formed the basis of a chapter in a book a few years later (Baker and Balch, 1907). Among the photographs illustrating this book are several taken by Martel.

Supply of photographs to and from France seems to have been quite common. A postcard written in English by Martel to Balch on 30 October 1904, and formerly in Wells Museum, makes arrangements for the return of half-tone blocks borrowed from Balch, no doubt those for the seven photographs by Bamforth already used in the Climbers' Club Journal (Balch, 1904a). The postcard also asks for the loan of some diapositives, for lecture purposes in France.

Long before Martel's first visit to England he had lent diapositives and provided information to Mark Stirrup (1890) for a lecture to the Manchester Geographical Society. A few years later Stirrup (1896), by now a member of the Société de Spéléologie, was talking to the Manchester Geological Society and "On the table were laid numerous plans and sections of English and Irish caves visited by M. Martel in July last, and drawn up by him".

In 1898 he wrote to an unidentified person in Ireland (Martel, 1987) thanking him for cave photographs. At the same time he pointed out the exploration and water tracing that were necessary so that "a nice and special paper" could be published with the photographs in Spelunca. His prompting was evidently unsuccessful for the paper never appeared.

Besides inducing foreigners to join the Société de Spéléologie, Martel himself was given honorary membership of cave societies abroad. Such events are difficult to trace, usually being reported only in membership lists and formal notices of proceedings. It is known that he was made an honorary member of the Yorkshire Ramblers' Club in 1905 (Anon, 1909a, p. 325) when he came to England again to give a lecture in Leeds. He also became an honorary member of the Mendip Nature Research Committee when it was founded in 1906.

CONCLUSION

It is often said that Martel was the father of speleology. Certainly there were uncles also, Kraus among them, and Schmidl was undoubtedly the grandfather of the subject (Shaw, 1980), with Valvasor as a distinguished and influential ancestor. But it is from Martel that there seems to have been a continuous tradition in many parts of the world; direct influence and personal contact can be traced back to him like an apostolic succession. Not only did Martel explore immense numbers of caves and publish many scholarly books and papers, he was also a traveller and publicist whose enthusiasm was spread by widespread personal visits and semi-popular writings as well as by his scientific papers. The Society that he founded had influence as a sound base for research and a place of publication for cave studies world-wide.

This paper had demonstrated the international links that he created by his own visits and publications abroad, and by attracting a high proportion of foreign members into the Société de Spéléologie with consequent papers by them printed in Spelunca. It has been shown how he aroused interest, inspired and encouraged activity, and helped in various ways afterwards.

Martel's importance was recognized by his contemporaries outside France as well as within, and not only by subsequent historians. Some of the remarks quoted here confirm this and it was in Italy that the first study of his overall achievements was published (Musoni, 1912).

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L'OBJET LE PLUS LARGE DES VOYAGES DE MARTEL A L'ETRANGER

Résumé

C'est de M. Martel qu'il y a une tradition continue aux régions nombreux, en France et dans les pays étrangers; l'influence directe mène à lui comme une succession des apôtres. Exprès, il a encouragé l'intérêt aux grottes à l'étranger. Martel n'a pas seulement exploré des grottes très nombreuses et écrit quelques cents des études scientifiques; aussi il était voyageur et publiciste qui a propagé son enthousiasme par des voyages répandues et des écrits populaires en plus des études scientifiques. La Société établie par Martel a faite des recherches sur les grottes et a editée des études universelles.

Cette étude indique les liasons internationales crée par ses propres voyages et ses écrits à l'étranger, et aussi la grande proportion des membres étrangers dans la Société de Spéléologie avec les études résultantes imprimées dans Spelunca. A sa première année, 1895, 22 % des membres de la Société étaient des pays étrangers, et en 1904 cette proportion était 29 %. Aux pays nombreux il a excité l'intérêt, et a stimulé et encouragé l'exploration, et aussi à aidé plus tard. Dans les pays comme l' Autriche et la Slovénie il n'y avait pas le même besoin de tel encouragement.

RAZLOGI MARTELOVIH OBISKOV TUJEGA KRASA

Povzetek

Martel ni obiskoval tujega krasa le zato, da bi ga raziskoval in si širil svoje znanje o krasu, ampak tudi zato, da bi vzpodbudil tamkajšnje speleološke raziskave. Od Martelovih 26 vsakoletnih raziskovalnih "kampanj" jih je bilo 19 usmerjenih v tujino, to je v 20 različnih današnjih držav. Poleg tega je prirejal "predavateljska" in druga potovanja v tujino.

Često pravimo, da je Martel oče speleologije. Vendar so tudi strici speleologije, med njimi Kraus, Schmidla lahko brez dvoma imenujemo za deda (Shaw 1980), Valvasorja pa štejemo za izjemnega in vplivnega prednika. Kaže pa, da v marsikateri deželi kontinuiteta izhaja prav od Martela. Martel ni le raziskal ogromno število jam in objavil mnogo temeljnih knjig in člankov, bil je tudi popotnik in publicist, katerega navdušenje so širili prav njegovi obiski, poljudnoznanstvene in tudi znanstvene objave. Société de Spéléologie, ki jo je ustanovil, je bila marsikdaj temelj raziskavam in mesto za objavo rezultatov z vsega sveta.

V prispevku so prikazane Martelove zveze v tujini, ki si jih je ustvaril s pomočjo obiskov in objav v tujini, pa tudi z vključevanjem velikega števila tujih članov v francosko speleološko društvo in z objavljanjem njihovih prispevkov v reviji Spelunca. Martelov pomen so priznavali njegovi sodobniki tako v Franciji kot izven nje in ne samo kasnejši zgodovinarji. Tudi navedbe v tem članku potrjujejo, da je bila študija o njegovem delu v celoti prvič objavljena v Italiji (Musoni 1912).

JAMA NA POTI IN ZGUBA JAMA

THE CAVES JAMA NA POTI AND ZGUBA JAMA

STANKA ŠEBELA

Izvleček UDK 551.442 (497.12 Postojna)

Šebela, Stanka: Jama na poti in Zguba jama

Martel omenja v svojem delu Les Abîmes (1894) tudi dve jami in sicer Jamo na poti (dolžina 65 m) in Zguba jamo (dolžina 122 m), ki ležita jugovzhodno od Črne jame in severno od Pisanega rova Postojnske jame. Obe jami ležita v severovzhodnem krilu Postojnske antiklinale in sicer severno od znanih rovov Postojnske jame.

Ključne besede: Postojnski jamski sistem, geologija, Jama na poti, Zguba jama, Martel, Slovenija

Abstract UDC 551.442 (497.12 Postojna)

Šebela Stanka: The caves Jama na poti and Zguba jama

Martel in his book Les Abîmes (1894) refers to two caves, namely Jama na Poti (65 m long) and Zguba Jama (122 m long), lying SE from Črna jama and N from Pisani rov of Postojnska jama. Both caves are in northeastern Postojna anticline limb and north from known passages of Postojnska jama.

Key words: Postojna cave system, geology, Jama na poti, Zguba jama, Martel, Slovenia

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INTRODUCTION

In the area above Postojnska jama cave system there are, according to the Cave Register 35 smaller or bigger caves, potholes and rock shelters. Most of them are about 10 m or less long, some of them, Zguba jama f.i. are more than 100 m long.

In 1993 hundred years passed since E.A. Martel's explorations in our caves. This was the reason that according to Martel's informations in his book Les Abîmes (1894) we again located the two caves which Martel refers to, among others, namely Jama na poti (cad. no. 583, page 449) and Zguba jama (cad. no. 6290 on page 448). The caves are interesting as they are situated between the known passages of Postojnska jama cave system (Fig. 1) and between Planinska jama.

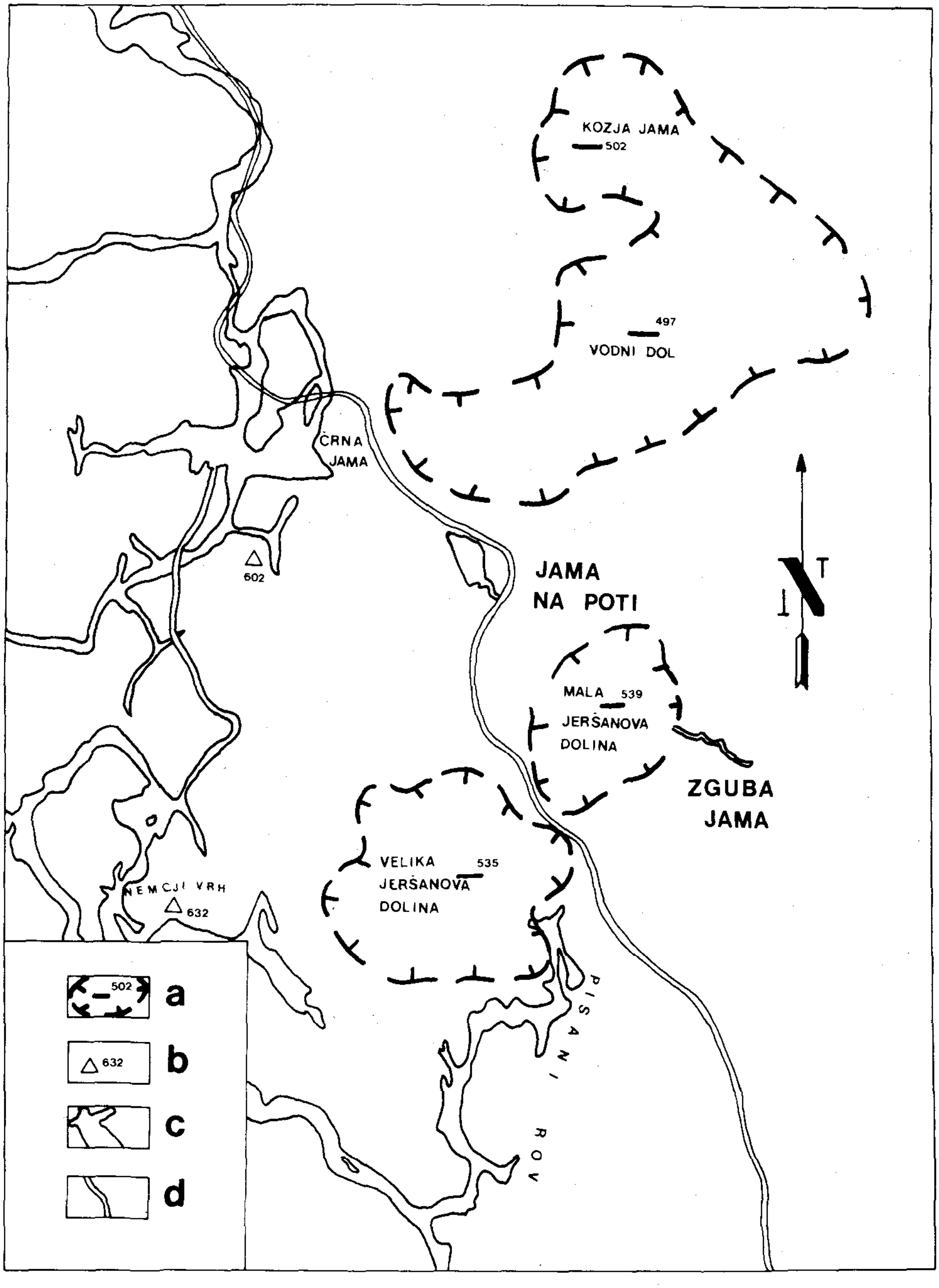
THE RESEARCHES OF JAMA NA POTI

Martel is the first to mention (1894) the Jama na poti cave. The entrance (568 m a.s.l. according to Martel) is 1 m wide and was discovered on the forest road (between the road Ljubljana - Postojna and Črna jama) in 1889 during the winter as a blowing hole. Some soil only was dug out and one could enter the cave developed along the bed planes and, according to Martel (1894) richly decorated. Northwestern part of the cave is transformed by breakdown and probably genetically connected to the origin of huge depressions in the vicinity. The length of the cave should be about 60 m (Martel 1894).

The entrance to the cave Jama na poti developed, referring to Martel (1894) in a fissure widened by the infiltration water. The flowstone and the block-fall must originally had the connection with one of the nearby caves. The cave was interesting to Martel because of its shape, as it developed from a simple joint to a rather spacious cave in the interior. Obviously two erosions complement each other - the external and the internal one (Martel 1894).

In the Cave Register the ground plan and the longitudinal section of the Jama na poti (Fig. 2) by A. Sartori is kept. According to these data the cave is 32,5 m deep and 65 m long. According to the Italian VG Cave Register the cave is 40 m deep and 65 m long.

According to the Cave Register of the Karst Research Institute on February 23, 1954 a part of the entrance was reopened. In a circle of about 5 m of diameter around this hole the snow melted and entering could be possible by some digging. The participants of this visit were Habe, Hribar, Modrijan and Savnik.


KOZJA JAMA
502
497
VODNI DOL
ČRNA
JAMA
602
JAMA
NA POTI
MALA 539
JERŠANOVA
DOLINA
ZGUBA
JAMA
VELIKA 535
JERŠANOVA
DOLINA
NEMCJI VRH
632
PISANI ROV
502
a
632
b
c
d

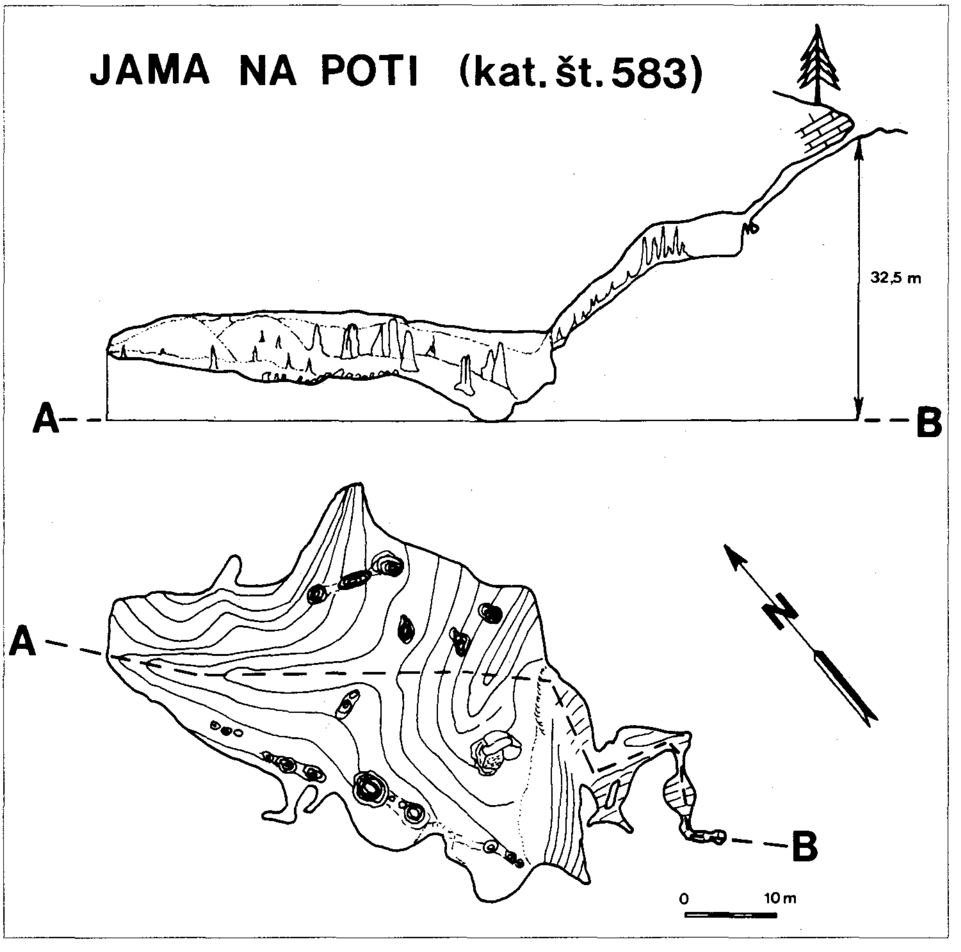


Fig. 2: Ground plan and longitudinal section of Jama na poti (according to A. Sartori, Cave Register)
Sl 2: Tloris in vzdolžni profil Jame na poti (po A. Sartori-ju, Kataster jam).

Fig. 1: Situation of Jama na poti and Zguba jama.
a-collapse doline
b-height above sea level
c-ground plan of cave passages
d-road

Sl. 1: Položaj Jame na poti in Zguba jame.
a - udornica
b - hrib z nadmorsko višino
c - tloris jamskih rovov
d - cesta.

From December the 7th, 1954 (Cave Cadastre) originate the data that the cave was in the past time named Pivčanova jama referring to the owner Vilhar, Veliki Otok 4 near Postojna. The cave was found by the Vilhar's children.

In the Postojnska jama cave system and in other near caves Gospodarič performed a lot of researches.

Among others he refers to Jama na poti where like in Postojnska jama the flood loam was known. It was deposited in the time when the collapse doline did not yet interrupt Pisani rov. This is a reliable proof that the Velika Jeršanova dolina was the most deepened after the sedimentation of the flood loam (Gospodarič 1969).

During the researches in Čarobni vrt in Postojnska jama this important speleological process was dated to the first Würm glacial (Gospodarič 1967, 27).

Gospodarič supposes (1969) that Jama na poti is the former continuation of Pisani rov towards north, northwest respectively.

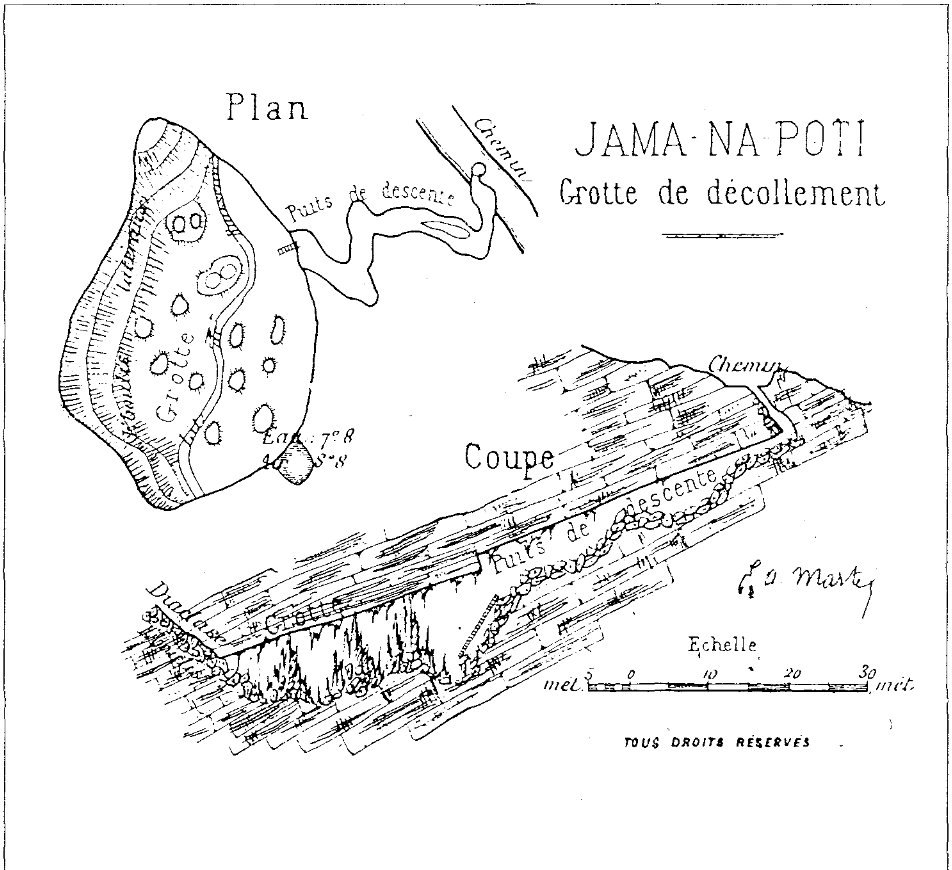


Fig. 2a: Martel's plan of Jama na poti (Les Abîmes 1894)
Sl. 2a: Martelov načrt Jame na poti (Les Abîmes 1894)

Fig. 3: Geological conditions of Zguba jama
1 - ground plan of the cave passage with denoted survey points
2 - stagnant water
3 - geological elements of Upper Cretaceous limestone
4 - remains of the rudists
5 - anticlinal knicked layers
6 - crushed zone
7 - broken zone
8 - fissured zone
9 - fault plane with geological elements

Sl 3: Geološke razmere Zguba jame.

1 - tloris jamskega rova z oznakami meritvenih tok
2 - stoječa voda
3 - geološki elementi zgornje krednega apnenca
4 - rudistni ostanki
5 - antiklinalno upognjene plasti
6 - zdrobljena cona
7 - porušena cona
8 - razpoklinska cona
9 - prelomna ploskev z geološkimi elementi

In spite of precise situation according to the Cave Register the Jama na poti is not accessible today as it was completely filled up at the construction of the road.

SPELEOLOGICAL DATA ON ZGUBA JAMA

In 1993 at detailed researches of the area above Postojnska jama we rediscovered Zguba jama (the name means the Lost Cave) (VG 583, cad. no. 6290) which had, according to the Italian VG Cave Register wrong co-ordinates.

It must be mentioned that at searching the cave entrance we used the Martel's survey (1894) which was proved to be correct. Otherwise the first to discover the cave was M. Kraiger and company (Martel 1894) on the eastern side of the Mala Jeršanova dolina. According to Martel the cave is about 100 m long.

Zguba jama (Fig. 3) is 122 m long and 4 m deep. The entrance to the cave is about 1 m high and 1.5 m wide. After some 6 m the roof of the cave elevates to 1.4 m and one can walk almost upright. After 25 m at the point 1 the passage is 2 m high already. At the point 3 there is the first pond with surface of 3 m^2. At the point 7 the passage is less than half a meter high and this is the height dug by the first explorers of the cave. Here the passage was entirely filled up by the sediment. It is the flysch deposit of reddish orange colour. After some 2 or 3 m the passage is higher again. Among the points 12 to 15 and 16 to 17 the passage was dug again. Between the points 15 and 16 there is on the northern side of the passage a chimney, about 2.5 m wide and at least 4 m high. At the point 17 the breakdown at the tectonically crushed zone started and closed the continuation of the cave.

Zguba jama lies at 561 m a.s.l. which is 26 m higher than the level of the nearest part of Postojnska jama, it is Pisani rov (point 25 lies at 535 m a.s.l.). Thus this caves developed on a higher level and probably presents a fossil cave.

The cave passage displays well preserved phreatic features. In respect to numerous scallops we may infer to the direction of the water flow from southeast towards northwest. In the cave there is a thick (2 m) sediment in the lower part of the passage of mostly red-brown colour. The uper layer of the sediment is probably flysch deposit. It is hard to assume from which direction the sediments were deposited into the cave. It is sure that after the sedimentation the layers were somewhere entirely (probably by the vertical percolation too) removed by the water flow which etched between the sediment and the rock the wall flutes.

In the cave there are two smaller ponds (about 1 to 3 m^2) where the water accumulates by vertical infiltration, out of chimneys mostly.

50 m from the entrance inside the cave the influence of the external temperature is still felt. There is no drought in the cave, at our visits during the survey the spaces became a bit misty.

Mostly at the entrance, but also some 60 m inside there is a lot of spiders, grass-hoppers and some Leptodirus as well. The cave is a genuine biological laboratory.

Hundred years ago already the explorers of Postojnska jama tried to realize a wish, not yet fulfilled, to join Postojnska jama and Planinska jama. During these efforts they discovered on the surface above Pisani rov among others also Zguba jama. The traces of digging in front of the cave and the excavated sediments in the cave evidence great wish and will that the cave would be as long as possible and that maybe even its continuation would be found.

At our visit we found the signature of Matija Vilhar from 1939 and an unrecognized signature from 1934.

TECTONIC-LITHOLOGICAL CONDITIONS IN ZGUBA JAMA

According to the Basic geological map, sheet Postojna (Buser, Grad & Pleničar 1967) the cave is built in Upper Cretaceous limestone. In the eastern part of the cave the limestone beds dip northeastwards (10-15^0) (Fig. 3). Between the points 11 and 12 the beds are gently knicked according to anticline and they dip in the western part of the cave northwestwards (10-20^0). One meter inside the cave one could observe on the roof extremely rich remains of rudists. Inside the cave there are a lot of rudists again, one may talk about lumachelle. Somewhere they stick out of the rock due to corrosional water activity. The thickness of the bed is half a meter in average.

Tectonically crushed zones are less distinctly expressed in the cave, partly due to phreatic passage shape where the geological basis are rather blurred.

The most distinctive is the fault zone 120/90 in the extreme southeastern part of the cave. The width of crushed to broken zone is up to 1 m. In this part the break-down boulders fallen off the fault zone blocked the supposed continuation of the passage.

Up to point 12 one may observe 25 m wide fissure zone 110-120/90, parallel to crushed zone or making an angle from 10 to 20^0.

Between the points 10 and 12 broken and fissured zone 60/90 and 80/90 prevail being parallel to the axis (making an axis respectively) of anticlinal knicked layers.

Between the points 1 and 2 a distinguished broken zone 80/90 lies.

At the entrance to the cave on the surface I established prominent broken zone 50/90 which is one of the most marked in the area and thus the crushed zones, found in the cave are actually secondary deformations.

CONCLUSION

The entrance to now buried cave Jama na poti lies 565 m a.s.l. (according to Italian data), 568 m according to Martel (1894), and 574-575 m according to data from 1954 and about 570 m according to topographic map in a scale 1:5.000. According to Italian and Martel's data the cave is 32.5 m deep and reaches (if we take the altitude of 570 m) 537.5 m in the depth.

Jama na poti lies about 300 m to the northwest of the last point in the Pisani rov. The point 25 in the Pisani rov is 535 m a.s.l., Jama na poti at 537.5 m and it shows a certain connection, namely possible continuation of the Pisani rov (before the formation of the collapse doline Velika Jeršanova dolina) towards north-west, or more precisely the continuation of this part of the system of the Postojnska jama in the northeastern limb of the Postojna anticline.

Zguba jama lies 561 m a.s.l. (the survey from 1993) which means 26 m at the entrance and 30 m at the end higher as is the level of Pisani rov. One of probable explanations would be that Zguba jama is linked with the Pisani rov, f.e. as its higher right passage, or that it presents the fossil level of the channel which was or was not linked with the level of the passages in the Pisani rov. Mala Jeršanova dolina probably interrupted the connection between Zguba jama and Pisani rov.

In 1967 a polygon above the Pisani rov was made. At that occasion the bottom of Velika Jeršanova dolina was defined to be at 519 m a.s.l. At the end of Pisani rov (Hill 531 m, the points 25 535.5 m respectively) they stopped digging after this survey as according to their opinion they could not reach a new passage but will hit after 10 m the middle of the southern slope of Velika Jeršanova dolina and thus the surface. The collapse doline Velika Jeršanova dolina thus interrupted the passage and deepened to the Hill 519, which is 16 m lower than Pisani rov (Gospodarič 1969).

To have a precise comparison of the geological setting of the surface and the cave the workers of the Karst Institute on March 31, 1993 resurveyed the polygon above Pisani rov. By laser theodolite NICON the Hill in the bottom of Velika Jeršanova dolina was established at 535 m, while on the map 1: 5.000 it lies at 539.5 m. According to these two data the bottom of Velika Jeršanova dolina lies some meters higher only than Pisani rov, or at the same altitude respectively.

Translated by Maja Kranjc

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JAMA NA POTI IN ZGUBA JAMA

Povzetek

Na površju nad Postojnskim jamskim sistemom se po podatkih Katastra jam nahaja 35 manjših ali večjih jam, brezen in spodmolov. Izmed teh jih je večina dolgih okrog 10 m in manj, nekatere, kot na primer Zguba jama, pa presežejo tudi 100 m.

Po Martelovih (1894) zapiskih v knjigi "Les Abîmes" smo ponovno določili položaj dveh jam, in sicer Jame na poti (kat. št. 583) in Zguba jame (kat. št. 6290), ki ju Martel omenja na strani 448 (Zguba jama) in 449 (Jama na poti). Jami sta zanimivi tudi zato ker ležita med znanimi rovi Postojnskega jamskega sistema (slika 1) in Planinske jame.

Vhod v danes zasuto Jamo na poti je v n.m.v. 565 m (po italijanskih podatkih), 568 m po Martelu (1894), 574-575 m po podatkih iz leta 1954 in okrog 570 m po topografski karti 1:5000. Po italijanskih podatkih, kot tudi po podatkih Martela (1894), je jama globoka 32.5 m in je tako v globini (če upoštevamo podatek 570 m) 537.5 m.

Jama na poti leži okrog 300 m severozahodno od zadnje točke Pisanega rova. Točka 25 v Pisanem rovu je v n.m.v. 535 m, Jama na poti pa 537,5 m, kar kaže na določeno povezavo, to je na možno nekdanje (pred oblikovanjem Velike Jeršanove doline) nadaljevanje Pisanega rova proti severozahodu, oziroma pravilneje nadaljevanje dela sistema Postojnskih jam tudi v severovzhodnem krilu Postojnske antiklinale.

Zguba jama leži v n.m.v. 561 m (merjenje iz leta 1993), kar je 26 m na vhodu in 30 m na koncu jame višje kot je nivo Pisanega rova. Ena od možnih razlag bi bila, da je Zguba jama bila povezana npr. s Pisanim rovom kot višji desni rov, oziroma da predstavlja star nivo rovov, ki je bil, ali pa ne, povezan z nivojem rovov Pisanega rova. Mala Ješanova dolina je verjetno prekinila zvezo med Zgubo jamo in Pisanim rovom.

Leta 1967 so opravili poligon nad Pisanim rovom. Pri tem so dno Velike Jeršanove doline določili na 519 m. Na koncu Pisanega rova (kota 531 m oz. v točki 25 535,5 m) so po tem merjenju končali s kopanjem, saj po njihovem mnenju ne bi dosegli novega rova, ampak bi že po 10 m zadeli v sredino južnega pobočja Velike Jeršanove doline in tako dosegli površje. Koliševka Velika Jeršanova dolina naj bi tako prekinila rov in se poglobila do kote 519, kar je 16 m nižje kot Pisani rov (Gospodarič 1969).

Zaradi natančne primerjave geološke zgradbe površja in jame smo 31.3.1993 sodelavci IZRK ZRC SAZU ponovno izmerili poligon nad Pisanim rovom. Z laserskim teodolitom znamke NICON je bila določena kota v dnu Velike Jeršanove doline 535 m, medtem ko je na karti v merilu 1:5000 dno na koti 539,9 m. Po teh dveh podatkih je dno Velike Jeršanove doline le nekaj metrov višje kot je Pisani rov, oziroma v isti višini.

ČLANKI

PAPERS

DVE DESETLETJI FUNKCIONALNO-MORFOLOŠKIH RAZISKAV PRI MOČERILU (*PROTEUS ANGUINUS*, AMPHIBIA, CAUDATA)

TWO DECADES OF FUNCTIONAL-MORPHOLOGICAL STUDIES OF *PROTEUS ANGUINUS* (AMPHIBIA, CAUDATA)

BORIS BULOG

Izvleček UDK 597.9 (497.12)

Bulog Boris: Dve desetletji funkcionalno-morfoloških raziskav pri močerilu (*Proteus anguinus*, Amphibia, Caudata)

Naša endemična repata jamska dvoživka, *Proteus anguinus*, ohranja številne neotenične značilnosti skozi celo življenje in kaže tudi nekaj splošnih troglomorfnih karakteristik. Fiziološke in funkcionalno-morfološke raziskave tega endemita potekajo vsaj dvajset let na Oddelku za biologijo, BF, Univerza v Ljubljani. Močeril je očitno odporen na nizke koncentracije kisika v vodi (1,4 - 0,3 mg/l). Ugotovljena je bila tudi najnižja koncentracija kisika v njegovem naravnem okolju (1,04 mg 0_2/l). Izmerjene so koncentracije kovin v vodah in sedimentih Pivke in Raka, ki tečeta skozi Planinsko jamo. Predhodne analize kažejo, da jetra močerila kopičijo največje količine kovin in jih lahko smatramo kot tarčni organ. Koža nepigmentirane vrste in pigmentirane podvrste ohranja mnoge larvalne značilnosti. V naših raziskavah je povdarek na analizi mehanoreceptornega in elektroreceptornega oktavolateralnega sistema ter fotoreceptornih čutilnih organih. Posebna adaptivna vrednost notranjega ušesa se kaže v zelo zapleteni orientaciji čutilnih celic enega od senzoričnih epitelov. Elektroreceptorni ampularni organi so odkriti in raziskovani na koži glave. Oči temne podvrste močerila so mnogo bolj diferenciranane v primerjavi z nepigmentiranimi osebki. Prehrana močerila se sezonsko spreminja. Prevladujejo jamski rakci in polži, poleti pa je hrana dopolnjena še z žuželkami. Na osnovi naših opažanj lahko ugotavljamo, da močeril lahko preživi brez hranjenja več kot deset let.

Abstract UDK 597.9 (497.12)

Bulog Boris: Two decades of functional-morphological studies of *Proteus anguinus* (Amphibia, Caudata)

Our endemic cave salamander, *Proteus anguinus*, preserves numerous neotenic characteristics throughout its life and also reveals some general troglomorphic peculiarities. The physiological and functional morphological investigations of this endemite have been going on for at least twenty years at the Department of Biology, BF, University of Ljubljana. *Proteus* is evidently resistant to low levels of oxygen in water (1,4 - 0,3 mg/l). The lowest oxygen value in the water of its habitat, 1.04 mg O_2/l, was also confirmed. Metal levels were measured in the rivers Pivka and Rak, both running through the Planina Cave, and their sediments. Introductory analyses indicate that the liver of *Proteus* accumulates the largest quantities of metals and may be considered as the target organ. The skin of pigmentless species and pigmented subspecies maintains many larval characteristics. In our studies we emphasize the mechanoreceptive and electroreceptive octavolateral system, and the photoreceptive sensory organs. The special adaptive value of the inner ear is suggested by the very complex orientation of the hair cells in one of the sensory epithelia. The electroreceptor ampullary organs have been found and analyzed in the skin covering the head. The eyes of the dark subspecies are much more differentiated as compared to those of the pigmentless specimens. The nutrition of *Proteus* varies with the season. The main organisms eaten were crustaceans and snails. In the summer the diet was supplemented by insects. Based on our observations, *Proteus* is able to survive for over ten years without feeding.

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UVOD

Močeril ali človeška ribica, je edini jamski vretenčar v Evropi in hkrati najpomembnejša biološka znamenitost podzemeljskih voda Dinarskega Krasa. Za predstavnike družine Proteidae, v katero sodi tudi naš endemit je značilno, da nimajo maksile, periotični kanal notranjega ušesa pa poteka horizontalno. Ta neotenična dvoživka ohranja celo življenje nekatere larvalne znake v odraslem stanju. Mednje sodijo predvsem zunanje škrge, škržne reže, koža z mnogimi larvalnimi značilnostmi in visceralni skeletni elementi. *Neotenija* je fenomen, pri katerem osebki dosežejo reproduktivno zrelost in ohranjajo zunanje larvalne znake. Po vsej verjetnosti pride do upočasnjenega somatskega razvoja pri relativno normalni hitrosti dozorevanja spolnih organov. Pri obligatnih neotenih (*Proteus, Necturus* in *Amphiuma*) je očitno razlog za ireverzibilno neotenijo v neobčutljivosti tkiv na tieoidne hormone. Eksperimenti z fakultativnimi neoteni (npr.: *Ambystoma*) kažejo, da tieoidni hormoni (T_3 in T_4) inducirajo metamorfozo (Duellman in Trueb 1986). Neotenija se pri repatih dvoživkah pojavlja v relativno stabilnem vodnem okolju z zadostnimi viri hrane, brez predatorjev. Takšno vodno okolje pa je običajno obdano s habitati v katerih so relativno neugodni pogoji (npr.: prisotnost predatorjev, pomanjkanje hrane, neugodne klimatske razmere ...).

Močeril kaže tudi nekatere splošne *troglomorfne karakteristike*: specializacije čutilnih organov, podaljšanje nekaterih telesnih delov, predvsem nesorazmerna rast glave v dolžino (Istenič in Bulog 1976), kar je značilno tudi za ameriške urodele z močno izraženim jamskim načinom življenja (Clerque-Gazeau 1974). Med te karakteristike vsekakor lahko prištevamo tudi reducirane oči, depigmentacijo kože, upočasnjen metabolizem, odpornost proti stradanju, morda tudi reducirano intraspeciesno agresijo (Christansen 1992).

Na Oddelku za biologijo Biotehniške fakultete v Ljubljani potekajo raziskave na močerilu že okoli 25 let. Sprva se je del raziskav usmeril v *proučevanje adaptacij močerila na njegovo podzemsko vodno okolje* (Istenič 1971, 1979, 1986, Sojar 1980). S tem namenom smo proučevali hidrokemijske pogoje v naravnem okolju močerila v povezavi z raziskavami porabe kisika živali v različnih pogojih okolja. *Vprašanje čutilne sposobnosti slepe jamske dvoživke* je usmerilo del raziskav v proučevanje čutilnih organov pri močerilu in na analizo kože s kožnimi čutilnimi organi (Istenič in Bulog 1976, 1979, 1984, Bulog 1987, 1988, 1989a, 1989b, 1990, 1993 1994, Kos in Bulog 1993, Bulog in Bizjak-Mali 1994). Stekle pa so tudi *raziskave na prebavnem traktu in metabolizmu pri proteju* (Mali 1992). V zadnjem času pa se raziskave širijo tudi na področje *proučevanja nalaganja težkih kovin v tkivih* *proteja*, in na *uvajanje tkivnih in celičnih kultur* pri tej živali (Cijan 1994, Cijan in Bulog v pripravi).

RAZISKAVE ADAPTACIJ MOČERILA NA PODZEMSKI VODNI HABITAT

V letu 1969 je bil odkrit v Putickovem jezeru Planinske jame 80 % deficit kisika (tudi do 1 mg/l vode) v vseh nivojih jezera od dna do površine in sicer v periodah izredno nizkega vodostaja v Planinski jami (Istenič 1971, 1979) Te meritve so bile petkrat potrjene in zadnje meritve hipoksičnih pogojev v letu 1985 so bile dopoljnene z analizo atmosfere nad jezerom (11% O_2 in 0,1% CO_2). Razlago za redno pojavljanje nizke koncentracije kisika na tej lokaliteti je avtorica iskala v visoki stopnji mineralizacijskih procesov v vodi s tega področja (Istenič 1986) V jezeru se namreč kopičijo sedimenti v terminalni fazi mineralizacije. Z oksidacijo anorganskih soli naj bi se povečevala poraba kisika. Jamska ilovica naj bi specifično delovala kot ionski izmenjevalec. Na tej lokaciji smo večkrat opazili tudi močerile.

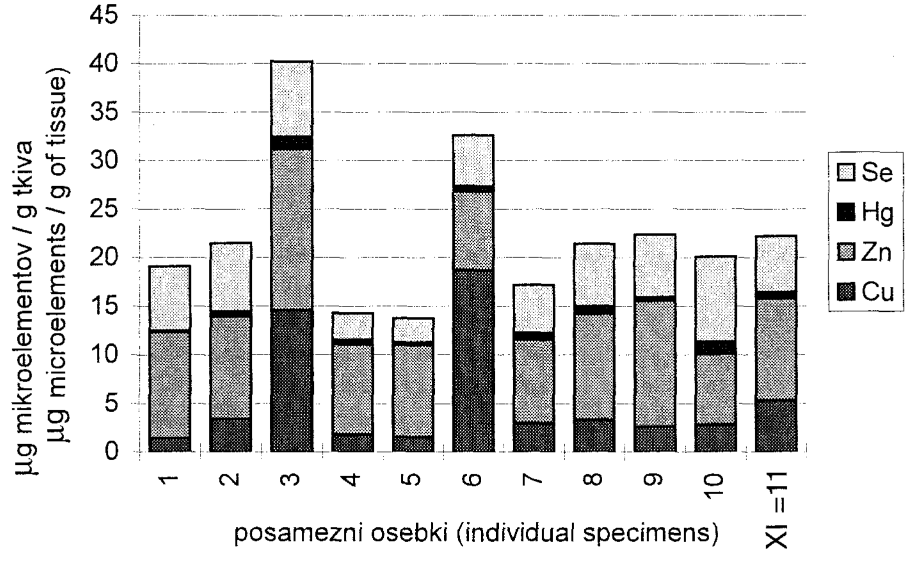
V povezavi s temi ugotovitvami pa je bila proučevana predvsem odvisnost človeške ribice od vsebnosti kisika v vodi. Žival diha s škrgami in tudi s kožo, če pa je vsebnost kisika v vodi nizka se poveča sicer razmeroma majhna dihalna vloga pljuč. V normalno oksigenirani vodi, pri 10° C prispevajo pljuča manj kot 5 % celotne preskrbe s kisikom. Ugotovljeno je bilo, da v primeru pomanjkanja kisika v vodi živali hodijo na površino po zrak. Kritična točka za močerila, pri temperaturi vode 10° C, je pri koncentraciji 2,9 mg kisika / liter vode (to je koncentracija kisika, pri kateri se najhitreje spremeni frekvenca inspiracij). Pri tem se močno zviša frekvenca respiracijskih gibov. Poskusi so pokazali, da pri več kot 64 odstotni nasičenosti vode s kisikom močerili ne uporabljajo pljuč kot akcesorno dihalo (Sojar 1980).

Po vsej verjetnosti pa v primeru zadrževanja močerila v kopenskem delu njegovega naravnega okolja v veliki meri uporablja kožo za izmenjavo dihalnih plinov v zraku. Očitno je močeril proti pomanjkanju kisika v vodi zelo odporen in preživi tudi v vodi, ki vsebuje komaj 1 mg O_2/l vode. Običajna vsebnost kisika v jamski vodi je 8 - 11 mg O_2/l. Glede na to, da je najdeno področje v njegovem naravnem okolju, kjer se koncentracija kisika v vodi zniža na vrednost blizu 1 mg O_2 / 1 vode in upoštevajoč laboratorijske poizkuse lahko predvidevamo, da je močeril dobro prilagojen na znižanje koncentracije O_2 v vodi (Sojar 1980).

V okviru teh raziskav poteka tudi proučevanje *kopičenja mikroelementov v naravnem okolju in tkivih močerila* (Dermelj et al. 1984, Cijan 1994). Vsebnost mikroelementov je bila merjena v podzemskih tokovih rek Pivka in Rak. in v rečnih sedimentih. Analizirana je bila vsebnost Fe, As, Cu, Sb, Zn, Hg, v rečnih usedlinah pa še Mn, Cd, Co,. Pri tem smo uporabili različne analitične metode (atomska absorpcijska spektrometrija hladnih par, nevtronska aktivacijska analiza , X-žarkovna fluorescenca). Rezultati analiz vsebosti kovin v vodah iz Planinske jame kažejo, da so njihovi koncentracijski nivoji znatno pod maksimalnimi dovoljenimi koncentracijami (MDK - Pristov 1992). Izmerjene vrednosti v Pivki in Raku so dokaj izenačene, kljub temu, da ju napaja voda iz različnega hidrografskega zaledja. Najnovejše primerjalne analize so pokazale , da bistvenih razlik v vsebnosti kovin med letom 1978 in 1993 ni (Cijan 1994, Cijan in Bulog v pripravi). Edina opazna razlika je v trendu upadanja koncentracij antimona, bakra in cinka. Upoštevajoč to, da gre le za enkratne meritve, lahko le domnevamo, da vode v Planinski jami niso obremenjene s kovinami. Poudariti moramo, da gre le za opis trenutnega stanja obremenjenosti voda s kovinami. Rečne usedline kopičijo precejšnje količine mikroelementov zaradi adsorbcije, hidrolize,... in se z desorbcijo ponovno sproščajo v vodo. Primerjava koncentracij kovin v jamskih rečnih usedlinah z naravnimi vrednostmi le teh (po Turekian in Wedepohl 1961) kaže, da se analizirane kovine kopičijo v rečnih usedlinah. Kopičenje kovin v rečnih usedlinah iz Planinske jame je sicer precejšnje, vendar pa vsebnosti kovin niso tako visoke, da bi lahko govorili o močnem onesnaženju. Za realno sliko vsebnosti kovin v vodi in usedlinah bo potrebno redno odvzemanje vzorcev skozi daljši čas.

V dosedanjih študijah je določena tudi vsebnost bakra, cinka, arzena, selena, antimona, kobalta, kadmija in živega srebra v ledvicah, jetrih, koži in mišicah močerila. Vsebnost teh mikroelementov je bila merjena z nevtronsko aktivacijsko analizo. Preliminarni rezultati kažejo, da jetra kopičijo največjo količino mikroelementov (Histogram 1). Privzem kovin v telo močerila bi lahko potekal na več načinov: 1/ z zaužitjem plena, usedline ali vode, 2/ z absorbcijo direktno iz vodnega okolja (koža, škrge), 3/ z absorbcijo iz zraka (pljuča). Privzem živega srebra pri dvoživkah naj bi potekal s konzumacijo hrane, preko kože in z zračno absorbcijo (Byrne et al. 1975). Upoštevajoč način prehranjevanja močerila, ki "rije"

Histogram 1. Mikroelementi v jetrih proteja. (Microelements in the liver of *Proteus*)



s sprednjim delom glave po dnu, ko išče svoj plen, bi bila velika verjetnost, da močeril sprejema precejšen del mikroelementov nakopičenih v rečnih sedimentih. V nadaljnjih raziskavah nameravamo vključiti redno kontrolo kopičenja kovin v tkivih in naravnem okolju močerila, proučevanje možnih poti privzema v telo močerila, transporta, porazdelitve, biotransformacij in izločanja mikroelementov.

RAZISKAVE KOŽE

Koža oz. integument ima pri močerilu ohranjene mnoge larvalne značilnosti. Med temi moramo vsekakor omeniti Leydigove žlezne celice in mikrovilarno zgradbo vrhnje plasti epidermisa, ki ima mukozno naravo . Dobro so diferencirani čutilni organi oktavolateralnega sistema (mehanoreceptorni nevromasti in elektroreceptorni ampularni organi)(Istenič in Bulog 1984, Bulog 1988, Bulog in Bizjak.- Mali v pripravi). V koži ni pterinov, to je barvil, ki so značilna za ostale dvoživke, prisotne pa so relativno *visoke koncentracije riboflavina* (330 - 340 µg/g suhe teže), ki naj bi bil osnova za rumenkasto osnovno obarvanost kože (Istenič in Ziegler 1974). Zadnje raziskave integumenta vključujejo kožo nepigmentiranega močerila in kožo temno pigmentiranih primerkov (Kos 1992, Kos in Bulog 1993), ki so bili najdeni v Beli krajini pri izviru Dobličice (1986) in nekoliko kasneje pri bližnjem Ješevniku in opisani kot podvrsta *Proteus anguinus parkelj* (Sket 1993, Sket in Arntzen 1994). Obe obliki močerila imata v koži zvezdaste pigmentne celice nameščene v zgornjem delu usnjice. Prve ultrastrukturne raziskave nakazujejo večjo gostoto odstavkov teh pigmentnih celic v usnjici kože pri pigmentiranem osebku, medtem ko je teh odstavkov manj v koži svetlih osebkov. Domnevamo lahko, da nastopa manjše število pigmentnih celic v koži pri svetlem osebku. Pri nepigmentiranih živalih postane koža, ki je dalj časa izpostavljena naravni ali umetni svetlobi temneje pigmentirana, kar dokazuje da sinteza melanina oz. njemu podobnega pigmenta v pigmentnih celicah ni povsem zavrta. Preliminarne ultrastrukturne analize kože obeh oblik močerila nakazujejo nekoliko več značilnosti kože metamorfoziranih reparih dvoživk pri temnih osebkih (Kos in Bulog 1993).

Koža na dorzalni strani glave, anteriorno od oči je pri temno pigmentirani podvrsti slabše pigmentirana. V tem predelu je v strehi medmožgan (diencephalon) razvito pinealno telo. Kaže, da bi pri močerilu ta ekstraoptični fotoreceptorni organ lahko imel pomembno vlogo v življenju teh živali.

Kompleks pinealnega organa in pinealnega telesa (pri žabah) in pinelno telo (pri repatih dvoživkah) naj bi bili pomembni v adaptaciji pigmentiranosti, sinhronizaciji cirkadiane lokomotorne ritmike in v orientaciji po soncu (Duellman in Trueb 1986). Fotoreceptorne celice v pinealnem telesu so inhibirane s svetlobo in stimulirane v odsotnosti svetlobe. Stimulacija receptorjev povzroči sproščanje hormona melatonina, ki deluje na dermalne melanofore. Povzroči agregacijo melanosomov v melanoforah in na ta način bledenje kože v temnem okolju.

RAZISKAVE ČUTILNIH ORGANOV

Vprašanje čutilne sposobnosti močerila je usmerilo del naših raziskav v *študijo čutilnih organov, pri katerih je bilo pričakovati ustrezne dražljaje v njegovem življenjskem okolju* (Istenič in Bulog 1976, 1979, 1984, Bulog 1986, 1987, 1988, 1989a, 1989b, 1990, 1993, 1994). Pozornost tujih raziskovalcev (predvsem francoskih) je bila usmerjena sprva v proučevanje pokrnelih oči, poznavanje drugih čutilnih organov pa je bilo v veliki meri zanemarjeno. Ostalo je namreč na nivoju klasičnih morfoloških raziskav iz prejšnjega stoletja.

OKTAVOLATERALNI SISTEM

V ta okvir sodi oktavolateralni sistem, ki vključuje tako bočno linijo z nevromasti in ampularnimi organi kot tudi notranje uho. Pomembno vlogo pa igrajo tudi kemoreceptorni okušalni brstiči in vohalni organ. Naša obnovljena anatomska analiza notranjega ušesa predstavlja osnovo za nadaljnje ultrastrukturno proučevanje otičnega labirinta, ki že nekaj let poteka v sklopu raziskovalnih projektov v okviru Skupine za primerjalno anatomijo in embriologijo vretenčarjev (Istenič in Bulog 1976). Svetlobnomikroskopske analize krovnih struktur v otičnem labirintu pri močerilu so prvič opozorile na prisotnost dveh kristalizacijskih oblik kalcijevega karbonata (kristali aragonita v sakulu in kristali kalcita v utrikulu) v notranjem ušesu dvoživk. Na podlagi rezultatov svetlobnomikroskopske analize lahko primerjamo morfološke značilnosti notranjega ušesa močerila z ustreznimi karakteristikami pri drugih repatih dvoživkah. Na osnovi enajstih karakteristik otičnega in periotičnega labirinta je bil ugotovljen trend k redukciji posameznih struktur zaradi pedomorfoze (neotenije) kot primitivne karakteristike, na drugi strani pa večja izdelanost senzoričnega sistema kot izpeljana karakteristika. V okviru neoteničnih skupin se značilnosti protejevega ušesa v največji meri ujemajo z značilnostmi pri pisanem nekturu (*Necturus maculosus*). Svetlobnomikroskopska analiza otičnega labirinta sicer podpira sistematsko uvrstitev proteja in njegovega površinskega ameriškega sorodnika nektura v skupno družino Proteidae, ne more pa prispevati k poznavanju prilagojenosti notranjega ušesa v povezavi s troglobiontskim načinom življenja. Specifičnosti v diferenciranosti posameznih čutilnih epitelov v notranjem ušesu močerila, ki naseljuje podzemski vodni habitat, v primerjavi z diferenciranostjo pri površinskih predstavnikih, lahko pokažejo kakšna je adaptiranost takega senzoričnega sistema na posebnosti podzemskega vodnega okolja. Nadaljnje raziskave smo zato poglabljali na ultrastrukturni nivo. Elektronskomikroskopska analiza je tako omogočila tudi funkcionalno-morfološki pristop v proučevanju morfogeneze otokonialnih kristalnih mas z ultrastrukturno analizo predstopenj v procesu nastajanja oz. obnavljanja otokonijev in morfogenezo tvorbe in degeneracije čutilnih celic senzoričnih epitelov v notranjem ušesu (Bulog 1989a, 1989b, 1993, 1994). Na osnovi SEM (vrstična elektronska mikroskopija) in TEM (presevna elektronska mikroskopija) analize posameznih čutilnih epitelov so bili proučevani posamezni morfogenetski stadiji v procesu nastajanja novih čutilnih celic. Procese morfogeneze smo spremljali z elektronskomikroskopsko analizo čutilnega epitela sakularne makule v notranjem ušesu pri mlajših subadultnih stadijih in pri adultnih osebkih. Dokazana je bila *permanentna tvorba novih čutilnih celic tekom življenja živali,* posebno na periferiji omenjenega čutilnega epitela (Bulog 1989b) V čutilnih epitelih notranjega ušesa pri močerilu je bilo ugotovljenih *vsaj pet različnih tipov čutilnih celic,* ki se ločijo po apikalnem ciliarnem delu. Na osnovi pestre morfologije ciliarnih delov čutilnih celic bi lahko predpostavili, da so nekateri čutilni epiteli v notranjem ušesu pri močerilu tonotopično organizirani in na ta način sposobni frekvenčne diskriminacije na periferiji. Tonotopična organiziranost pomeni sposobnost sekundarnih čutilnih celic v notranjem ušesu, da delujejo kot mehanski filtri z različno "uglašenostjo" na osnovi različne dolžine in togosti ciliarnih delov čutnic (Bulog 1989b, 1990). Na osnovi mnogo bolj zapletene funkcionalno-morfološke orientiranosti čutilnih celic v sakularni makuli močerila v primerjavi z drugimi urodeli lahko predpostavimo vlogo tega čutilnega epitela v zaznavanju smeri vira zvočnega valovanja. Pri tem moramo upoštevati tesno funkcionalno-morfološko povezavo sakularne makule z obsežno otokonialno maso v sakulu notranjega ušesa pri močerilu. Ta značilnost nakazuje specifično adaptiranost notranjega ušesa jamske dvoživke(Bulog 1989b, Bulog 1990).

Elektronskomikroskopske raziskave so omogočile ultrastrukturno analizo otokonialnih membran in natančno kristalografsko analizo otokonialnih mas nad posameznimi makulami in potrdile domnevo o prisotnosti dveh različnih kristalizacijskih oblik kalcijevega karbonata (Bulog 1989a, Bulog in Rode 1989). Relativno mala masa nad utrikularno makulo ima diferencirane *velike kalcitne kristale,* podobne kristalom v notranjem ušesu višjih vretenčarjev. Po drugi strani pa sta ogromna otokonialna masa sakularne makule in manjša otokonialna masa lagenarne makule grajeni iz *mnogo manjših aragonitnih kristalov* značilnih za nižje vretenčarje. V sakulusu in lageni notranjega ušesa smo uspeli analizirati organske globularne predstopnje za aragonitne kristale. Najmanjše kroglaste predstopnje so znotraj celic posameznega senzoričnega epitela. Te globularne predstopnje z gladko površino prodirajo skozi apikalne dele opornih celic celic čutilnega epitela in se na prehodu skozi mukopolisaharidno in glikoproteinsko otokonialno membrano pretvarjajo v večje kroglaste predstopnje s spužvasto površino. Te predstopnje imajo verjetno tudi več kalcija in se ob prodiranju skozi apikalno površino otokonialne membrane pretvarjajo v končno formirane kristale aragonita na spodnji strani otokonialne mase (Bulog 1989a, 1994). Te analize so pokazale, da je ohranjena potenca tvorbe novih aragonitnih kristalov tekom življenja živali. Zadnje ultrastrukturne analize čutilnih epitelov krist v polkrožnih kanalih notranjega ušesa pri močerilu so pokazale prisotnost nekaterih čutilnih celic v različnih fazah degeneracije, kar je podkrepila tudi prisotnost specifičnih organelov podobnih lizosomom v teh čutilnih celicah in jasno opazno sproščanje celičnega materiala (apoptoza) skozi apikalno površino celic (Bulog 1993, 1994).

Slušne sposobnosti urodelov so ostale relativno slabo raziskane. Za razliko od anurov urodeli nimajo votline srednjega ušesa in ne timpanalne membrane. Kljub temu, da pri urodelih ni razvito tipično uho za izenačevanje impendance, so eksperimentalne raziskave pokazale, da je njihovo notranje uho občutljivo na zvok večjih intezitet, ki se širi po zraku, in vibracije s podlage (Hetherington in Lombard 1982). Pod vodo pa se razmere spremenijo. Raziskave pri nekaterih drugih dvoživkah so pokazale, da votlina srednjega ušesa, ustna votlina in verjetno tudi pljuča lahko pod vodo služijo kot pretvorniki zvočnega tlaka (Hetherington in Lombard 1983). Pri analizi histoloških rezin v predelu notranjega ušesa smo pri močerilu ugotovili tesno anatomsko povezavo med stropom ustne votline in ovalnim oknom. Preko te povezave bi se lahko zvočno valovanje iz vodnega okolja močerila prenašalo skozi obsežno ustno votlino do notranjega ušesa.

Predpostavimo lahko, da je notranje uho pri močerilu pomemben mehanoreceptorni čutilni organ, ki živali omogoča orientacijo v specifičnem podzemnem vodnem habitatu. Upoštevajoč fiziološko dokumentacijo o možnostih registracije zvočnega pritiska pri urodelih lahko predvidevamo, da močeril zaznava določeno zvočno valovanje, v območju nižjih frekvenc. Morda notranje uho lahko služi tudi za medsebojno zvočno komunikacijo med sovrstniki upoštevajoč tudi sicer nepreverjene podatke nekaterih starejših avtorjev, da se močeril lahko oglaša s šibkimi cvilečimi zvoki.

Sistem bočne linije spada v oktavolateralni sistem in zajema *mehanoreceptorne nevromaste in elektroreceptorne ampularne organe.* Svetlobnomikroskopske raziskave so omogočile histološko analizo nevromastov v vrhnjici kože na glavi in na bočnem delu vrhnjice kože na trupu. Na glavi pa smo odkrili nov tip čutilnih organov, ki so jih klasični morfologi pri močerilu opredelili kot razvijajoče se nevromaste (Istenič in Bulog 1984). S poglobljeno ultrastrukturno analizo teh kijasto oblikovanih čutilnih elementov smo podprli domnevo, da gre za elektroreceptorne ampularne organe. S serijskimi prečnimi ultrastrukturnimi rezinami smo uspeli izdelati tridimenzionalno rekonstrukcijo tega na novo odkritega čutilnega sistema, ki smo ga podrobno analizirali (Istenič in Bulog 1984). Ugotovili smo tri velikostne razrede mehanoreceptornih nevromastov pri močerilu, kar si razlagamo *s tvorbo sekundarnih nevromastov znotraj obstoječih garnitur čutilnih elementov* (Bulog in Bizjak-Mali v pripravi).

Sklepajoč po dosedanjih fizioloških raziskavah mehanoreceptornih nevromastov pri ribah so ti čutilni elementi občutljivi na bližnje oscilacije in lokalne premike v vodi, oddaljenih virov zvočnega valovanja pa ne zaznavajo (Schuijf in Buwalda 1980, Sand 1981). Upoštevajoč te ugotovitve, lahko zaključimo, da se oba mehanoreceptorna sistema (notranje uho in nevromasti bočne linije) uspešno dopolnjujeta v zaznavnju različnih kvalitet zvočnega valovanja.

Ampularni organi zaznavajo šibka električna polja animaličnega in neanimaličnega izvora v okolju in posredujejo živali informacije za komunikacijo in orientacijo, istočasno pa verjetno omogočajo močerilu, da zazna svoj plen. Ampularne organe so našli skoraj izključno pri vodnih vretenčarjih s šibkim vidom in sama elektroreceptivnost se praviloma povezuje z življenjem v pogojih slabe vidljivosti (Zakon 1988). Upoštevajoč redukcijo oči v odraslem stanju in specifični podzemski vodni habitat, močeril lahko s pridom uporablja svoje elektroreceptorne čutilne elemente.

V potrditev teh naših domnev so na osnovi etoloških in fizioloških raziskav nekaj let kasneje nemški raziskovalci eksperimentalno dokazali, da močeril zaznava direktna tokovna polja in njihovo polarnost. Reagira na tokovno gostoto 0,03 mA/cm (Roth in Schlegel 1988, 1994). Z elektrofiziološkimi odvajanji od aferentnih živčnih končičev so ugotovili, da ampiularni elektroreceptorji pri močerilu odgovarjajo s porastom hitrosti razelektritev pod vplivom katodnih tokov in znižanju le te pod vplivom anodnih tokov (prag: do 0,1mV/cm)

OKUŠALNI BRSTIČI

Analizirali smo tudi strukturne diferenciacije ustno žrelne sluznice pri močerilu s pomočjo svetlobne in elektronske mikroskopije ter ugotovitve vključili v funkcionalno-morfološko obravnavo (Istenič in Bulog 1979). Na serijskih rezinah glave smo s pomočjo svetlobne mikroskopije ugotavljali razsežnost ustno-žrelne sluznice, njeno zgradbo in histokemijo. Analizirali smo *okušalne brstiče,* ki nimajo pore in segajo z receptornimi deli na površino ustno-žrelne sluznice. Osnovna zgradba brstičev v ustni in žrelni sluznici pri močerilu kaže ustrezno zgradbo okušalnim brstičem , ki so bili opisani pri nekturu (Farbman in Yonkers 1971). Glede na določene ultrastrukturne karakteristike so bile ugotovljene določene razlike med posameznimi brstiči v ustni sluznici v primerjavi s tistimi ob vhodih v škržne reže. Specifični brstiči ob vhodu v škržne reže morda služijo lahko preizkušanju kemizma vode in s tem v deoksigenirani vodi posredujejo ustrezno senzorično informacijo, ki sproži zračno dihanje. Močeril plena ne melje ali razkosava ampak požira celega. Plen se zadržuje v ustni votlini in prihaja v tesen kontakt z okušalnimi brstiči.

OKO

Odkritje črne podvrste močerila (Istenič in Bulog 1986, Istenič 1987, Sket 1993, Sket in Arntzen 1994) je omogočilo tudi prve morfološke analize oči, ki so že na prvi pogled bolj diferencirane kot pri odraslih osebkih nepigmentirane vrste (Bulog 1992). Metrična analiza serijskih semitenkih rezin je omogočila določitev maksimalnega premera očesnega zrkla (1300 μm) pri črnem osebku (subadultna samica s telesno dolžino 187 mm). Premer bolj ali manj okrogle leče znaša okoli 200 μm. Opravili smo tudi preliminarno analizo posameznih delov mrežnice in pozornost usmerili predvsem na fotoreceptorne čutilne celice in na sinaptične povezave med posameznimi sloji mrežnice.

Francoski raziskovalec Durand (1971) je v svoji obsežni raziskavi proučeval zgodnji razvoj močerila in morfogenezo ter končno degeneracijo očesa. V subadultni fazi (osebki dolžine 100-220 mm) imajo "beli" osebki očesno zrklo s premerom 300 - 520 μm. Premer leče pa se zmanjšuje od 105 μm do 0 μm oz. leča popolnoma zgine. Izležena larva ima maksimalno diferencirano oko in v obdobju larvalnega razvoja se oko le nekoliko poveča brez nadaljnje diferenciacije. V nadaljnjem regresivnem razvoju očesa postane supraoptični epidermis debelejši. Oko zadrži splošen embrionalni videz tudi po juvenilni fazi razvoja, štiri mesece po izleženju. V tem času se oko pomika vedno globje v tkiva na glavi. Pomanjkanje pigmentacije in očesna degeneracija se smatrata kot dve bistveni karakteristiki adaptacije živali na podzemske biotope. V bistvu se pigmentacija pri močerilu pojavlja na začetku razvoja v odsotnosti kakršnekoli svetlobne stimulacije kot ugotavljajo francoski raziskovalci (Durand 1976). Mlade ličinke, osvetljevane z lučjo imajo melanofore in rumene kromatofore. Pigmentacija je očitno kontrolirana s fiziološko regulacijo odvisno od prisotnosti svetlobe ali teme v njenem okolju. Očitno ima pomanjkanje pigmenta v koži pri močerilu adaptivni karakter in ne degenerativne značilnosti. Francoski raziskovalci so z eksperimenti osvetljevanja z naravno in umetno svetlobo ugotavljali morebitno regeneracijo oči. Rezultati so pokazali, da pod vplivom večletnega osvetljevanja živali ni prišlo do preprečitve degeneracije vključno z ugrezanjem očesa v orbito, izginjanjem leče in zadebelitvijo dermalne roženice (Durand 1976). Nekateri avtorji degeneracijo očesa pri močerilu razlagajo kot sekundarno adaptacijo na podzemsko okolje, drugi jo nasprotno smatrajo kot neotenični razvojni karakter ali kot zgodnejšo preadaptacijo na jamski način življenja (Hawes 1945). Po eni hipotezi naj bi bila očesna redukcija pri močerilu odvisna od neotenične preadaptacije, sekundarno ojačena z jamskim načinom življenja. Na osnovi ontogenije močerila francoski raziskovalci sklepajo, da redukcija očesa ni odvisna od omenjenih faktorjev, vsi anatomski in eksperimentalni dokazi pa potrjujejo, da so determinirajoči faktorji regresije genetski (Durand 1976). Rudimentarne oči pri močerilu in morda tudi pri drugih jamskih vretenčarjih naj bi bile posledica specifičnega razvoja in so rezultat motnje normalnih ontogenetskih procesov in celičnega metabolizma.

RAZISKAVE PREBAVNEGA TRAKTA IN PREHRANE

Raziskave prehrane pri naši jamski dvoživki so potrdile predatorsko naravo ter dale podatke o vodilnih prehranjevalnih organizmih. Ugotovljeno je bilo sezonsko kolebanje prehrane. Vodilni prehranjevalni organizmi v jesenskem času so raki in polži, poletna prehrana pa je bila dopolnjena z žuželkami. Sezonsko se pojavljajo tudi nematodi, ki so bili najdeni v srednjem delu prebavne cevi. Masovno se pojavljajo v zgodnjem poletnem času, pozno poleti le posamično, kasneje v jeseni jih ni bilo zaslediti. Pojav nematodov v lumnu prebavne cevi povezujemo z značilnimi kalcifikacijami v pankreasu (ciste s kalcificirano steno). Te kalcifikacije imajo morda značaj aktivnih skladišč za kalcij. Problematika homeostaze in skladiščenja kalcija je pri neoteničnih urodelih slabo poznana. Potrebno bo proučiti vlogo sezonskega pojavljanja kalcifikacij v predelu srednjega črevesa močerila ter izkoriščanje naloženih soli v vezivnih cistah za vzdrževanje mineralne homeostaze.

Znano je, da lahko proteji izredno dolgo stradajo (Briegleb 1962). Na splošno pri dvoživkah stradanje ni redek pojav in domneva se, da nekatere larve dvoživk lahko preživijo mesece brez hrane. V tem času naj bi se hranile s pomočjo bakterij, ki se naselijo v mukusu vrhnjice kože. V literaturi se navaja sposobnost preživetja močerila v laboratorijskih pogojih brez hranjenja dve do osem let (Vandel 1965). Pri kontroliranih poskusih stradanja v našem laboratoriju je bila ugotovljena velika sposobnost stradanja tudi do 10 let. V naših raziskavah proučujemo vplive stradanja na morfologijo in histokemijo stene prebavnega trakta (Mali 1992). Študije pa bomo poglobili tudi na ultrastrukturni nivo s citokemijskimi analizami z različnimi metodami za EM analizo glikoproteinov.

Prof.dr. Lili Istenič je kot ena največjih avtoritet v raziskavah močerila postavila temelje za funkcionalno-morfološke raziskave naše endemične jamske dvoživke in pričujoči prispevek je posvečen njenemu dolgoletnemu plodnemu raziskovalnemu delu.

SUMMARY

Proteus anguinus is the single species of the European cave salamander and the most famous troglobiont in the underground waters of the Dinaric Karst. It maintains neotenic characteristics throughout its life, for example, three pairs of outer gills, two pairs of gill slits, an integument with numerous larval characteristics, and typical visceral skeletal elements. *Proteus* also reveals some general troglomorphic characteristics: specialization of the sensory organs, elongation of individual body parts, especially the asymmetric growth of the head length, reduced eyes, skin depigmentation, slow metabolism, starvation resistance, expanded life period, and probably also the reduction of its intraspecific aggression.

The study of our endemic cave salamander has continued for at least 25 years at the Biotechnical Faculty, Department of Biology, University of Ljubljana. Part of the researches were focused to studies of *Proteus* adaptations to its underground aqueous habitat. This research included the terminal part of the Rak Branch of the underground river which ends as Lake Putick in the Planina Cave. There we determined 80% oxygen deficit, with a concentration of 2 mg/l. (Istenič 1979, 1986). The lowest oxygen concentration in the water (1,04 mg O_2/l) was also measured. The usual oxygen concentration in the other parts of Rak Branch is approx. 8-10 mg./ l. The established hypoxic state is obviously a regular event connected to the high degree of mineralization in the underground water flow, which comes to a stand-still in the lake during low water levels (Istenič 1986). We first verified this by experimentally checking *Proteus* resistance in low levels of oxygen in water (1,4 - 0,3 mg/l). Physiological and biochemical studies demonstrated its ability to survive in these waters (Sojar 1980).

Metal levels were measured in the rivers Pivka and Rak, both streaming through the cave, and their sediments. (Dermelj et al. 1984; Cijan 1994). Contents of the microelements Fe, As, Cu, Sb, Zn, Hg, Mn, Cd, Co were measured with neutron activation analysis, cold vapor atomic absorption spectrometry, atomic fluorescence spectrometry and X-ray fluorescence. The comparison of metals' concentrations in the river sediments (Turekian and Wadepohl 1961) demonstrates their accumulation. The concentrations of metals in the water are far under the permitted maxima determined by Pristov (1992). We also established the contents of copper, zinc, arsenic, selenium antimony, cobalt, cadmium, and mercury in the liver, kidneys, integument, and muscles of *Proteus*. These were measured by neutron activation analysis. Preliminary analyses indicate that the liver of *Proteus* accumulates the largest quantities of metals and may be considered a target organ.

The integument of pigmentless and pigmented specimens of *Proteus* maintains numerous larval characteristics. The microvillous surface differentiation of the mucous surface of the epidermis, composed of nonkeratinized cells, well-developed figures of Eberth, and a dermal basement lamella composed of layers of collagen fibrils, are also characteristics of the integument (Kos 1992, Kos and Bulog 1993). The analyzes of pigments in the skins of the pigmentless specimens manifested a total absence of tetrahydrobiopterin and a marked accumulation of riboflavin, up to 330 to 340 μg/g dry weight (Istenič and Ziegler 1974). The mechanoreceptory and electroreceptory octavolateral system are also differentiated in the epidermal portion of the integument (Istenič and Bulog 1984, Bulog 1988, Bulog and

Bizjak-Mali in prep.). Both forms of *Proteus* have stellate pigment cells with pigment granules in the dermis. The processes of melanophores under the basement lamella are more abundant in the pigmented specimen (Kos, Bulog 1993). The influence of the pineal organ on body pigmentation will be investigated in both the dark and pale forms, as well as the darkening of pigmentless specimens under a light stimulus. The pineal has also a significant role in the circadian rhythms of vertebrates.

A portion of our research has been related to studies of those sensory organs that are presumably important to *Proteus* life in its underground habitat: the inner ear, lateral line neuromasts, and ampullary organs (Istenič and Bulog 1976, 1979, 1984, Bulog 1986, 1987, 1988, 1989a, 1989b, 1990, 1993, 1994). We considered eleven characteristics and found the greatest similarity to lie between the gross morphology of the otic labyrinth of *Proteus* and its relative *Necturus*. Comparative ultrastructural analyses among specimens of different sizes confirms that new sensory cells are generated throughout life, mainly along the periphery of the saccular macula (Bulog 1989a). The inner ear of *Proteus* incorporates at least five types of sensory cells that differ in their apical ciliary part. The tonotopical functional organization of the maculas and amphibian papilla is suggested by the rich differentiation of the apical ciliary part of the sensory cells. Ultrastructural analyses of the P_0 cells support the assumption that these are developing sensory cells (Bulog 1989b). Contrary to this, preliminary ultrastructural analyses of the sensory cells in the cristae, lacking apical ciliary parts, infer that they are presumably degenerating sensory cells (Bulog 1993, 1994). There are two types of calcium carbonate crystals in the otoconial masses within the inner ear. The relatively small otoconial mass of the utricular macula occupies an area no greater than the diameter of the sensory epithelium, and is composed of calcite crystals. The enormous otoconial masses of the saccular macula and the lagenar macula are composed of aragonite crystals (Bulog 1989a). The presence of the globular precursors of the aragonite crystals in adult specimens shows that the formation of new crystals is a permanent, continuing process. The special adaptive value of the otic labyrinth is demonstrated by the complex functional-morphological orientation of the hair cells in the saccular macula (Bulog 1989a, 1990). Maybe *Proteus* uses these cells to orient itself in its underground water habitat, even using far-field sound source localization. The capability of sound pressure registration in *Proteus* is supposed to be accomplished by the tight anatomical junction between the ceiling of the oral cavity and the oval window (Bulog 1989b, 1990).

Beside the studies of inner ear sensory epithelia and mechanoreceptive lateral line system (Bulog 1988), we also determined the electroreceptor ampullary organs by electron microscopic analyses in the skin covering the head (Istenič and Bulog 1984).Later, the electroreceptors were experimentally proven by others: conditioning experiments pointed out that *Proteus* discriminates a back-and-forth moving direct-current field as well as its polarity (Roth and Schlegel 1988, 1994). The general morphology and the cytoarchitecture of the taste buds of Proteus is in agreement with the gustatory buds in the tongue of *Necturus* (Farbman and Yonkers 1971). We found differences in *Proteus* of the configuration between the buds in the mouth and those in the pharynx (Istenič and Bulog 1979).

The eyes of matured specimens of *Proteus* are degenerated (Durand 1971): the eyeball undergoes normal development until growth and differentiation come to an end, and degeneration sets in. A few years ago, one dark pigmented specimen of *Proteus* was found near Črnomelj (Slovenia), and its morphological description was published (Istenič and Bulog 1986, Istenič 1987, Sket and Arntzen 1994). The dark examples of *Proteus* diverge from the pigmentless specimens of "normal" animals in their eyes as well as numerous other morphological differences. The eyes of the dark subspecies are much more differentiated in comparison with those of pigmentless specimens, as we ascertained in our preliminary light and transmission electron microscopic studies (Bulog 1991, 1992). The metrical analysis of the serial semi-thin sections established the maximal diameter of the bulb parallel to the surface of the skin: 1300 µm. The lens had a diameter of about 200 µm. The outer segments of the receptor cells were composed of regular series of discs but this regularity was not always present in the outer segment of the sensory cells. In the outer plexiform layer we analysed typical synaptic bodies in the form of dense bars by electron microscopy.

The degeneration of the eye in *Proteus* could be a secondary adaptation to the subterranean environment, or a neotenic developmental character, or an earlier pre-adaptation to a cavernicolous life (ref. by Durand 1976).

The nutrition of *Proteus* alternates with the season. The main organisms eaten were crustaceans and snails. In the summer the diet was supplemented by insects. The seasonal alterations were also proven by the discovery of Nematodes in the middle part of the digestive tract. The seasonal appearance of Nematodes may be related to the characteristic calcifications in the pancreas, possibly a calcium reserve. Based on our observations, *Proteus* is able to survive for over ten years without any food. We wonder how starvation influences the morphology and histochemistry of the digestive tract. Its histological, histochemical, and ultrastructural characteristics will be studied in the fed and the starved animals using animals at different periods of food deprivation.

Prof.Dr. Lili Istenič is one of the greatest authority on *Proteus*: she has placed the fundamentals of the functional-morphological studies of our endemic cave salamander. This article is addressed to her long and successful research work.

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KVALITETA VODE V CERKNIŠKEM JEZERU IN NJEGOVIH PRITOKIH

WATER QUALITY IN CERKNICA LAKE AND ITS TRIBUTARIES

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Izvleček UDK 556.538 (497.12 Cerknica)

Gaberščik, Alenka & Kosi, Gorazd & Krušnik, Ciril & Urbanc-Berčič, Olga & Bricelj, Mihael: Kvaliteta vode v Cerkniškem jezeru in njegovih pritokih

V članku je podana ocena stanja vode v Cerkniškem jezeru in njegovih pritokih v letu 1993. Raziskave vključujejo analize fizikalnih, kemijskih in bioloških parametrov. Na podlagi vrstne analize bentoške združbe uvrščamo večino pritokov v II kakovostni razred. Najbolj onesnažena je Cerkniščica, ki smo jo uvrstili v II-III kakovostni razred.

Ključne besede: Cerkniško jezero, pritoki, kvaliteta vode, perifiton, zoobentos, makrofiti.

Abstract UDC 556.538 (497.12 Cerknica)

Gaberščik, Alenka & Kosi, Gorazd & Krušnik, Ciril & Urbanc-Berčič, Olga & Bricelj, Mihael: Water quality in Cerknica Lake and its tributaries

In this work the estimation of water quality in Cerknica Lake and its tributaries is presented. Investigations include analysis of physical, chemical and biological parameters. On the basis of the bentic community structure the majority of tributaries were ranked into II quality class. The most polluted Cerkniščica was classified into II-III water quality class.

Key words: Cerknica Lake, tributaries, water quality, periphyton, zoobentos, macrophytes.

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UVOD

Cerkniško jezero se po svojih značilnostih precej razlikuje od drugih jezer. Kot presihajoče jezero je edinstven kraški fenomen, ki zahteva poseben način obravnave. Hutchinson (1975), ki Cerkniško jezero omenja v svojem delu, ga po nastanku uvršča med jezera, ki so nastala na topni kamnini (solution lake), zaradi presihanja pa ga uvršča med občasna jezera (temporary lake). Podobno bi lahko Cerkniško jezero opredelili po klasifikaciji, ki jo navaja Wetzel (1975). Po Odumu (1971) lahko ta ekosistem opredelimo kot tip ekosistema, kjer so značilna nihanja vodne gladine (fluctuating water level type). Presihanje jezera ustvarja pogoje, ki neposredno vplivajo na življenje v jezeru. Nihanje vodne gladine omogoča hitrejše kroženje nutrientov. V sušnem obdobju se pospeši aerobna razgradnja nakopičenih organskih snovi, nutrienti, ki se pri tem sproščajo pa ob poplavljenju omogočaju bujno rast jezerske vegetacije. Jezero napajajo številni pritoki. Večina pritokov je kraških in so že pri izviru nekoliko onesnaženi (Hidrometerološki zavod Slovenije 1992). Zaradi presihanja jezera je kakovost vode v njegovih pritokih še pomembnejša kot bi bila, če bi bilo polje stalno poplavljeno. V času, ko Cerkniško polje, ki je poraščeno z bogato močvirsko vegetacijo, preplavlja jezero, rastline sproti porabljajo nutriente in filtrirajo strupene snovi, ki jih pritoki prinašajo v jezero. Sistem, ki deluje kot velika biološka čistilna naprava pa preneha delovati, ko jezero presahne.

Do nedavnega je bilo spreminjanje vodne gladine mogoče predvideti. Cerkniško polje se je za osem mesecev na leto spremenilo v kraško jezero, ki včasih ni presahnilo vse leto. Kadar je bil vodostaj najvišji, se je na področju polja akumuliralo tudi do 80 milijonov m^3 vode (Habič 1976). V zadnjem času pa je zaradi precejšnih meteoroloških sprememb polnjenje in praznjenje jezera nepredvidljivo. Namen našega dela je bil, na podlagi kemijskih in bioloških analiz ovrednotiti kvaliteto voda, ki pritekajo v jezero in spremembe kakovosti vode v jezeru. V letu 1993 smo zabeležili ekstremne razmere, saj se je jezero napolnilo in izsušilo do skrajnih razsežnosti. Ob koncu poletja je od jezera ostal le še skromen potoček v strugi Stržena, jeseni pa se je jezero hitro napolnilo in razlilo, ponekod celo preko običajnih meja.

MATERIALI IN METODE

Vzorce smo pobirali v petih pritokih Cerkniškega jezera (Sl. 1). S pobočja Slivnice priteče manjši potok Martinjščica (1). Vodo z Bloške planote prinašata kraška izvira Žerovniščica (2) in Lipsenjščica (3). Najpomembnejši kraški pritok je Obrh (4), ki prinaša vodo iz Loške doline. Na površino pride na jugovzhodnem delu polja kot Cemun in Obrh. Po površju priteče na Cerkniško polje še Cerkniščica (7). Na severnejšem delu polja, kjer dolomit prehaja v propustnejši apnenec so številni požiralniki. V svoje raziskave smo vključili Veliko Karlovico (8) v Jezerskem zalivu. Voda, ki tam odteka v podzemlje pride na dan v Zelških jamah (9) (Habič 1976). Občasno pa smo vzeli vzorce tudi na Vodonosu (10) pri Dolenjem jezeru, od koder poteka najdaljša podzemna vodna pot do izvirov pri Bistri. Poleg tega pa smo vzorčevali tudi pri Zadnjem kraju (5) in v Stržonu (6). Vzorce vode za kemijske in fizikalne analize smo na večini lokacij pobirali enkrat mesečno (Tabela 1). Izjeme so lokacije Zadnji kraj in Vodonos, kjer je bilo občasno presušeno. Kadar pa je bilo jezero popolnoma poplavljeno, smo vzorce jezerske vode pobirali le na lokaciji 6.

Na mestu vzorčevanja smo izmerili naslednje parametre; temperaturo zraka in vode, pH vrednosti s pH-metrom, prevodnost in raztopljene snovi (TDS) s konduktometrom (Iskra MA 5968, SLO), koncentracijo raztopljenega kisika in nasičenje s kisikom z merilcem kisika (Oxygen Meter WTW OX196). V laboratoriju pa smo po standardnih metodah spektrofotometrično določili anorganski fosfor ($P-PO_4$), celokupni fosfor, nitratni, nitritni, amonijev, aluminijev in železov ion, silicij kot silicijev dioksid, detergente, fenole in formaldehid (Spektrofotometer Iskra Spekol 221 MA 9524). S titriranjem smo določili celokupno, kalcijevo in magnezijevo trdoto, kemijsko porabo kisika (KPK), biološko porabo kisika v petih dneh (BPK_5), klorov in sulfatni ion. S plamenskim fotometrom (C.Z. Flapho 4, Germany) smo določali koncentracijo kalijevga, kalcijevega in natrijevega iona. Vse analize so bile narejene po standardnih metodah (APHA 1985). MPN bakterij fekalnega izvora smo določali z gojitvijo na McConcky gojišču, MPN koliformnih bakterij pa na LAP z gojitvijo na LAP gojišču.

Biološka analiza je obsegala naslednje skupine: zoobentos, perifiton in makrofite. Ker v jezeru v poletnem času ni bilo vode, planktonskih organizmov praktično ni bilo. Nabrane vzorce smo shranili v 4% raztopini formalina in jih kasneje v laboratoriju določili. Pri bentoških organizmih smo določili tudi relativno pogostost posameznih taksonov (1 - posamič, 2 - pogosto, 3 - masovno). Na podlagi bentoških organizmov smo nato izračunali saprobne indekse po Pantle-Bucku, modificirano po Marvanu (Pantle & Buck 1955; Marvan & Rotschein & Zelinka 1980). Saprobiološke analize smo naredili junija, julija in novembra. Te analize niso bile narejene v primeru, ko je bilo mesto vzorčevanja popolnoma presušeno ali pa prekomerno poplavljeno. Podobnost raziskanih lokacij glede na prisotnost bentoških organizmov smo analizirali s klastersko analizo, izračun po Bray-Courtisu (Clarke & Warwick 1990).

FIZIKALNE IN KEMIJSKE MERITVE

Rezultati fizikalnih in kemijskih meritev so podani na slikah 2 in 3 in v tabeli 2. Če primerjamo vrednosti fizikalnih in kemijskih parametrov ugotovimo, da najbolj odstopajo vzorci vode iz Žerovniščice, Cerkniščice in z lokacije pred Karlovico, glede na specifičnost biotopa pa tudi vzorci Raka iz Zelških jam. pH vrednosti nihajo med 7.5 in 8.5, kar je običajno za vode, ki tečejo po karbonatni podlagi. Večje so razlike v temperaturi vode. Voda krajših pritokov (Martinjščice, Žerovniščice, Lipsenjščice in Obrha), ki izvira razmeroma blizu mesta vzorčevanja je poleti precej hladnejša od vode na ostalih lokacijah, kar je razvidno tudi iz povprečnih letnih vrednosti. Manjša pa so tudi temperaturna nihanja. To pa je v poletnem času, ko so pritoki bolj onesnaženi precejšna prednost, saj se z višanjem temperature aktivnost organizmov povečuje, kar pomeni tudi povečano porabo kisika. Vrednosti kemijske porabe kisika nihajo med 2 in 6 mg kisika na liter (več kot 11 mg O_2/l pa smo določili maja v Zelških jamah in avgusta v Cerkniščici). Biološka poraba kisika v petih dneh (BPK_5) je majhna. Če primerjamo vrednosti anorganskega fosforja izstopajo Martinjščica, Žerovniščica in Cerkniščica, ki so posebno v poletnem času precej onesnažene. Najvišje vrednosti pa smo izmerili julija v Cerkniščici (0.48 mg/l). Podoben vzorec je razviden iz koncentracij celokupnega fosforja z maksimumom 1.11 mg/l (Cerkniščica v avgustu) in 1.19 mg/l (Obrh - Gornje jezero v avgustu). Vrednosti nitrata nihajo med 1 in 7 mg/l, precej večjo koncentracijo nitrata pa smo določili v vzorcih Raka v Zelških jamah, kar pa ni nič nenavadnega, saj v podzemeljskih vodah ni pogojev za razvoj primarnih producentov, ki so porabniki anorganskih snovi. Nitritni in amonijev ion se v največjih koncentracijah pojavljata v Cerkniščici in pred Karlovico. Podobno velja tudi za silicij. V Cerkniščici smo določili tudi povečane koncentracije kalijevih, natrijevih in kalcijevih ionov. Ostali parametri, ki so bili analizirani le občasno, ne kažejo velikih nihanj (tabela 2).

BIOLOŠKE ANALIZE

Bentoški organizmi

Seznam bentoških organizmov je predstavljen v tabelah 3 in 4. Primerjava posameznih lokacij glede na prisotnost perifitona in zoobentosa kaže, da je navečja diverziteta organizmov v pritokih Žerovniščica in Lipsenjščica. Ob vzorčevanju v juliju smo na teh dveh lokacijah določili 42 oziroma 48 perifitonskih vrst. Po diverziteti bentoških organizmov sta si podobni tudi Cerkniščica in Martinjščica. Najmanjša pa je pestrost v Zelških jamah, kar je glede na tip biotopa razumljivo. Podobnost posameznih lokacij glede na bentoške organizme je predstavljena na sliki 4. Iz slike je razvidno, da tudi ta analiza nakazuje podobnost nekaterih lokacij. Rezultati so podobni ugotovitvam dobljenih na podlagi kemijskih parametrov.

Saprobni indeksi

Pritoki Cerkniškega jezera (z izjemo Cerkniščice) so kratki, kljub temu pa so vrednosti saprobnih indeksov visoke, saj uvrščajo večino pritokov v II. kakovostni razred (Sl. 5). Ob vseh treh vzorčevanjih je bilo najboljše stanje Lipsenjščice, ki jo lahko uvrstimo v I-II kakovostni razred. Stanje pritokov je posledica človekove aktivnosti v neposrednem zaledju Cerkniškega jezera, delno pa tudi posledica onesnaženosti kraških pritokov že na izviru. V najslabšem stanju je Cerkniščica (II-III kakovostni razred), kar je posledica urbanega okolja (industrija in kmetijske površine). Še nekoliko slabša pa je bila ob nizkem vodostaju kakovost vode na lokaciji pred Karlovico. Kljub kratki podzemni poti vode od Karlovice do Zelških jam pa kažejo biološke analize Raka precej boljše stanje. Razlago za to lahko najdemo v dejstvu, da se voda, ki priteče iz Cerkniškega polja, razredči z vodo, ki priteče z Javornikov. Odvzemno mesto v Zelških jamah tudi sicer težko neposredno primerjamo z ostalimi lokacijami, saj gre v slednjem primeru za jamski biotop.

Makrofiti

V spremenljivem okolju, kakršno je Cerkniško jezero, prevladujejo močvirske in amfibijske rastline. Velik del vodne vegetacije predstavlja emergentna vrsta navadni trst (*Phragmites australis*), ki ima kot kozmopolitska vrsta širok razpon uspevanja. Zaradi velikih nihanj vodne gladine je submerznih makrofitov malo. V času, ko je jezero poplavljeno, se na nekaterih lokacijah množično pojavlja hara (*Chara sp.* - Zadnji kraj, Rešeto). Submerzni makrofiti se nahajajo v glavnem v pritokih Cerkniškega jezera in v strugi Stržena. Našteti submerzni makrofiti (tabela 5) so se pojavljali posamično ali v manjših sestojih. Bolj množično je bil v strugi Stržena pri Dolenjem jezeru zastopan dristavec (*Potamogeton lucens*). V Lipsenjščici in Obrhu so bile v bližini brega večji monosestoji vodne zlatice (*Batrachium trichophyllum*), medtem ko je bil osrednji del struge, kjer je tok močnejši, mozaično poraščen z nizkoraslimi amfibijskimi vrstami (*Ludwigia palustris*, *Myosotis scorpioides* in *Mentha aquatica*). V strugah Martinjščice in Cerkniščice (za čistilno napravo) in pred Karlovico, ni bilo makrofitov.

DISKUSIJA

Cerkniško jezero nima tipičnih lastnosti pravega jezera. Spremenljivi pogoji, predvsem pa nihanja vodne gladine, vplivajo na kvaliteto vode in življenje v jezeru. Raziskave so pokazale, da se pritoki razlikujejo po kvaliteti vode in po stanju biocenoze. Znano je, da število vrst v vodotoku pod vplivom onesnaženja upade. Tako iz pestrosti bentoških vrst na različnih lokacijah lahko sklepamo, kakšna je kakovost vode. Na podlagi bioloških in kemijskih raziskav lahko zaključimo, da je od vseh preiskanih pritokov Cerkniškega jezera Lipsenjščica v najboljšem stanju. Nekoliko slabšo sliko kaže Žerovniščica. Zaskrbljujoči pa so rezultati analiz Martinjščice in Cerkniščice, ki sta vse leto precej onesnaženi. Prav v času presihanja pa je kvaliteta vode v pritokih zelo pomembna. V času, ko je jezero polno, se strupene snovi in nutrienti, ki pritekajo v jezero s pritoki, hitro porabijo in nevtralizirajo v sestojih vodne vegetacije, ki deluje kot naravni filter (Jorgensen 1990, Pieczynska, 1990, Wetzel, 1990). V sušnem obdobju je tudi vodostaj v pritokih nižji in onesnaženost vode je povečana. Navadno takrat tudi jezero presahne. Močvirska vegetacija, ki je prej opravljala funkcijo filtra in je sproti prestregla vse prinešene snovi ostane na suhem in tako izgubi funkcijo filtra. Vode pritokov se zbirajo v strugi Stržena. Samočistilna sposobnost Stržena je zanemarljiva v primerjavi s celotno površino jezera, zato vode onesnažene izginjajo v podzemlje. Do kakšne mere je voda v času nizkega vodostaja onesnažena, je razvidno iz vzorcev vode pred požiralnikom Veliko Karlovico.

Pričujoče raziskave kažejo, da so nihanja v kvaliteti vode preko leta precejšnja. Cerkniško jezero v času vodnatosti deluje kot naravni čistilni sistem, ki pa odpove, ko voda presahne. Onesnaženje se takrat lahko nekontrolirano širi preko podzemnih poti, zato bi bilo potrebno v tem času skrbno nadzorovati dejavnost v zaledju.

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Tabela 1: Mesta vzorčevanja vzorcev za ovrednotenje kvalitete vode.
Table 1: Sampling points.

Št.	Lokacija	Mesto vzorčenja	Čas vzorčevanja (mesec)
1	Martinjščica	za sotočjem obeh krakov	I - XII
2	Žerovniščici	za sotočjem Grahovščice z Žerovniščico	I - XI
3	Lipsenjščica	pod mostom	I - XII
4	Obrh	pod mostom pri Gornjem jezeru	I - XII
5	Zadnji kraj	pod mostom	I II IV V VII IX XII
6	Stržen	pod mostom pri Dolnjem jezeru	I - XII
7	Cerkniščica	za čistilno napravo	II - XII
8	Karovica	pred Karlovico	II III V VI VII
9	Rak	Zelške jame	II IV - IX XI
10	Vodonos	-	IV V IX

Tabela 2: Maksimumi in minimumi nekaterih kemijskih parametrov (določeni v septembru, oktobru in novembru) in MPN (most probable number) bakterij (v LAP in Mc Concky mediju vzorčevano od maja do decembra - v oklepaju je mesec maksimuma, oziroma minimuma). Parametri, razen trdote vode (nemške stopinje - °N) in MPN (največje možno število v 100 ml), so izraženi v mg l^{-1}.

Table 2: Minimum and maximum values of some chemical parameters (in September, October and November) and MPN (most probable number) of bacteria (in LAP and Mc Concky medium) sampled from May to December - the month of sampling is in parenthesis. The parameters, except water hardness (German degree - °N) and MPN (in 100 ml), are in mg l^{-1}.

		1	2	3	4	5	6	7	8	9
Totalna	Min	15.300	12.400	10.800	6.500	-	-	-	-	6.900
trdota	Max	15.800	12.600	12.400	9.400	-	-	-	-	8.200
Ca	Min	8.000	5.300	3.600	3.800	-	-	-	-	3.900
trdota	Max	9.200	10.100	7.100	7.700	-	-	-	-	6.500
Mg	Min	6.100	2.500	5.100	1.700	-	-	-	-	0.400
trdota	Max	7.800	7.300	7.200	2.700	-	-	-	-	4.300
Suspendirane	Min	257.50	291.500	236.000	188.500	212.500	201.000	239.500	-	188.500
snovi	Max	293.50	337.500	263.000	245.000	212.500	228.000	283.500	-	248.000
Alkaliteta	Min	158.60	152.500	311.100	103.700	-	-	-	-	24.400
	Max	475.80	445.300	439.200	164.700	-	-	-	-	262.300
Fe^{2+}	Min	0.000	0.000	0.000	0.000	-	0.000	0.000	-	0.000
	Max	0.000	0.000	0.000	0.000	-	0.000	0.000	-	0.000
Cl^-	Min	7.800	7.100	8.500	7.100	-	-	-	-	1.300
	Max	14.200	15.600	18.400	24.100	-	-	-	-	21.300
Detergenti	Min	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-	-
	Max	0.010	0.010	0.010	0.010	0.010	0.010	0.010	-	-
Fenoli	Min	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-
	Max	0.010	0.000	0.010	0.000	0.000	0.000	0.010	0.000	-
Formaldehid	Avg	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-	0.000
MPN/	Min	190 (5)	336 (5)	76 (6)	29(11)	29 (5)	7(12)	>336 (5)	>336 (5)	58 (5)
LAP	Max	>4384 (9)	> 4384 (8)	4384 (9)	439 (9)	3501(12)	439(9)	9000 (6)	9000 (6)	>438 (7)
MPN/	Min	104(08)	0(11)	0(11)	0(11)	0 (5)	0(12)	760(11)	457 (7)	15(11)
McC	Max	4384 (9)	2712 (9)	492 (9)	190(10)	46(12)	76 (9)	9000 (6)	9000 (6)	190 (9)

Tabela 3: Seznam bentoških alg prisotnih v pritokih Cerkniškega jezera. Vzorci so označeni z dvomestnimi številkami. Prva cifra predstavlja lokacijo, druga pa čas vzorčevanja (junij - 1, julij - 2, november - 3).

Table 3: The list of bentic algae determined in the tributaries of Lake Cerknica. Samples are indicated by numbers. The first sign represents location, the second means the time of sampling (june - 1, july - 2, november - 3).

	11	13	21	22	23	31	32	33	41	42	61	71	72	73	81	82	91	92	93
BACTERIA																			
Sphaerotilus natans	-	1	-	-	3	-	-	-	-	-	-	-	-	3	1	-	-	-	-
Tetracladium sp.	-	1	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CYANOPHYTA																			
Merismopedia punctata	-	-	-	1	-	1	1	-	1	1	1	-	-	-	-	-	-	-	-
Chamaesiphon confervicolus	-	-	-	3	-	-	1	-	1	-	-	-	1	-	-	-	-	-	-
Gloeocapsa montana	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	1	-
Lyngbya kutzingii	-	-	-	-	-	3	-	-	3	3	-	-	-	-	-	-	-	-	-
Lyngbya martensiana	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Lyngbya purpurascens	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lyngbya sp.	-	-	-	3	-	-	3	-	-	3	-	-	-	-	-	-	-	-	-
Nostoc sp.	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Oscillatoria irrigua	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Oscillatoria limosa	3	-	-	-	-	-	-	-	-	-	-	3	-	-	3	-	-	-	-
Oscillatoria sp.	-	1	-	1	-	1	1	-	1	-	1	-	-	-	-	-	-	-	-
Pleurocapsa sp.	-	-	-	-	-	-	-	-	-	1	-	-	-	3	-	-	-	1	-
Phormidium favosum	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
Phormidium incrustatum	-	-	-	1	-	3	-	-	3	-	-	-	-	-	-	-	-	-	-
Phormidium inundatum	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-
Phormidium lividum	1	-	-	-	-	1	-	-	1	-	-	-	3	-	-	-	-	-	-
Phormidium sp.	1	-	-	3	1	3	3	-	3	1	1	-	3	1	-	1	-	-	-
Rivularia haematites	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-
Schizothrix sp.	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-
Tolypotrix distorta	-	-	-	1	-	1	3	-	1	-	3	-	-	-	-	-	-	-	-
Hydrurus foetidus	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Tribonema viride	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-
BACILLARIOPHYTA																			
Achnanthes inflata	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Achnanthes lanceolata	-	1	-	1	1	-	1	1	1	-	-	-	-	-	-	-	-	-	-
Achnanthes sp.	3	1	3	3	3	3	3	3	3	3	3	3	3	3	1	-	-	1	-
Amphora ovalis	-	-	1	1	1	1	1	1	-	-	-	-	-	-	-	-	-	-	-
Amphora ovalis v.pediculus	-	-	1	3	1	1	1	-	-	-	-	-	-	1	-	-	-	-	-
Amphipleura pellucida	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Caloneis silicula	-	-	-	-	-	-	-	1	-	-	1	-	-	-	-	-	-	-	-
Ceratoneis arcus	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cocconeis pediculus	1	-	1	1	-	1	-	1	-	3	-	3	1	1	1	1	-	-	-
Cocconeis placentula	-	-	1	-	3	3	3	3	3	3	-	-	-	-	-	1	-	1	-
Cyclotella meneghiniana	-	-	1	-	1	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Cymatopleura elliptica	-	-	-	1	1	-	1	-	-	-	1	-	-	-	-	-	-	-	-
Cymatopleura solea	1	-	1	1	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-
Cymbella cesatii	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Cymbella lanceolata	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cymbella prostrata	-	-	-	1	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Cymbella sinnuata	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Cymbella ventricosa	3	1	3	3	3	3	3	3	3	3	1	3	3	3	3	-	-	-	-
Denticula tennuis	-	-	1	1	1	1	3	1	1	1	-	-	-	1	-	-	-	-	-
Diatoma vulgare	-	-	3	1	3	1	1	1	1	1	-	1	-	3	1	1	-	-	-
Diploneis elliptica	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Eunotia praerupta	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-

	11	13	21	22	23	31	32	33	41	42	61	71	72	73	81	82	91	92	93
Fragilaria capucina	3	-	-	1	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-
Fragilaria crotonensis	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-
Fragilaria pinnata	-	-	1	3	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Fragilaria vaucheriae	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Frustulia vulgaris	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gomphonema acuminatum	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Gomphonema angustatum	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
Gomphonema constrictum	-	-	-	-	1	-	-	1	-	-	3	-	-	-	-	-	-	-	-
Gomphonema intricatum	-	-	3	1	-	1	-	-	-	1	-	-	-	-	-	-	1	1	-
Gomphonema olivaceum	-	-	-	1	-	-	-	1	-	-	-	-	-	3	-	1	-	-	-
Gomphonema parvulum	3	-	1	1	1	-	1	-	1	-	1	3	3	3	3	3	-	-	-
Gomphonema sp.	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Gyrosigma acuminatum	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Gyrosigma attenuatum	-	-	1	1	1	1	-	1	-	-	-	-	-	-	-	-	-	-	-
Gyrosigma scalproides	1	1	1	1	1	-	1	-	-	-	-	-	-	-	1	-	-	-	-
Melosira arenaria	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1	1	-
Melosira varians	3	-	1	3	3	1	3	3	-	-	-	1	-	-	-	-	-	1	-
Meridion circulare	1	1	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-	1	-
Navicula avenacea	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-
Navicula bacillum	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Navicula cryptocephala	-	1	1	1	3	-	1	1	-	1	-	1	3	-	1	1	-	-	-
Navicula crypt. v.veneta	3	1	3	3	-	-	-	-	-	-	3	-	-	1	-	-	-	-	-
Navicula dicephala	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Navicula halophila	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Navicula gracilis	1	1	3	3	3	-	3	3	1	1	1	-	1	1	-	-	1	-	-
Navicula pupula	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Navicula radiosa	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-
Navicula rhynchocephala	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-
Navicula sp.	3	1	1	1	-	1	3	1	3	-	3	1	1	-	-	-	-	-	-
Neidum iridis	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Nitzschia acicularis	1	-	-	-	-	-	1	-	1	1	1	3	-	-	1	-	-	-	-
Nitzschia angustata	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Nitzschia dissipata	-	1	1	1	-	1	1	-	1	-	-	-	-	1	-	-	-	-	-
Nitzschia fonticola	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-
Nitzschia linearis	1	1	-	1	1	-	3	1	1	1	1	-	-	1	1	-	-	-	-
Nitzschia palea	3	-	-	3	-	1	1	-	3	-	3	3	3	1	5	3	1	-	-
Nitzschia sigmoidea	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-
Nitzschia sp.	-	1	3	3	3	1	3	3	3	1	3	1	1	1	1	1	-	-	-
Pinnularia viridis	-	-	1	-	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Rhoicosphenia curvata	1	-	1	-	-	-	1	1	-	-	-	1	1	1	1	-	-	1	-
Rhopalodia gibba	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Stephanodiscus sp.	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Surirella angusta	-	-	-	-	-	-	-	1	-	-	-	1	-	1	1	-	-	-	-
Surirella ovata	1	1	-	-	1	-	1	-	1	1	-	1	-	1	1	-	-	-	-
Surirella sp.	-	-	-	-	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-
Surirella spiralis	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Synedra ulna	3	1	1	-	3	-	1	3	-	1	1	1	-	1	-	-	-	-	-
Synedra vaucheriae	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
CHLOROPHYTA																			
Ankistrodesmus falcatus	-	-	-	-	-	1	-	-	-	-	1	-	3	-	-	1	-	-	-
Chlamydomonas sp.	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Cladophora fracta	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-
Cladophora sp.	3	-	-	-	-	1	3	3	-	3	-	3	-	3	1	1	-	-	-
Closterium acerosum	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-	-	-
Closterium ehrenbergii	-	-	-	1	1	3	1	-	-	-	-	-	-	-	1	-	-	-	-
Closterium leibleinii	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Closterium moniliferum	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Closterium sp.	-	-	-	1	1	-	1	1	-	-	-	-	-	-	-	-	-	-	-
Closterium striolatum	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Cosmarium sp.	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-
Cosmarium subprotumidum	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Microspora quadrata	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-

	11	13	21	22	23	31	32	33	41	42	61	71	72	73	81	82	91	92	93
Microspora sp.	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Microspora stagnorum	-	-	-	-	-	-	1	3	-	-	-	-	-	-	-	-	-	-	-
Mougeotia sp.	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Oedogonium sp.	-	-	-	-	-	3	-	3	-	-	-	1	1	-	1	-	-	-	-
Pandorina morum	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-
Pediastrum boryanum	-	-	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-	-	-
Pediastrum duplex	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleurococcus sp.	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	1	-	-	-
Scenedesmus ecornis	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Scenedesmus obliquus	-	-	-	-	-	-	-	-	-	-	3	-	3	-	1	3	-	-	-
Scenedesmus quadricauda	-	-	-	-	-	-	-	-	-	1	1	1	3	1	3	3	-	-	-
Scenedesmus sp.	-	-	-	-	-	-	-	-	1	1	-	-	3	-	-	-	-	-	-
Spirogyra sp.	3	-	-	-	-	1	-	-	-	-	5	1	-	-	-	-	-	-	-
Staurastrum punctulatum	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stigeoclonium tenue	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
Ulothrix zonata	-	-	-	-	1	-	-	-	-	-	-	-	-	3	-	-	-	-	-
Audouinella chalybea	-	-	-	1	1	1	-	-	-	-	-	-	-	-	-	-	1	-	-

Tabela 4: Seznam zoobentoških organizmov prisotnih na posameznih lokacijah. Vzorci so označeni z dvomestnimi številkami. Prva cifra predstavlja lokacijo, druga pa čas vzorčevanja (junij - 1, julij - 2, november - 3, oznaka r.v. pomeni različne vrste).
Table 4: The list of zoobentic organisms determined on the different lacations. Samples are indicated by numbers. The first sign represents location, the second means the time of sampling (june - 1, july - 2, november - 3).

	11	13	21	22	23	31	32	33	41	42	61	71	72	73	81	82	91	92	93
TURBELLARIA																			
Dendrocoelum lacteum	1	-	1	3	3	-	-	-	1	-	-	-	-	-	-	-	1	-	-
Polycelis nigra	-	-	-	-	-	-	-	-	3	1	-	-	-	-	-	-	-	-	-
Dugesia(Planaria) sp.	-	3	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Polycelis sp.	-	-	-	1	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-
NEMATODA	-	3	-	-	-	1	-	-	1	-	-	1	-	1	-	-	-	-	-
OLIGOCHETA																			
Eiseniella tetraedra	-	1	-	1	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
Enchytraeidae r.v.	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
Lumbricidae r.v.	1	1	1	-	-	-	1	-	1	1	1	1	-	-	-	-	1	1	-
Lumbriculidae r.v.	-	-	-	-	-	-	-	-	1	1	1	3	-	-	-	3	1	1	-
Stylaria lacustris	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	1
Naididae r.v.	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
Tubificidae r.v.	3	3	3	1	3	-	1	1	-	-	-	-	3	-	5	3	-	-	1
HIRUDINEA																			
Erpobdella sp.	3	-	-	1	1	1	-	-	1	1	-	1	1	-	3	3	-	1	-
Glossiphonia sp.	1	-	-	1	-	1	1	-	1	1	-	1	-	1	-	-	-	-	-
Haemopis sanguisuga	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
Helobdella sp	-	-	-	-	1	-	-	-	-	1	-	-	3	-	-	1	-	-	-
Piscicola geometra	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
GASTROPDA																			
Ancylus fluviatilis	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	1	1	-
Bythinella sp.	-	-	1	-	-	-	-	-	-	1	-	-	-	-	-	-	1	1	1
Lymnaea peregra	1	-	-	-	-	-	-	1	-	-	1	-	1	1	-	-	-	-	-
Planorbis sp. juv.	1	1	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-
Sadleriana fluminensis	-	-	-	1	-	5	5	3	1	-	-	-	-	-	-	-	-	-	-
Viviparus viviparus	-	-	-	-	-	-	-	-	-	3	1	-	-	-	-	-	-	-	-

	11	13	21	22	23	31	32	33	41	42	61	71	72	73	81	82	91	92	93
BIVALVIA																			
Pisidium sp.	1	-	3	1	3	3	1	1	3	1	-	-	-	1	-	-	-	1	-
COPEPODA	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	3	-	-
AMPHIPODA																			
Gammarus fossarum	-	-	5	5	3	3	5	1	1	1	-	-	-	1	-	-	3	3	1
Niphargus sp.	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Synurella ambulans	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	3	-	-
ISOPODA																			
Asellus aquaticus	3	3	-	3	1	1	-	-	3	3	3	5	5	1	5	3	1	-	-
HYDRACARINA	1	1	-	1	1	1	-	3	-	1	1	-	-	1	-	1	-	-	-
EPHEMEROPTERA																			
Baetis sp.	-	1	1	-	1	3	1	1	1	-	-	-	-	1	-	-	3	1	1
Cleon sp.	-	-	-	-	-	1	-	-	-	1	-	-	-	-	-	3	-	1	-
Ecdyonurus sp.	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	3	3	-
Ephemera sp.	-	-	-	1	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-
Ephemerella sp.	-	-	3	3	1	3	5	-	-	1	-	3	1	-	-	-	1	1	-
Habroleptoides sp.	-	-	1	-	1	-	-	-	-	-	-	-	-	1	-	-	1	1	1
Habrophlebia sp.	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1	-	-	-
Heptagenia sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Paraleptophlebia sp.	-	-	-	-	-	1	1	1	-	-	-	-	-	-	-	-	-	-	-
Siphlonurus sp.	-	-	-	-	-	3	3	-	3	3	-	-	-	-	-	-	1	-	-
Torleya sp	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
PLECOPTERA																			
Brachyptera sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Capnia sp.	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Isoperla sp.	-	-	-	-	-	1	-	1	-	-	-	-	-	1	-	-	1	-	-
Leuctra sp.	-	-	1	1	-	3	5	-	-	-	-	1	-	1	-	-	-	-	-
Nemoura sp.	-	1	-	-	1	3	-	3	3	1	-	-	-	-	-	-	-	-	-
Sialis sp.	-	-	-	1	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-
HEMIPTERA																			
Corixidae r.v.	-	-	-	-	-	-	-	-	-	-	3	-	1	-	-	1	-	-	-
TRICHOPTERA																			
Glossosomatidae r.v.	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Goeridae r.v.	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Hydropsyche sp.	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	-
Hydroptilidae r.v.	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-
Lepidostomatidae r.v.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Leptoceridae r.v.	-	-	1	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-
Limnephilidae r.v.	1	3	1	3	-	3	1	3	-	-	-	-	-	1	1	-	-	-	-
Odontocerum albicorne	-	-	1	-	-	3	1	-	1	-	-	-	-	-	-	-	-	-	-
Philopotamidae r.v.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	3	-
Plectrocnemia sp.	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Polycentropodidae r.v.	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Rhyacophila sp.	1	-	1	1	-	1	1	-	-	-	-	3	-	-	-	-	1	1	-
DIPTERA																			
Atherix sp.	-	-	-	1	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Bezzia sp.	3	-	1	-	-	1	-	-	1	1	1	-	-	-	-	1	1	1	-
Chironomidae r.v.	5	3	3	1	3	3	1	3	3	3	3	5	5	3	3	3	1	1	3
Limonidae r.v.	1	-	1	-	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-
Psychodidae r.v.	-	1	-	-	-	-	-	1	-	-	-	-	-	1	-	-	-	-	-
Simulium sp.	3	-	-	-	1	-	1	1	1	1	-	1	1	1	-	-	1	1	1
Tabanidae r.v.	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
Tipulidae r.v.	-	1	-	-	-	1	1	-	-	1	-	1	-	-	-	-	-	-	-

COLEOPTERA																			
Dryops sp.	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-	-	-	-	-
Elmidae r.v.	-	-	3	1	-	3	3	-	-	1	-	-	1	-	-	-	-	-	-
Elmis sp.	-	1	-	-	1	-	-	3	1	-	-	1	-	1	-	-	1	-	-
Dytiscidae	3	-	-	-	1	1	1	1	1	1	3	1	1	-	1	1	-	-	-
Esolus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
Haliplidae	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-
Helophorus sp.	-	1	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Hydraena sp.	1	1	-	-	1	-	-	-	-	1	-	1	1	1	-	-	-	-	-
Hydrophilidae	-	1	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-	-
Riolus sp.	-	-		-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Tabela 5: Makrofiti najdeni na mestih vzorčevanja v pritokih Cerkniškega jezera in v jezeru.
Table 5: Macrophyte species in different locations in tributaries and in Cerknica Lake.

1. Za sotočjem obeh krakov Martinjščice
Phragmites australis
Lytrum salicaria
struga brez makrofitov

2. Za sotočjem Grahovščice in Žerovniščice
Epilobium hirsutum
Polygonum lapatifolium
Filipendula ulmaria
Iris pseudacorus
Sparganium erectum
Phragmites australis
Myriophyllum spicatum

3. Lipsenjščica
Lytrum salicaria
Calhta palustris
Epilobium hirsutum
Phragmites australis
Veronica anagalis
Myosotis scorpioides
Mentha aquatica
Ludwigia palustris
Callitriche sp.
Batrachium trichophyllum
Fontinalis antipyretica
Cladophora sp.

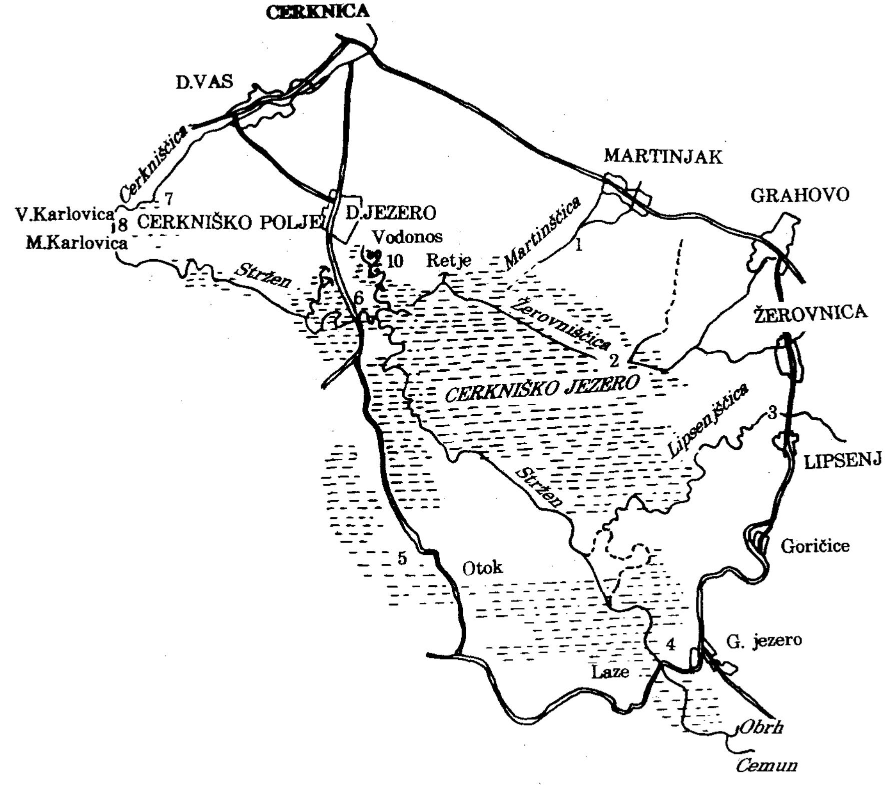
4. Obrh pri Gornjem jezeru
Myosotis scorpioides
Ludwigia palustris
Rorippa amphibia

5. Zadnji kraj
Carex elatae
Gratiola officinalis
Senecio paludosus
Galium palustre
Lysimachia vulgaris
Sium latifolium
Lytrum salicaria
Alisma plantago aquatica
Plantago altissima
Mentha aquatica

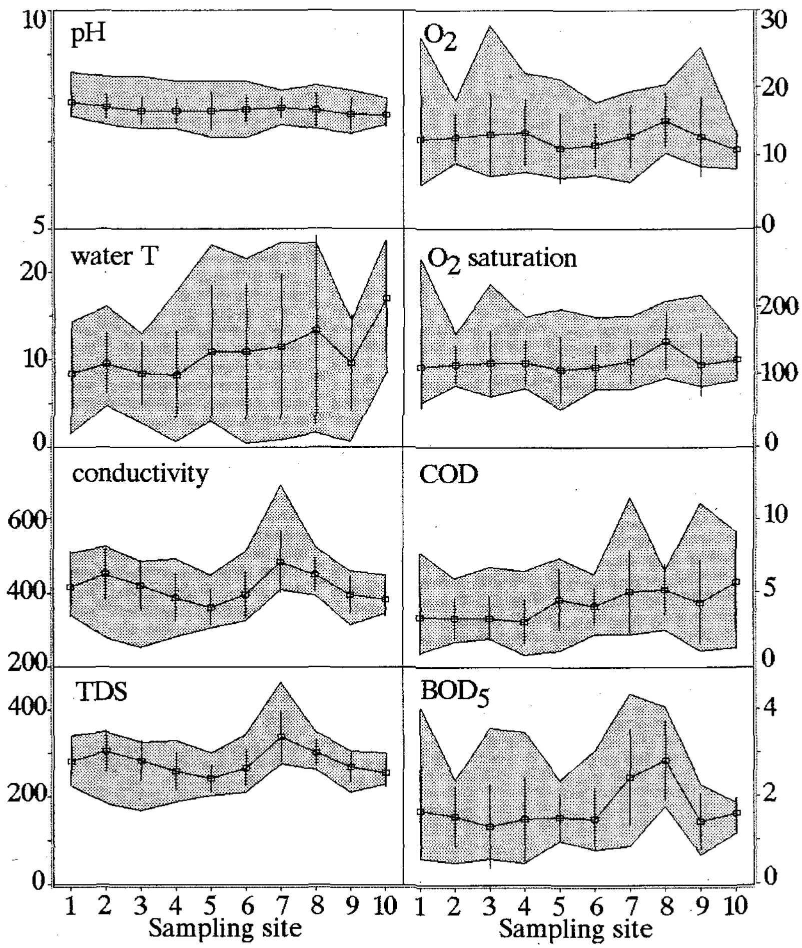
6. Stržen pri Dolenjem jezeru
Alisma plantago aquatica
Alisma gramineum
Rorippa amphibia
Sium latifolium
Senecio paludosus
Schenoplectus lacustris
Butomus umbelatus
Nuphar luteum
Potamogeton lucens
Myriophyllum spicatum
Batrachium trichophyllum

7. Cerkniščica
Epilobium hirsutum
Polygonum lapatifolium
Filipendula ulmaria
Sparganium erectum

Alisma plantago aquatica
Alisma gramineum
Potmogeton filiformis
Potamogeton crispus
Batrachium trichophyllum

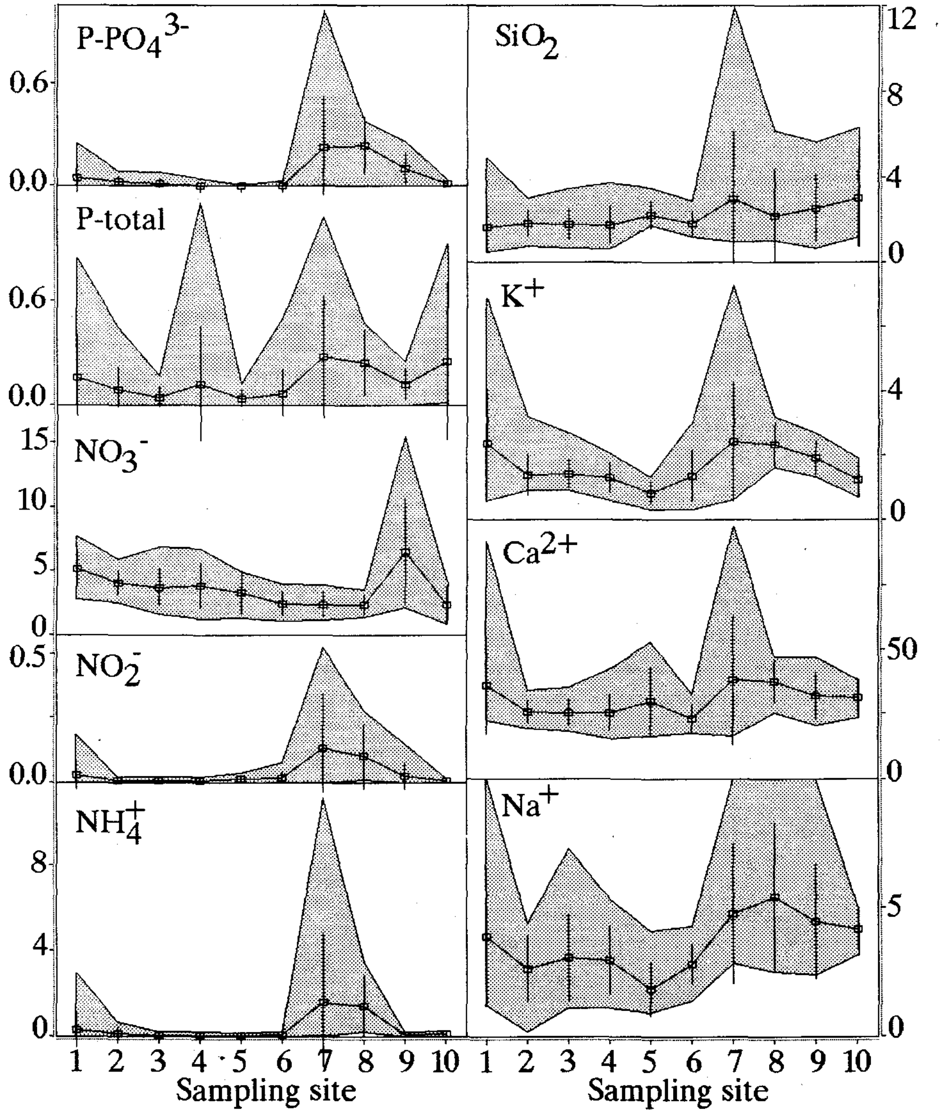


Sl. 1: Zemljevid Cerkniškega jezera s pritoki. Mesta vzorčevanja so označena s številkami.
Fig. 1: The scheme of Cerknica Lake and its tributaries. Sampling locations are indicated with numbers.



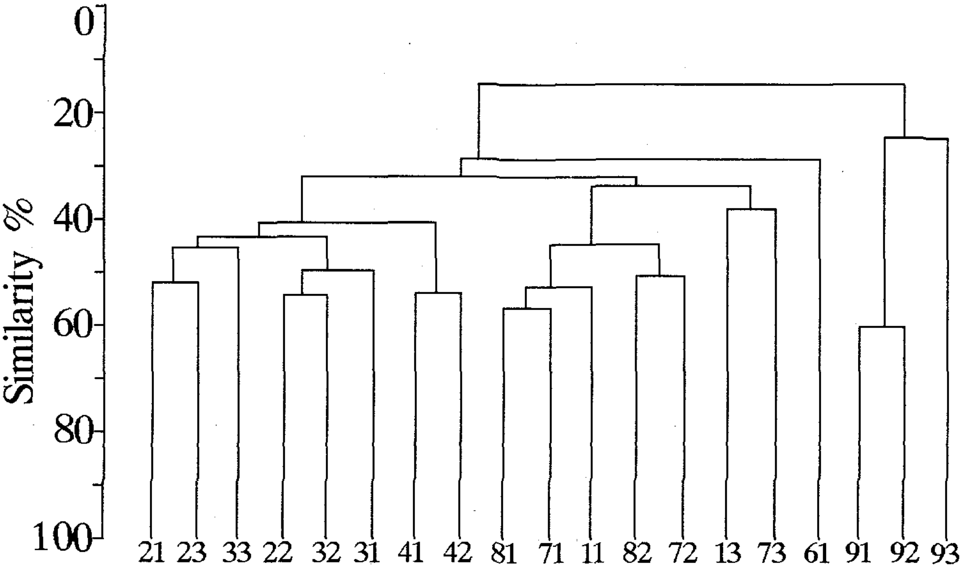
Sl. 2: Povprečne letne vrednosti pH, temperature (°C), električne prevodnosti (µS), raztopljenih snovi (TDS - ppm), kisika (mgl-1), saturacije kisika, kemijske porabe kisika (KPK - mgl-1) in biološke potrebe po kisiku po 5 dneh (BPK - mgl-1). Pokončne črte pomenijo standardno napako (n=10-12). Sivo polje predstavlja območje med minimalnimi in maksimalnimi vrednostmi.

Fig. 2: Average annual values of pH, temperature (°C), conductivity (µS), Total dissolved solids (TDS - ppm), oxygen (mgl-1), oxygen saturation, chemical oxygen demand (COD - mgl-1) and biological oxygen demand after 5 days (BOD - mgl-1). Vertical bars mean standard error (n=10-12). Grey area represents variation between minimum and maximum values.



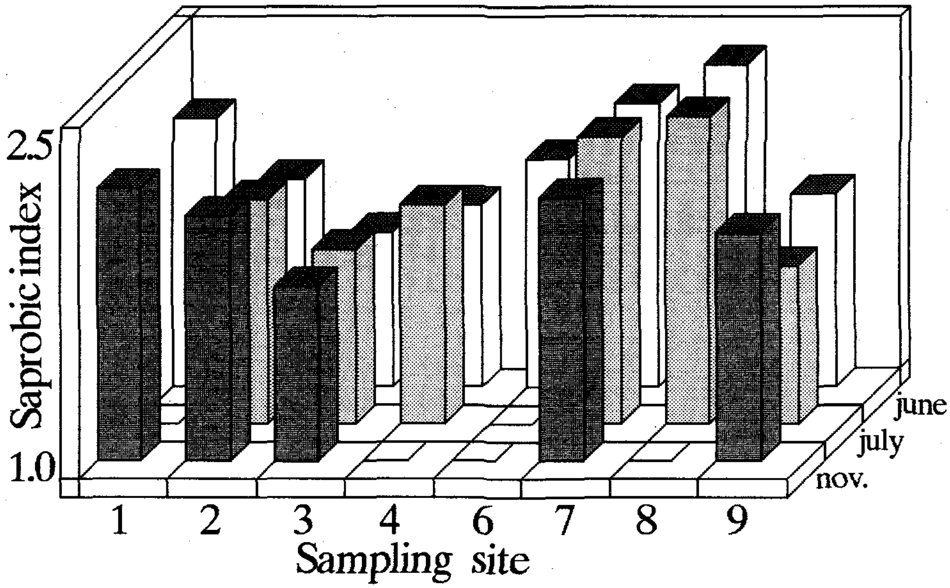
Sl. 3: Povprečne letne vrednosti P v obliki ortofosfata, totalnega P in nitratnega, nitritnega, amonijevega, silicijevega, kalijevega, kalcijevega in natrijevega iona. Vse vrednosti so podane v mgl^{-1}. Pokončne črte pomenijo standardno napako (n=10-12). Sivo polje predstavlja razpon med minimalnimi in maksimalnimi vrednostmi.

Fig. 3: Average annual values of phosphorus (ortophosphate), P-total, nitrate, nitrite, amonium, silicium, sodium, calcium and potassium. The values are in mg l^{-1}. Vertical bars mean standard error (n=10-12). Grey area represents variation between minimum and maximum values.



Sl. 4: Primerjava posameznih lokacij (izračun po Bray-Courtisu) glede na bentoške organizme. Vzorci so označeni z dvomestnimi številkami. Prva cifra predstavlja lokacijo, druga pa čas vzorčevanja (junij - 1, julij - 2, november - 3).

Fig. 4: The comparison of different locations (after Bray-Courtis) with respect to bentic organisms. Samples are indicated by numbers. The first sign represents location, the second means the time of sampling (june - 1, july - 2, november - 3).



Sl. 5: Vrednosti saprobnih indeksov, ki smo jih določili na osnovi vrstne sestave zoobentosa in perifitona.

Fig. 5: Values of saprobic indexes, estimated on the basis of zoobentos and periphyton.

WATER QUALITY IN CERKNICA LAKE AND ITS TRIBUTARIES

Summary

During the year 1993 water quality of Lake Cerknica and its tributaries was monitored. The results of some physical, chemical and biological analysis were taken as a cryteria. Lake Cerknica is not a typical lake. Great fluctuations of water level influence water quality and organisms in the lake, as well. Our investigations showed variations in water quality. The best was water quality of Lipsenjščica, somewhat worse situation showed the results of analysis of Žerovniščica. Cerkniščica and Martinjščica were affected with the pollution. During the dry period the quality of water is the most important. When the area of Cerknica Lake is flooded, toxic substances and nutrients which reach the lake by the tributaries are actively mineralized and neutralised in stands of dense aquatic vegetation, which function as natural filter. In dry period the water level drastically decreases. The areas covered with aquatic vegetation become dry and they lose the filtering ability. The water from the tributaries flows into the bed of Stržen. The self-purification efficiency of Stržen is negligible in comparison with the efficiency of the whole lake area. Polluted waters are spread through the underground pathways without any control. Our results showed the extend of variations of water quality during the year.

TYPES OF THE POLJES IN SLOVENIA, THEIR INUNDATIONS AND LAND USE

TIPI KRAŠKIH POLJ V SLOVENIJI, NJIHOVE POPLAVE IN RABA TAL

IVAN GAMS

Izvleček UDK 551.44 (234.422.1)(197.12)

Gams, Ivan: Tipi kraških polj v Sloveniji, njihove poplave in raba tal

Prispevek prinaša nove elementa za klasifikacijo kraških polj, kot dodatno gradivo k avtorjevi zasnovi, objavljeni 1983 (Gams). Predvsem se naslanja na povezavo med tipom kraškega polja, poplavami na njih in izrabo tal. Skupna lastnost polj je aluvijalni pokrov na dnu polja kot posledica odlaganja rečnega transporta v zastajajoči vodi pred ponori. Intenzivno kmetijsko rabo in gosto naseljenost kraških polj v Sloveniji izpričuje gostota naseljenosti z nad 200 prebivalci/km^2, medtem ko je v visokem dinarskem krasu, izven kraških polj, med 10 - 20 prebivalcev/km^2.

Ključne besede: geomorfologija, geomorfogeneza, kraška morfologija, klimatska geomorfologija, kraško polje, raba tal, Dinarski kras, Slovenija, Dinarski visoki kras Slovenije

Abstract UDC 551.44 (234.422.1)(197.12)

Gams, Ivan: Types of the poljes in Slovenia, their inundations and land use

The article contributes new elements to the karst poljes' classification as additional arguments to the one the author published in 1983 (Gams). In the foreground are connections between the polje type, floods and land use. Common characteristic of all the poljes is alluvial cover of the bottom of the polje as the result of fluvial transport sedimentation in the calm water in front of ponors. Intense agricultural land use as well as dense population of Slovene karst poljes are prooved by 200 inhabitants/km^2, while in the high dinaric karst, out of karst poljes, this density is not higher than 10 - 20 inhabitants/km^2.

Key words: geomorphology, geomorphogenesis, karst morphology, climate geomorphology, karst polje, land use, Dinaric karst, Slovenia, high Dinaric karst in Slovenia.

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Opomba: Prispevek je bil predstavljen na 2. mednarodni krasoslovni šoli "Klasični kras", ki je bila v Postojni med 27. - 30. junijem 1994

FOREWORD

The topics dealt with in this paper were suggested by the organizers of the present karst school devoted mainly to the poljes and man's impact on karst. It contains new argumentation for classification of the poljes in Slovenia in respect to the sheme published in 1983 (Gams). In foreground are relations among the polje type, floods and land use. For the more detailed picture see the references cited at the end of this article. The most recent description of the poljes of Notranjsko is published in the Guide-book of the Study group IGU - Man's Impact in Karst (1987).

PIEDMONT POLJES

The Velo polje (= Great Polje) is situated among the peaks Mišelj vrh (2350 m), Vernar (2225 m) and Mali Triglav (2738 m) in the Julian Alps. It is 330 m long and 300 m wide. The local name polje denies the opinion that in the Slavonic languages polje means field only. Its bottom at altitude 1700 m is too high for tillage. In the Slovene popular language it means also larger plain (Badjura, 1953, p. 43). In the Slovenian Dinaric Karst the poljes are called usually "dolina" (= valley) (Loška, Ribniška dolina) or "dol" (Globodol = Globoki dol). Rubble which built the bottom is deposited by the torrent from the Veljska dolina (valley) after snow melting in spring and heavy storm. The surface drainage is there enhanced by the steep slope below the massif of Triglav and inlayers of semipermeable strata. On the polje's bottom the water of torrent penetrates into the rendzina which covers the rubble. The suballuvial corrosion of the limestone basis is proved by collapse alluvial dolines which are often on the margin.

The limestone ridge which divides the two basins - Velo and Malo polje is only few metres high at its lowest point. Both poljes represent the beginning of the dry valley with glacier in the glacial periods of the Pleistocene. In Malo polje the hydrochemical measurements of the water flowing from the spring at one side for a while on the humus black soil mixed with limestone rubble have shown the increase of the total hardness from 100 $CaCO_3$/l to 124 mg $CaCO_3$/l and from 108 mg $CaCO_3$/l to 125 mg $CaCO_3$/l of the carbonate hardness. Higher on the slope at the Vodnik hut where the tree-line is at the altitude of 1850 m (Lovrenčak 1986) the spring water began its running on the humus rendzina of the pasture. Up to Malo polje its carbonate hardness increased from 76 to 113 mg $CaCO_3$/l. This increase is congruent with the similar measurements of the water flowing from bare lime-

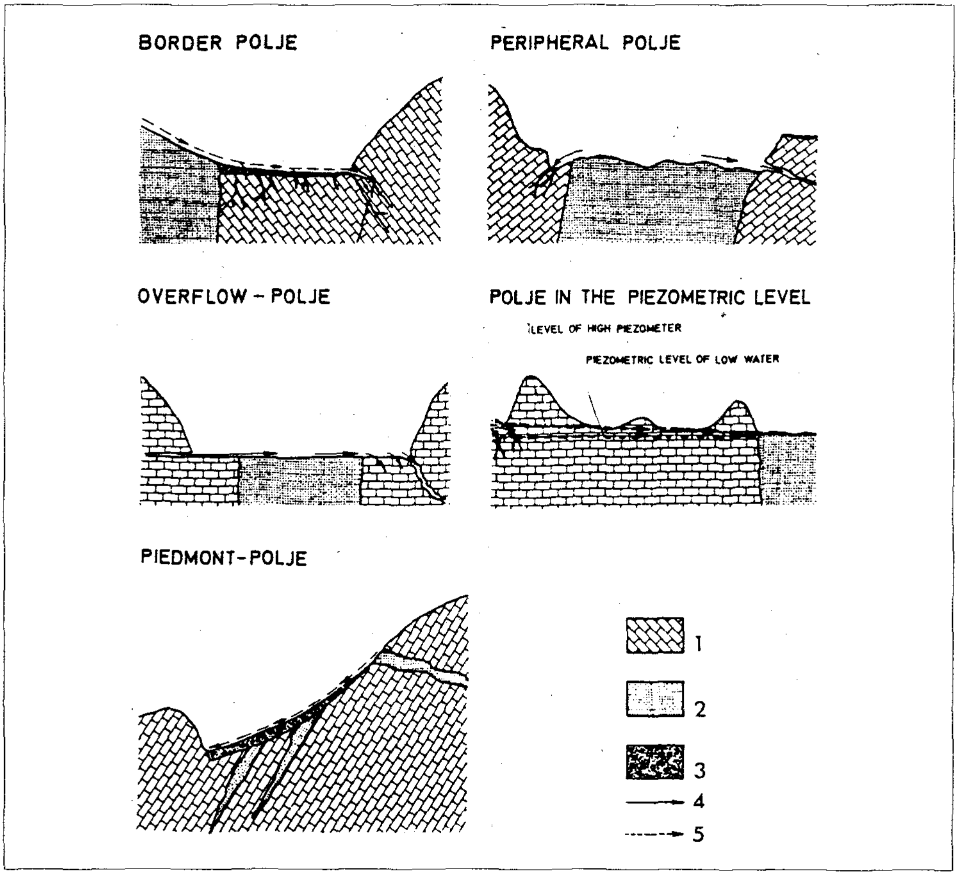
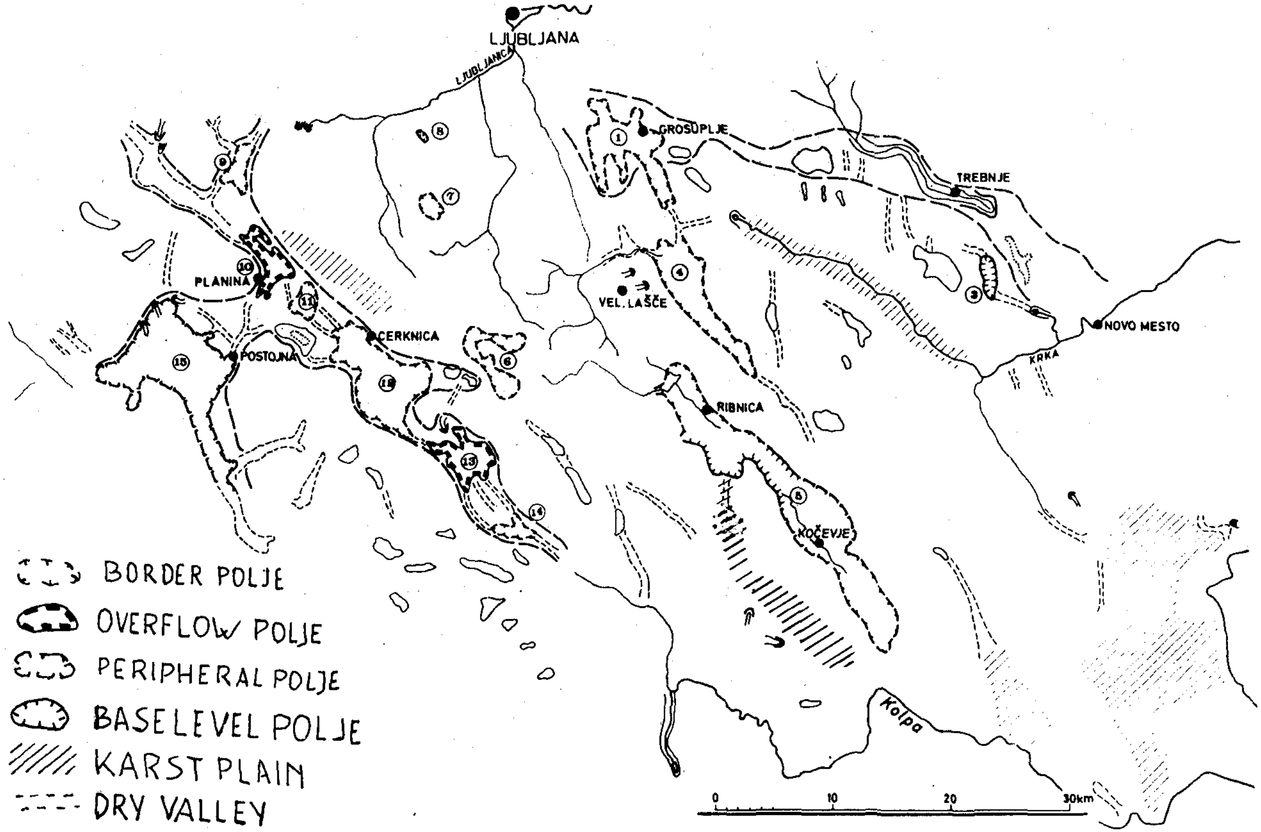
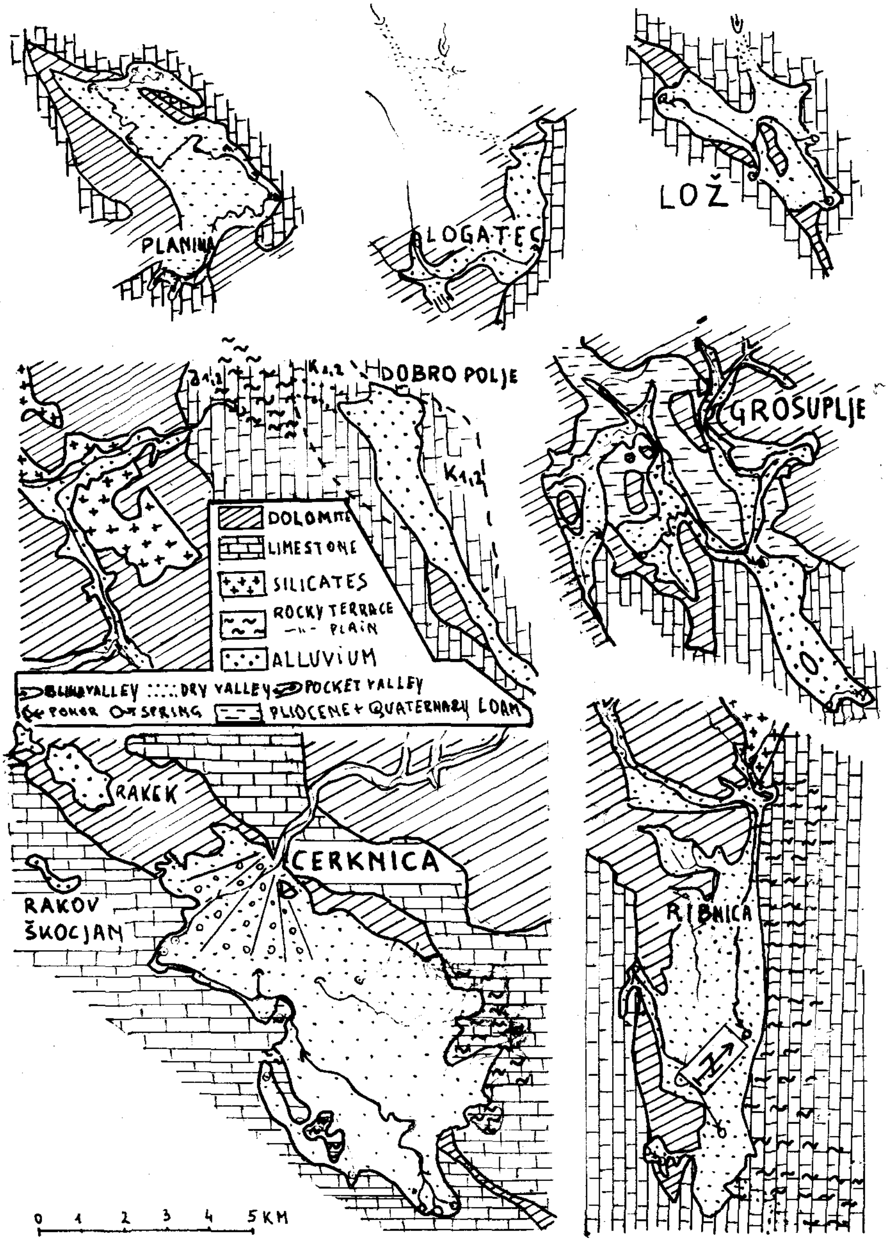


Fig. 1: The types of Karst poljes in Slovenia.
Legend: 1 = Permeable sediments (limestone).
2 = Unpermeable and partially permeable sediments (flysch, dolomite etc.).
3 = Alluvium.
4 = Permanent flow.
5 = Periodic flow.
Sl. 1: Tipi kraških polj v Sloveniji.
Legenda: 1 = prepustni sedimenti (apnenec)
2 = neprepustni in deloma prepustni sedimenti (fliš, dolomit, itd.)
3 = aluvij
4 = stalni tok
5 = občasni tok

Fig. 2: Karst poljes in Slovenia.
Sl. 2: Kraška polja v Sloveniji.


LJUBLJANA
LJUBLJANICA
GROSUPLJE
TREBNJE
PLANINA
CERKNICA
POSTOJNA
VEL. LAŠČE
NOVO MESTO
KRKA
RIBNICA
KOČEVJE
Kolpa
0
10
20
30km
BORDER POLJE
OVERFLOW POLJE
PERIPHERAL POLJE
BASELEVEL POLJE
KARST PLAIN
DRY VALLEY


PLANINA
LOGATEC
LOŽ
DOBRO POLJE
GROSUPLJE
DOLOMITE
LIMESTONE
SILICATES
ROCKY TERRACE
—"— PLAIN
ALLUVIUM
DRY VALLEY
POCKET VALLEY
SPRING
PLIOCENE + QUATERNARY LOAM
RAKEK
CERKNICA
RAKOV
ŠKOCJAN
RIBNICA
0 1 2 3 4 5 KM

stone of the Julian Alps to the karst covered by soil. The development of the basins of Malo and of Velo polje may be attributed to the suballuvial and to this type of accelerated corrosion. As the vegetational belts in the Pleistocene glacial periods were lower for 800-1300 m, then the similar processes are presumed to be active also in the poljes situated in Dinaric Karst in Carniola in the altitude 400 - 800 m (Gams 1965; 1967).

Since the Middle Ages on Velo polje existed the pasture with the cattle pens. Floods are often but of short duration as the bottom is inclined and the ground permeable. Two concrete dams were built till now to retain the rubble from spreading on the pasture and both are filled already.

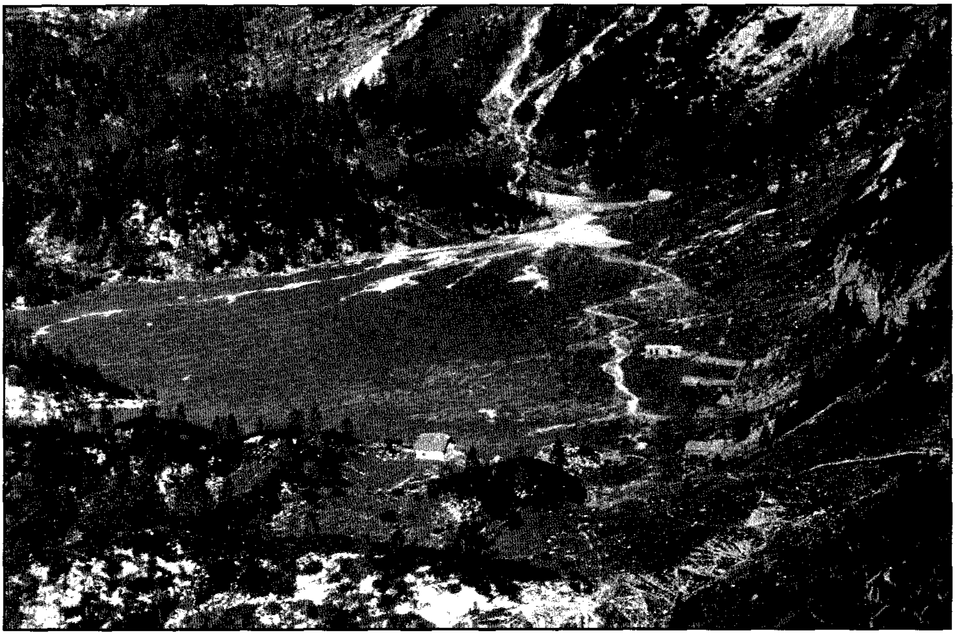


Fig. 4a: The piedmont (foot-hill) polje Velo polje (Julian Alps) is situated on the contact between the forested-grass and stony surface. Belts of rubble, deposited by torrent are shifted in last some tens of years, as they are soon overgrown by grass. In spite there is no sign of the thickening of the alluviation in Holocene. The local accelerated corrosion is proved (photo by I. Gams).

Sl. 4a: Piedmontsko kraško polje Velo polje (Julijske Alpe) ima dno na stiku skalnatega in gozdnato-travniškega površja. Gruščati tokovi (svetle proge) hudournika so se zadnjih nekaj desetletjih večkrat premestili, ker jih kmalu preraste trava. Kljub temu ni znakov, da bi postala gruščnata naplavina na polju v holocenu debelejša. Dokazana je lokalno pospešena korozija (foto I. Gams).

Fig. 3: Some examples of Karst poljes of the Slovene Karst.

Sl. 3: Nekaj primerov kraških polj s slovenskega krasa.

BORDER POLJES

The most impressive border poljes in the world are situated on the contact of impermeable silicious sediments with the limestone (see Lehmann 1959). In Slovenia the water sinking in the border poljes is draining the semipermeable Triassic dolomites and is recently mostly saturated with carbonates. But near to the tree-line, as today lies the Velo polje, in the following border poljes in Slovenia an aggressive sinking water is supposed to exist in the glacial periods of the Pleistocene. As seen on the geomorphological sketch, the bottoms of the border poljes developed mostly inside the dolomite and only at very high level the water reaches the ponors in the border limestone in case of bigger poljes.

The second geomorphological feature is a higher terrace in limestone at the outflow side of the polje. On it remains of the Pleistocene river sediments were found. This is proved for the polje of Logatec (Mihevc 1986. See the sketch!). A similar but narrower

Fig. 4b: In 30 years younger photograph of Velo polje the torrential rubble dams essentially differ from those in the previous photograph. In front the Malo polje border (photo by I. Gams).

Sl. 4b: Na 3 desetletja mlajši fotografiji Velega polja so hudourniški gruščnati nasipi precej drugačni kot na fotografiji iz l. 1994. V ospredju rob Malega polja (foto I. Gams).

1-3 m higher border limestone terraces are on the effluent side of the dolomitic polje at Rakitna and Babno polje. Already Melik (1955) stated the shortening of the river flow on the bottom of the polje as the result of the Holocene removal of the alluvium und unveiling the older sinks. The normal sinks of the water are at present in dolomite far from the end ponors in the limestone. In the polje of Bloke the final ponor of the Bločica under the village Metulje is 5.5 km distant from the ponor at low level. In the Logaško polje, the tributary Petkovški potok in the Pleistocene spreaded on the northern part called Pusto polje a thick cover of gravel and sand. At present its normal ponor is 2 km distant (Mihevc 1986) and it reaches the polje through the dry valley once in many decades.

In the transition belt from northern Triassic dolomite to the southern limestone there is between Ljubljana Moor and Krka basin a series of all sorts of karst basins with sinking rivers. There the largest border polje is the polje of Grosuplje (see the sketch!). Numerous tributaries concentrate in the main river Grosupeljščica. Near the village Boštanj are the main ponors at the contact limestone. Behind these ponors stretches 4 km long and 1 km wide "blind valley" called Radensko polje. The river floods it once in some years. This exceptionally big "blind valley" Melik (1955) explained by the primary flow of the river Raščica through Dobro polje to the Ljubljanica river. Contrary to that, Gams (1986) sees in the "blind valley" Radensko polje the end ponor of the Paleoljubljanica which by Quaternary tectonical subsidence of the Ljubljana Moor was captured by the Sava river. This opinion is based also on the Pliocene-Quaternary clay and loam, thick 1 - 10 m, building a slightly higher polje's bottom without sharp transition. Holocene flooded plain along the tributaries are built of clay and loam and they are according to the pollen analyses of Pleistocene and Holocene age (Buser 1965). On them meadows prevail and settlements on the higher bottom and on the dolomitic ridges are dense (Melik 1955).

More marked Holocene shortening of the main river occured at the river Raščica. In Pleistocene it has spread over the northern, larger part of the Dobro polje (19.5 km^2) accumulation terraces and also gravel (Šifrer, 1967). The rivers draining the Triassic dolomite usually transported no gravel or it was soon chemically and mechanically weathered. But in the river basin in the region Velike Lašče patches of the Permian schists and sandstone enabled the river to transport the silicious gravel from the region. But today the river sinks 3 km from the polje and only once in many years its flood reaches through the dry valley the NW, lower part of the polje (Kranjc 1980; Melik 1955) and endangers the settlements in the south-eastern narrower continuation of the polje called Struge (see the sketch!). It does not deposit at the normal ponor near the village Ponikve (=ponor) before Dobro polje (=good field) any gravel.

At the village Ponikve (=ponor) is 2 km wide and 3 km long karst plain without considerable alluvium. The difference of the Pleistocene gravel deposits in the Dobro polje and the absence of it in the present river can be explained by the climatical geomorphology. In this sense the karst plain at Ponikve may be explained as the result of the flooding in the warm periods of the Pleistocene. Now the final part of the river is regulated.

In the east of the Grosuplje polje geomophological evidence of the historical man made reverse transformation of a periodical border polje (or large blind valley) into normal river valley exists. Once the river Višnjica normaly disappeared in the ponors near the village

Muljava in the southern end of the 1,3 km wide plain and only at high level continued its surface course to the head of the river Krka. As this head tectonically subsided, the denivelation enabled the tributary to sink at low and middle level in the border limestone around Muljava. To avoid inundations and for the drive of the mills the surface river bed was regulated and collapse dolines as new swallow holes were artificially filled. So the sinking river became a steady surface flow and thus the development of the rudimental semipolje stoped (Gams 1986).

OVERFLOW POLJES

The dam which forces the underground water on the inflow side of the polje to flow on the surface toward the ponors on the outflow side in limestone is in Slovenia built of Triassic dolomite only. The classical form of the overflow polje in Slovenia is the polje of Planina (9 km^2, see sketch!). On this polje the project was prepared for the water storage for HP by blocking cca 120 ponors on the NE side (Jenko 1959). The project was refused for the sake of natural conservation of the typical Slovenian polje.

In the Slovenian karst geomorphology the factors of poljes development are a matter of discussion between the advocates of tectonics (Habič 1982, and some geologists) and of suballuvium solution (Gams 1980). In this regard is to mention that along the main, Idrija fault, the contact of the Cretaceous limestone and Triassic dolomite transverses the top of the Jakovica ridge. It divides the main polje bottom from the bay Babni dol where around the numerous ponors and ponor caves behind them the basin is at most enlarged on the border limestone.

The predominant dolomitic bottom and its enlargement on the limestone are covered by in average 2-5 m thick loam and sand of Holocene age. Locally up to 20 m deep swallow holes were found beneath (Jenko 1962; Melik 1955). The Holocene alluviation was explained by the trees fall. As the roots retaining the soil rotted the flood water blocks with loam the entrances to the stony ponors. Thus floods lasted longer, now about 3-5 weeks in the year. Although the ammelioration of ponors shortened the time of flood the bottom is in spite of the fertile soil still without fields and settlements and used only for meadows (Gams 1980). So the polje of Planina is an example in this regard.

The dolomitic belt stretches through the whole Notranjsko podolje and is a dam also for the Veliki Obrh in the polje of Lož (12 km^2). Contrary to the Planina polje here the floods are restricted to the two valleys of the Veliki and Mali Obrh and the settlements are dense on the higher dolomitic terrace where once fields prevailed (Gams 1973b).

NW of the Lož polje the same dolomitic belt is enlarged in the bottom of the most famous Slovenian polje Cerkniško polje (45 km^2). The river takes rise at the SE and E border limestone created in Pliocene parallel valleys which rested only some metres above the bottom between the poljes of Cerknica and Rakek (see the sketch! The geology is taken from the geological maps in the scale 1 : 100.000). Probably due to the tectonical sinking which is proved also for the Holocene time (Gospodarič & Habič 1979; Habič 1980) the main ponors near the recent settlement Cerknica developed. With them the basin began to form. Before the Würmian these ponors were blocked by gravel and sand of the river

Cerkniščica which drains the predominant Triassic dolomite. But there are also patches of silicious inlayers which provide together with steep dolomitic slopes the gravel. Before capturing and diverting into the polje the river has flown on the surface to Ljubljana Moor (Melik 1955). The fan at the Cerknica which is now used for fields of the settlements has blocked the ponors and so prolongated the floods in the seasonal lake which lasts 285 days in average per year (Kranjc 1981). The fan shifted the border corrosion to the NW edge thus enlarging the bottom on the limestone. Recently the ponors in dolomite renewed but only on the rim of the fan. From them the water flows directly to the Bistra river on Ljubljana Moor.

The water from the Cerknica polje ponoring in the border limestone rises again in the spring on the SE side of the little polje in dolomite - polje of Rakek. It is seldom flooded and then the water is sinking in dolomite on the N side - the same as it was in the Cerknica polje before the fan the ponors were blocked (Gams 1965).

Later the near basin composed of a pocket and blind valleys, called Rakov Škocjan developed as a consequence of the shifting the outlet from the Cerknica polje to the south. We may consider its 1.3 km long and narrow belt of alluvium as the beginning of the development of a new polje in the rocky bottom of the 4 km long and 40 m deep wooded uvala. This has to be explained as a result of tectonical subsidence. No other reliable reason of the uvala origin is known.

After the shifting of the outlet from the Cerknica polje to the Rakov Škocjan the high water from there invaded the Rak channel of the Planina Cave which was previously used for the outflow of the Postojna polje (Gospodarič 1976). This water sinks on the effluent side of the dolomite dam of Planinsko polje after flowing over the same dolomitic belt where before the fan the Cerkniščica accumulated sand near the bordering limestone.

For the same reason that the project for water storage in the Planina polje was abondoned also the experiment of making the Cerknica lake permanent by means of the dam on the ponor caves, this time for development of tourism, was given up. The dam only slightly prolongated the lake stage (20,3 km^2 or 53 % of the polje's bottom) and the dry season still remained. The lake bottom is useless for agriculture which centered the fields in the higher dolomitic and limestone terraces on NE and SE border. There the settlements are dense (Kranjc 1985).

PERIPHERAL POLJES

The centrifugal drainage of the larger patch of the Eocene flysch of the Mt. Brkini allowed on its border on the southern and northern side development of the blind valleys only. The area of Eocene flysch near the Postojna town and in the drainage basin of the Pivka river is drained mostly in one river - that of the Pivka. It was therefore able to create with its tributaries the belts of alluvial plains. South of the Postojna town the plain at the confluence with the Nanoščica is 2-3 km wide, enough to determine the basin, 90 m deep with karst drainage as the (peripheral) polje. The northern plains mostly developed in the flysch. In SE they stretch also on border limestone. Between the villages Slavina and Pivka the Pivka river receives some torrents from the western side draining the Eocene flysch belt, which is now reduced. Originally longer brooks presumably sank on the eastern border limestone. Thus developed dry valley Vlačno, 4 km long which generated probably as a blind valley, as well the bay of plain at the village Trnje. The estavellas in the periodical lakes of Petelinje and Palčje probably originated as ponors of the brooks from flysch. The bottoms of the basins with periodical lakes are at the same level as the river bed of the Pivka.

The land surface in flysch was in the Quaternary lowered more than the limestones in the surroundings (Radinja 1972). This occured also with the flysch in the drainage basin of the Notranjska Reka bordering to the upper Pivka basin between the Pivka and Knežak settlements. There the plain of the Pivka consists of numerous open basins which are flooded at high water. Their origin may be considered as the effect of the ancient drainage from the higher surface built of flysch. Now it is separated by a crest built mostly of the Paleogene limestone. Later lowering of basins to the present level can be explained by the suballluvial corrosion in the piezometric water level maintained by the flysch inliers below the marginal limestone.

To the north and east of the Postojna polje there is 10 to 80 m higher hilly terrace, many hundred metres wide. Till now only the northern terrace ("Postojna step") is attributed to the fluvial processes of the Pliocene Pivka. According to the sheme of the polje development and of the border solution also the eastern hilly terrace may be explained by the primary border corrosion of the river sinking below the Mt Javorniki.

With more intense Pleistocene lowering of the surface in flysch the bottom plain of the peripheral polje was essentially reduced and thus the flooded area also. The deepest floods occur in front of the ponor of the Pivka in the Postojna Cave. The flooded plains are used for meadows, which predominate over the fields around the dense villages on the flysch hills. Limestone border terrace is overgrown by forest.

BASELEVEL POLJE

The Ponikve polje with its 450 m wide bottom is on the limit for a polje recognition (Gams 1973). Its often floods are caused by the fact that the outlet of the polje is rising on the border of the 1,2 km distant Ljubljana Moor about 4 m lower than the polje's bottom. The origin of the basin cannot be explained by lithological differences - it is in the Triassic dolomite - nor by fault line. The only fault line is acc. to the geological map higher on the NE slope on the contact with the Jurassic limestone. The basin can be explained mostly with the suballuvial corrosion and areal tectonical subsidence of the wider surroundings of Ljubljana Moor. This is proved also with the pothole, 47 m deep in the lake at the near village Jezero, both situated in a similar oval depression as Ponikve.

Entirely in the same carbonate rock (limestone) is also the deepest polje in Slovenia, the polje Globodol. Its bottom is flooded mostly in the lower edge dotted with dolines. The central bottom is higher, with deep loam and gley soil. There are three settlements which are isles of densely populated area in the wooded surroundings. The floods occur in the level of the high piezometric level maintained by the spring of the Prečna in the near pocket valley Luknja (Gams 1959). Ford and Williams (1989) called this type baselevel polje.

Three kilometres eastwards of Globodol is a basin with many similarities with Globodol - that of Mirna peč: a similar size, a similar direction towards Luknja and in the same Jurassic limestone. But in the basin of Mirna peč which is combined pocket and blind valley, the river flows with spring at one and sinks at the opposite end. The primary flow of the Paleo-Temenica through Globodol is therefore presumed. In it the NW corner where the river takes its spring is narrower and the southern end wider and there begins the dry valley stretching toward the Luknja. In it more than 100 m high mountain ridge is lowered to 50 m.

COMBINED TYPE OF POLJE

The Ribnica polje (see the sketch!) is a combination of the border and overflow type. The Triassic dolomite predominates in the alluvial bottom where in NW thick gley loam predominates (Rus 1925) considered by Melik (1955) to be of lacustrine origin . The NW dolomitic belt which reaches the spring Rakitnica, forces the underground water from the limestone mountain to rise also in the main spring Ribnica. These two rivers contribute to the border polje the additional overflow polje as they sink on the polje (Melik 1955). The border polje's type is represented by the river Sodraška Bistrica which drains mostly the dolomitic hills on the NW side. It sinks near to the limestone border S of the Ribnica town. When turning to south the river bed is connected by the artificial ditch with the ponor cave Tentera to avoide the flood on the polje's bottom at high water level or to prolongate the river flow on the polje at the drought (Rus 1925). The Ribnica town is not called according to the Bistrica which flows through it but according to the 2 km distant smaller river Ribnica. In respect to the medieval finding of the settlement the swallow hole of the Bistrica was presumably the Tentera cave.

The polje's bottom is in Slovenia exceptional regarding the rocky plain on the NE side, mostly 2 km wide. It begins behind the ponor of the river Tržiščica (or Žlebiščica) in form of some metres higher rocky terrace. Its first part in the northern edge of the polje, has considerable inclination which corresponds to the gravel transport of the Tržiščica which drains not only dolomite but also silicate-Permian sandstone, schistes and conglomerates. The rest of gravel built of these sediments can still be found on the northern part of the terrace. Later the rocky terrace gets a similar inclination as the alluvial plain of the Bistrica. The common flow of the Bistrica and Tržiščica over the rocky terrace ended when the Bistrica eroded in the 10 - 25 m high ridge a through valley near the contact of dolomite and limestone of the rocky terrace and invaded the dolomitic part of the polje.

An even older change is recognizable. The dolomitic surface NW of Ribnica is levelled near the village Dane with terrace of 620 m of the altitude. Its continuation is between the ridge Bukovica and Mt. Mala Gora. South of Rakitnica begins in the mountainous relief in the altitude of 510-520 m a large karst plain. South of Grčarice and at Gotenica it is tectonically uplifted to 600 m and later lowered to 550 m at the village Morava. No other river can form this karstic plain as the combined rivers Sodraška Bistrica, Ribnica and Rakitnica, the last two ones before they were captured by the dolomite belt in the polje.

At high water level the joint water from the Ribnica polje flows through the dry valley which divided two hills Jasnica and Svinjski grič towards the polje of Kočevje.

The dense settlements on the polje of Ribnica are situated on the dolomitic elevations and on the higher rim of the alluvial polje's bottom. It was used mostly for the fields and recently mostly for meadows and on the rocky terrace for forest. The floods have been diminished with ammelioration of river beds and ponors.

The polje of Kočevje is a combination of peripheral and border type. The underground water from the limestone mountains is forced by the Jurassic dolomite to spring as the Rinža. After flow in the limestone it sinks in the final ponors in the isolated Triassic dolomite near the village Črni potok.The peripheral character is given to the polje by the patch of the Tertiary sediments N of the town. It is built at the base of Miocene sediments. Upwards follow Pliocene schists, sandstone, marls and clay (Savić & Dozet 1985). The 100 m deep sediments are the rest of the largelly sized impermeable sediments with centrifugal drainage. On the NE side the rocky terrace continues from the Ribnica polje along the abondoned railway. The terrace is about 10 m higher than the surface of the Pliocene sediments and polje bottom along the Rinža. For the not yet explained reason the rocky terrace has no inclination toward SE. According to the geological map Delnice the lower surface is covered by lacustrine sediments.

The Rinža flooded at very high level the whole alluvial plain and partially also the town. At low water its superficial flow is for 5 km shorter. The final ponors near the village Črni potok are ammeliorated (Kranjc 1972, 1982). As the alluvial plain covers less than one half of the bottom, the polje settlements are recently less dense than usually in the Slovene poljes and forests on the limestone terrace cover greater percentage. As towards SE the basin is open and because of the large rocky terraces the size of polje is discutable (from 100 km^2 - Kranjc 1972 - to 72 km^2 - Gams 1978).

CONCLUSIONS

The review of the polje types in Slovenia and their mutual comparison resulted in the priorities of the geomorphological processes for their development.

Tectonics as the initial state of the formation of the polje basin is obvious in the case of the uvala Rakov Škocjan. Due to the tectonic subsidence the cave ceilings are thin and liable to collapse. So the cave channels opened on air and in the narrow river basin floods began with deposition of the loam.

The second case, the tectonical subsidence of the valley head with spring of the Krka created the vertical difference between it and the tributary Višnjica which began to sink in the border limestone near Muljava. The seasonal dry-up of the last river section and also the forming of the rudimentary polje were interrupted by man blocking the ponors and ammeliorating the river bed for drive of mills and to avoid the floods.

Besides of the baselevel poljes which are related to the tectonics, the poljes in Slovenia are developed by other processes too. All are situated in front of the ponors near to the petrological contact of impermeable or semipermeable sediments with permeable limestone. Sinking of the river brings about the floods and sedimentation of the river load. Its accumulation is resulting in two morphological processes - border corrosion and suballuvial corrosion. The first one was in Slovenia measured by means of hydrochemical analyses in the blind valleys with sinking water from less carbonate flysch (Gams 1962). These basins have similar origin as the border polje. Technically is nearly impossible to measure the suballuvial corrosion, but it is consistent from the geomorphological point of view. The impermeable alluvial cover would make the underground rock higher than the karst surroundings where the corrosion of the precipitation water steady lowers the surface. This would lead to the disappearing of the basin. Prove of the suballuvial corrosion are the numerous collapse dolines encountered on the polje's bottom.

In the altitude of climatic tree-line on the contact of covered and bare karst surface in the Alps the measurements proved the special type of the locally accelerated corrosion. During the flow on the Malo polje (1670 m) draining the higher bare surface, the water hardness considerably increased. In the cold Pleistocene periods the similar processes contributed to the deepening of the poljes in the Dinaric karst being situated at the altitude of 400-800 m. Then on the dolomitic surface and on the alluvial fan seasonal permafrost prolongated the surface rivers from dolomite to the ponor in the limestone border. But coarser river load was consequently favourable for the suballuvial solution.

In the border poljes in Slovenia the rivers, draining the semipermeable dolomite sink. Their basins are shallow and presumably young. Before the basin fomation the surface rivers lowered the dolomite with erosional and solutional processes. After they lowered the dolomite surface below the surrounding limestone karst water from limestone began to spring on the contact with dolomite and invaded the initial polje (case of Ribnica and Cerknica). So the overflow poljes developed. The alluvium cover also in them enhanced the suballuvial solution based on the higher biological activity in the moist soil. Erosional widening of the rocky ponors is of second importance. By this process originated rubble is absent in the springs and must have been dissolved in the underground channels or transformed in sand (Kranjc 1989).

The geomorhological study of the poljes in Slovenia revealed changes in the polje type in the geological past. The overflow polje of Rakek is now a dry polje in the dolomite. In the geological past it developed as the overflow polje so as the near Planina and Cerknica poljes are. The border polje of Ribnica was later combined with the overflow type. The role of the peripheral polje at Kočevje is diminished together with the diminishing size of the isle of the Neogene impermeable sediments. The centrigufal drainage in the peripheral polje at Postojna is now reduced and with it also the peripheral type of the polje.

Due to the diminishing river load in Holocene the water streams on the bottoms of border and peripheral poljes are shortening but the exceptional floods rest although they are more seldom. The longest floods are in the baselevel polje. The periodical lake in the overflow polje of Cerknica is a consequence of the accidental piracy of the neighbouring river. Its gravels in form of a fan blocked the ponors near Cerknica. The flooding of the total bottom of the Planina overflow polje is attributed to the man's activity in Holocene where once grove and now only meadows are, and despite of the fertile soil the fields and settlements are absent.

The plain bottoms of the poljes in the Dinaric karst are isles of the intensive land use and dense settled similar to the intramountainous basin in the nonkarstic Slovenia. In them the population density is more than 200 inhabitants/sq km, and outside them in the karst is in average 30 inh./sq km. In the so called high Dinaric Karst the communal seats are all in the poljes.

TIPI KRAŠKIH POLJ V SLOVENIJI, NJIHOVE POPLAVE IN RABA TAL

Povzetek

Tematiko tega članka so predlagali organizatorji kraške šole v Postojni 1994, namenjeni predvsem kraškim poljem v Sloveniji in človekovemu posegu v kras.

Nova argumentacija za tipe kraških polj v Sloveniji in njihovo medsebojno iskanje skupnih pogojev in razlik po tipih sta dala nove poglede na razvoj več kraških polj. Skupna lastnost polj je aluvialni pokrov na dnu kotanje kot posledica odlaganja rečnega transporta v zastajajoči poplavni vodi pred ponori rek. Ti so locirani na stiku vodoneprepustnih flišev ali polprepustnih dolomitov z apnenci. Drobnozrnati aluvialni pokrov pospešuje robno in grobozrnati, kot je bilo v hladnih pleistocenskih razdobjih, podaluvialno (podnaplavinsko) korozijo. Tektonsko grezanje uvale Rakovega Škocjana je omogočilo začetek nastajaja novega kraška polja vzdolž rečnega toka Raka. Grezanje izvirnega območja Krke je zaradi nastale denivelacije omogočilo ponore Višnjice pri Muljavi, kjer pa je nastajajoče rudimentarno kraško polje preprečil človek z regulacijo reke in zamašitvijo nastajajočih novih ponorov za za odpravo poplav in pogon mlinov.

Dna robnih polj so v Slovenija razvita predvsem na robnem dolomitu in tam so razdalje med ponori nizke in visoke vode dolge do več kilometrov. Kraški ravnik pri vasi Ponikve je pripisan toplodobnemu kvartarnemu naplavljanju Raščice, ki je v ledenih dobah nasula prodno teraso v 3 km oddaljenem Dobrepolju. Robna polja so plitve in mlade kotanje, nastale v območju predhodnega znižanja dolomita s skoncentriranimi rečnimi dolinami. Po nastanku kotanje je pričela pritekati voda iz robnih apnencev, kjer je podzemno vodo prisililo k dvigu dolomitna pregrada. Ribniško in Cerkniško polje sta s tem dobila kombinirani tip robnega in prelivnega polja. Reke Sodraška Bistrica, Ribnica in Rakitnica so pred spremembo skupno odtekale proti JV in izdelale kraški ravnik, ki ga je med Grčaricami, Gotenico in pol poti do Kočevske Reke tektonika dvignila na ok. 600 m, nakar se zniža do Morave na 540 m. V naslednji fazi sta Sodraška Bistrica in Tržiščica, slednja z bolj agresivno vodo, izravnali na apnencu kraški ravnik, ki sega mimo Ribniškega še v Kočevsko polje, tu pa iz neznanih razlogov nima strmca. Kočevsko polje je kombiniran tip robnega in perifernega polja; slednji je nastal zaradi nekoč obsežnejšega otoka noegenih sedimentov pri Šalki vasi.

Intenzivno kmetijsko rabo in gosto naseljenost kraških polj v Sloveniji izpričuje prebivalstvena gostota z nad 200 ljudi na km^2. Izven polj je v visokem Dinarskem krasu v

povprečju med 10 in 20 preb./km^2. Tam so na poljih, po stanju 1994, vsa občinska središča te regije.

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PALEOEKOLOŠKE ZNAČILNOSTI VREMSKIH PLASTI V OKOLICI ŠKOCJANSKIH JAM

PALEOECOLOGICAL PROPERTIES OF THE VREME BEDS IN THE VICINITY OF ŠKOCJANSKE JAME (ŠKOCJANSKE JAME CAVES, SLOVENIA)

MARTIN KNEZ

Izvleček UDK 551.44 . 551.781 (497.12)

Knez, Martin: Paleoekološke značilnosti vremskih plasti v okolici Škocjanskih jam

Iz vremskih plasti sta iz paleoekološkega in deloma biostratigrafskega stališča obdelana dva profila iz neposredne okolice Škocjanskega jamskega sistema. Osnovni namen naloge je bil torej proučevanje okolja sedimentacije plasti z giroplevrami in aprikardijami v vremskih plasteh. Ugotovljeno je, da so številne školjke iz rodu Gyropleura, Apricardia in morda še druge školjke v apnencih vremskih plasti na drugotnem mestu. Giroplevre so živele v plitvi vodi nedaleč od obale. Na drugotno mesto so jih prinesli valovi in tokovi, ki so jih povzročila neurja in nevihte. Odsotnost rapidionin v horizontih z giroplevrami potrjuje trditev, da so bile lupine nametane proti obali, saj so rapidionine živele v izrazito lagunskem okolju. Na plitvo okolje sedimentacije kažejo tudi laminiti.

Ključne besede: geologija, paleoekologija, biostratigrafija, vremske plasti, Gyropleura, Apricardia, Škocjanske jame, Slovenija

Abstract UDC 551.44 . 551.781 (497.12)

Knez, Martin: Paleoecological properties of the Vreme beds in the vicinity of Škocjanske jame (Škocjanske jame Caves, Slovenia)

From paleoecological and partly biostratigraphical point of view two profiles of Vreme beds from the immediate vicinity of Škocjanske jame cave system are treated. The basic goal of this study was to find out the sedimentary environment of the layers containing Gyropleura and Apricardia within the Vreme beds. It was assessed that numerous shells of Gyropleura and Apricardia genus and maybe some other shells too within the limestones of the Vreme beds lie on the secondary site. The shells lived in shallow water not far from the coast. To the secondary site they were transported by the waves and currents caused by storms and tempests. The absence of Rhapydionina within the horizons containing Gyropleura and Apricardia confirms the statement that the shells were thrown towards the coast as the Rhapydionina lived in prominently lagoon environment. The laminites too indicate the shallow sedimentary environment.

Key words: geology, paleoecology, biostratigraphy, Vreme beds, Gyropleura, Apricardia, Škocjanske jame, Slovenia

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UVOD

Iz vremskih plasti sta predvsem iz paleoekološkega in deloma biostratigrafskega stališča obdelana dva profila iz neposredne okolice Škocjanskega jamskega sistema.

V vremskih plasteh sem podrobno proučeval predvsem plasti z giroplevrami ter način pojavljanja lupin in njihovih odlomkov v posameznih horizontih. S tem sem želel dobiti paleoekološke podatke, oziroma rešiti vprašanje primarnosti ali sekundarnosti ostankov giroplever. Poleg giroplever so v nekaterih delih vremskih plasti številne tudi foraminifere in alge.

Iskreno se želim zahvaliti mentorju prof. dr. R. Pavlovcu za kritične in vstrajne pripombe, sodelavcem na Inštitutu za raziskovanje krasa ZRC SAZU za razumevanje in moralno podporo, akad. prof. dr. M. Pleničarju in doc. dr. B. Ogorelcu za ogled terena, pregled zbruskov in nasvete, T. Kolar-Jurkovšek za pomoč pri izbiri literature ter M. Zaplatilu, I. Lapajni in M. Grmu za izdelavo fotografij.

DOSEDANJE RAZISKAVE OZEMLJA MED DIVAČO IN VREMSKIM BRITOFOM GLEDE NA OBRAVNAVANO PROBLEMATIKO

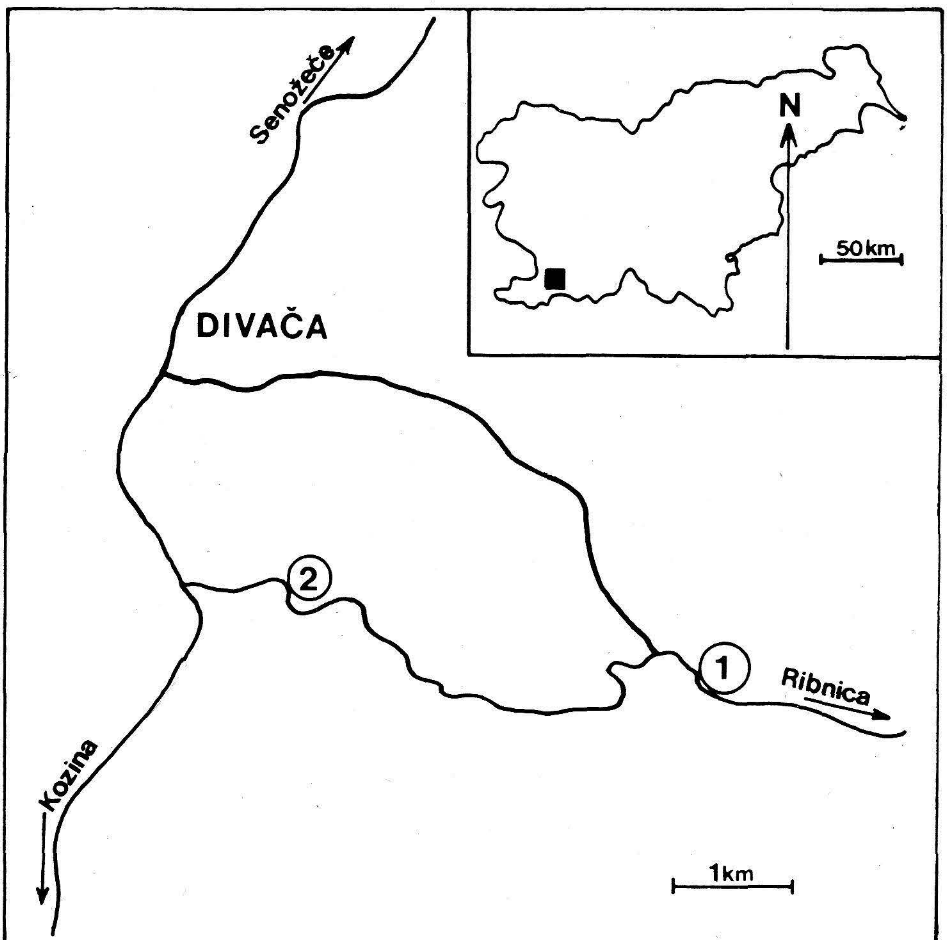
POLOŽAJ PROFILOV VREMSKI BRITOF IN ŠKOCJANSKE JAME GLEDE NA ŠIRŠO GEOLOŠKO ZGRADBO

Raziskana profila sta na prostoru Osnovne geološke karte listov Trst (Pleničar, Polšak & Šikić 1969) in Ilirska Bistrica (Šikić, Pleničar & Šparica 1972) in sicer v neposredni bližini Divače (sl. 1). To je na jugovzhodnem robu tektonske enote Tržaško - Komenska planota blizu meje z brkinskim terciarjem (Šikić & Pleničar 1975; Pleničar, Polšak & Šikić 1973). Kot tektonska enota nižjega reda pripada Tržaško - Komenska planota oziroma Tržaško - Komenski antiklinorij (Buser 1973) Jadransko - Jonski nagubani coni (Pleničar 1970). To celotno ozemlje je del nekdanje Dinarske karbonatne platforme (Drobne et al. 1988; Buser 1989). Po Buserju (1988) pripada to ozemlje Zunanjim Dinaridom, M. Herak (1986, 1989) pa področje južne Slovenije uvršča v Adriatik.

Na Tržaško-Komenski planoti so relativno homogene strukture, od katerih so najpogostejše sinklinale, antiklinale in obsežne prelomne cone. Te so posledica enotne karbonatne sestave ozemlja, ki so bile kot samostojen tektonski blok ob tektonskih pritiskih (Jurkovšek et al. 1989). Geološke strukture imajo v glavnem dinarsko smer. V zahodnem delu planote so tektonske linije usmerjene predvsem v smeri vzhod-zahod.

LIBURNIJSKA FORMACIJA

Pretežno karbonatne sedimente, ki nastopajo v jugozahodni Sloveniji in Istri med rudistnimi apnenci in apnenci z alveolinami ter numuliti, kamor danes uvrščamo tudi vremske



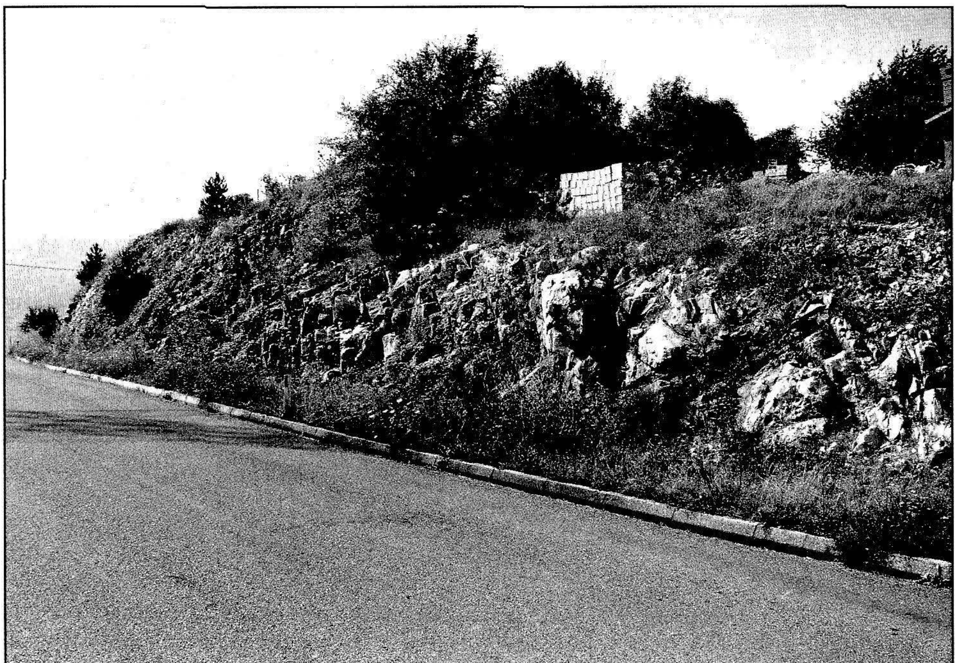
Sl. 1. Položaj profilov. 1-Vremski Britof, 2-Škocjanske jame.
Fig. 1. The location of profiles. 1 - Vremski Britof, 2 - Škocjanske jame.

plasti, je imenoval G. Stache leta 1872 liburnijska stopnja ali protocen. To skladovnico kamnin je (Stache) podrobno preiskoval v letih 1859, 1864, 1867, 1872, 1875 in jo 1889 razdelil na tri dele: spodnji foraminiferni (imperforatni) apnenci, kozinske plasti z vložki glavnega haracejskega apnenca in zgornji imperforatni (miliolidni) apnenec. Stachejeva razdelitev naj bi imela le facialni pomen (Hamrla 1960). Kasneje so liburnijsko stopnjo ovrednotili kot formacijo. Liburnijska formacija (Pavlovec & Pleničar 1979, 1981a) naj bi bila kronolitološki pojem. To pomeni, da vključujemo v liburnijsko formacijo litološko in facialno podobne plasti iz istega razvojnega cikla (od maastrichtija do thanetija).

D'Ambrosi (1931) je liburnijsko formacijo vzporejal s "spilecciano", Hamrla (1959, 1960) pa tudi "liburnik".

Plasti liburnijske formacije so različni avtorji uvrščali v kredo, v terciar ali spodnji del v kredo in zgornjega v terciar (Stache 1889; Pavlovec 1963a, 1963b, 1968; Bignot 1972, 1987; Pavlovec & Pleničar 1981a).

Danes imenujemo spodnji del liburnijske formacije vremske plasti, ki so zgornjemaastrichtijske starosti, srednji del so danijske kozinske plasti, vrhnji del pa miliolidni apnenci thanetijske starosti (Stache 1889; Pavlovec 1963a, 1963b, 1965, 1981a, 1981b; Hamrla 1959, 1960; Drobne 1968, 1979; Bignot 1972, 1987; Hötzl & Pavlovec 1979, 1981; Drobne et al. 1988, 1989; Pavlovec & Drobne 1991).



Sl. 2. Profil Vremski Britof.
Fig. 2. Vremski Britof profile.

Obsežen zgodovinski pregled biostratigrafskih, geotektonskih, hidrogeoloških, paleolitskih, speleoloških, paleogeografskih raziskav ter raziskav mineralnih nahajališč v liburnijski formaciji navajajo Pavlovec in sodelavci (1989). V sestavku, ki opisuje razvoj geološkega znanja o Krasu, kjer so tudi številni podatki o liburnijski formaciji, podaja Martinis (1989).

Meje treh delov liburnijske formacije so zaradi vertikalnega in horizontalnega prepletanja favne nestalne (Stache 1880, 1889; Pleničar 1956). To pomeni, da so istočasno na raznih krajih nastajali različni faciesi ali da ponekod nekaterih delov liburnijske formacije sploh ni. V Istri in Dalmaciji ni vremskih plasti. Favna kozinskih plasti v Istri se nekoliko razlikuje od značilnih oblik v južni Sloveniji (Hamrla 1960).

Nastanek liburnijske formacije sovpada z laramijsko fazo (Buser 1989; Herak 1989). S tem si lahko razložimo heterogenost in hitro spreminjanje sedimentacijskih pogojev (Pavlovec, 1981c).

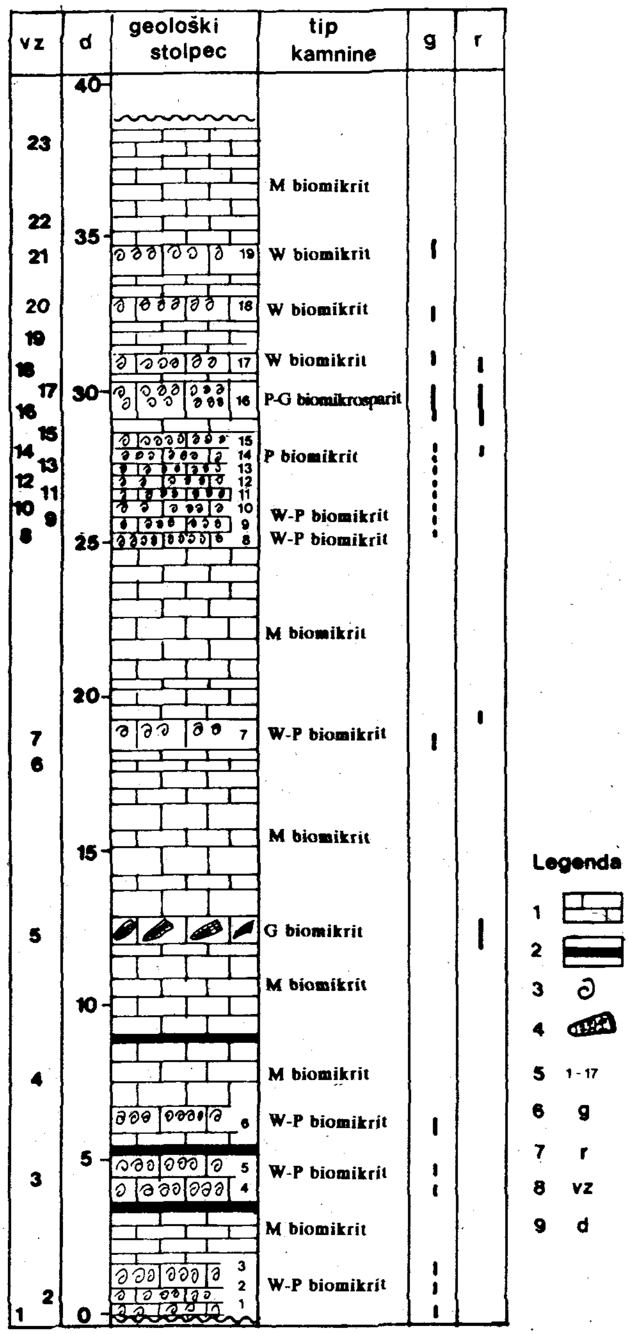
VREMSKE PLASTI

Glede starosti vremskih plasti je bilo zelo veliko različnih mnenj. Stache (1889) jih je uvrstil v "protocen", Schubert (1905) v danij (kreda), Vardabasso (1923) v eocen (paleocen) in D'Ambrosi (1942, 1955) v zgornjo kredo. Pleničar (1961) in Martinis (1962) imenujeta vremske plasti "apnenci z giroplevrami" in jim pripisujeta danijsko (kreda) starost. Pavlovec (1963a) je vremskim plastem dal ime in jih uvrstil v spodnji del liburnijske formacije v danij (paleocen). Po Bignotu (1972) so vremske plasti senonijske starosti. Za danijsko starost se je opredelila tudi Drobne (1977, 1979). Ker Pavlovec in Pleničar (1979) trdita, da je meja med kredo in terciarjem nad vremskimi plastmi, Hötzl in Pavlovec (1979) zagovarjata maastrichtijsko starost plasti z giroplevrami v profilu Vremski Britof. Podobno se opredeljujeta tudi Pavlovec in Pleničar (1981a) in prideta istega leta (1981b) do zaključka, da so vremske plasti zgornjemaastrichtijske, kar velja še danes (Hötzl & Pavlovec 1979; Pavlovec 1981c; Drobne et al. 1988, 1989; Pavlovec & Drobne 1991).

Vremske plasti sestavljajo predvsem temni drobnoplastnati, ponekod močno bituminozni apnenci, redkeje laporni apnenci in premogovi skrilavci ter vložki premoga (Pleničar 1956; Hamrla 1959, 1960; Pavlovec 1965). Med omenjenimi plastmi so najverjetneje tudi singenetske breče (Drobne & Pavlovec 1991). V nekaterih horizontih so številne "hamidne školjke" (Pleničar 1961) iz rodu Gyropleura in Apricardia (Pleničar 1992), foraminifere Rhapydionina liburnica, Montcharmontia appenninica in miliolide (Drobne 1981; Pavlovec & Drobne 1991).

Sl. 3. Geološki stolpec profila Vremski Britof. 1-apnenec, 2-močno bituminozna kamnina, 3- giroplevre, 4-rapidionine, 5-št. horizonta z giroplevrami, 6-giroplevre, 7-rapidionine, 8-vzorec, 9-debelina (m).

Fig. 3. The geological column of Vremski Britof profile. 1 - limestone, 2 - very bituminous rock, 3 - Gyropleura, 4 - Rhapydionina, 5 - no. of Gyropleura horizon, 6 - Gyropleura, 7 - Rhapydionina, 8 - sample, 9 - thicknes (in m).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Fosilni ostanki kažejo, da se je večji del vremskih plasti sedimentiral v plitvem morju (Hötzl & Pavlovec 1981; Pavlovec 1981c), blizu obale in deloma v plitvih lagunah (Drobne & Pavlovec 1991), ki so bile najverjetneje občasno omejene z rudistnimi biohermami (Pavlovec & Pleničar 1983).

OKOLICA PROFILOV VREMSKI BRITOF IN ŠKOCJANSKE JAME

Na podlagi 16-tih raziskovalnih vrtin, podatkov iz premogovnika in površinske geologije je Hamrla (1959) opisal profil produktivnih liburnijskih plasti pri Vremskem Britofu v skupni debelini okrog 300 m. V tem opisu so posredno vključene tudi vremske plasti, ki naj bi po njegovih podatkih nastale deloma v morskem, deloma v brakičnem in sladkovodnem okolju.

Hamrla (1959) horizontov z giroplevrami in rodu Gyropleura izrecno ne omenja. Prav tako ne omenja vrste Rhapydionina liburnica, temveč le peneroplide, čeprav so vsi ti fosili pogosti v opisanem profilu. Hamrla omenja nekatere rodove haracej, polžev in miliolid. Kaj misli z "morsko favno školjk" iz besedila ni jasno razvidno, vendar so to gotovo horizonti z giroplevrami.

Pri ponovnem opisu profila iz okolice Vremskega Britofa Hamrla (1960) ne navaja bistvenih novosti. Podobno kot leta 1959 ugotavlja pod glavnim morskim horizontom v splošnem tri sladkovodne z dvema vmesnima morskima fazama, nad glavnim morskim horizontom pa dve sladkovodni fazi z vmesno morsko.

Pleničar (1961) je pri podrobnejši obdelavi krednih plasti južne Primorske in Notranjske raziskoval tudi spodnji del liburnijske formacije, kamor spada tudi okrog 350 m debel profil številka 2 (Pleničar, 1961), ki se začne pri Škofljah ob kontaktu spodnjesenonijskih in zgornjesenonijskih apnencev (vremske plasti) in sega do "morskega horizonta" južno od Vremskega Britofa.

Iz "morskega horizonta" v bližini Divače opisuje Pleničar (1961) dve pol metra debeli plasti hamidnih školjk iz rodu Gyropleura, ki sta med seboj oddaljeni okrog 1 m. Med njima je apnenec z redkimi oogoniji haracej, foraminiferami in malimi ostrigami, ki kažejo na morsko okolje. Po njegovih podatkih dobimo obe plasti pri Divači, Kozini, vzdolž pasu liburnijske formacije od Vremskega Britofa do Lipice, ter na robu Reške flišne kadunje. Omenja tudi vrsti Rhapydionina liburnica in Rhipidionina liburnica, tekstularide in rotalide.

Pleničar (1961) je prvi opisal rod Gyropleura iz "foraminifernih apnencev in apnencev z giroplevrami", kot je imenoval te plasti. Med drugim ugotavlja, da so v spodnjem delu kozinskih apnencev giroplevre na primarnem mestu in da pripadajo ti apnenci kredni dobi.

Pavlovec (1963a) se opira na Pleničarjev (1961) profil iz okolice Vremskega Britofa, opisal pa je med drugim tudi do takrat iz tega ozemlja neznane favnistične in floristične vrste. K Vremskem Britofu se vrača tudi pri problemu starosti vremskih plasti ter pri paleogeografski predstavitvi.

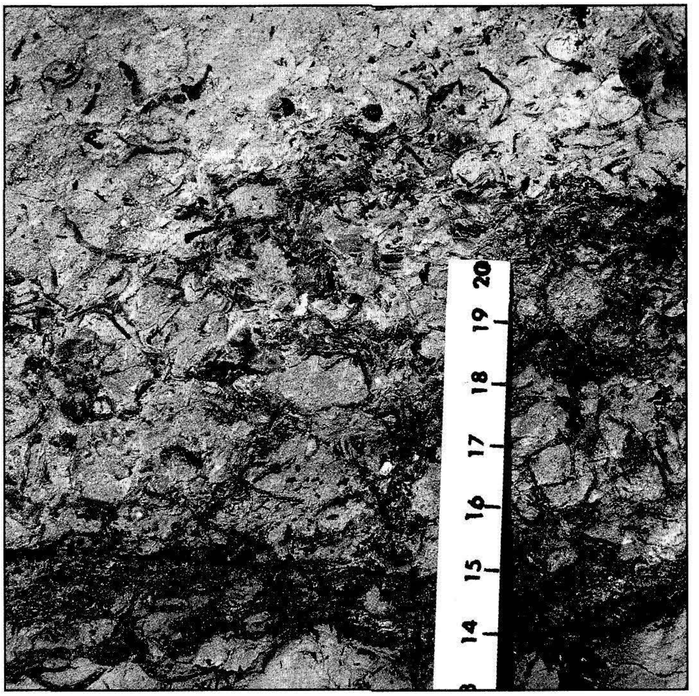
Istega leta je Pavlovec (1963b) objavil podobno tematiko, vendar s poudarkom na stratigrafiji produktivnih liburnijskih plasti.

Stratigrafski pregled liburnijskih plasti v severozahodni Jugoslaviji je Pavlovec podal leta 1964. Kratek pregled plasti s premogom iz Vremskega Britofa povzema Bignot (1972) po Lodinu (1883) in Iwanu (1904).

Drobne (1979) omenja iz senonija ali danija v okolici Vremskega Britofa dva ali več horizontov školjk iz rodu Giropleura, med katerimi so v nekaterih plasteh foraminifere Rhapydionina liburnica in Rhipidonina liburnica. V apnencih naj bi bili pogosti tudi ostanki haracej, miliolide in polži iz rodu Stomatopsis.

Profil v cestnem useku pri vasi Vremski Britof sta prvič opisala Hötzl in Pavlovec (1979). Od skupne debeline 50 m sta na skici litološkega stolpca predstavila le 16 m. V spodnjem delu profila sta opisala svetlosiv apnenec z lupinami giroplever, ki so v nekaterih delih kamnotvorne. V srednjem delu se izmenjavajo plasti z giroplevrami s plastmi temnega bituminoznega apnenca, ki ponekod vsebuje do 10 cm premogu podobne vložke. V apnencu so pogoste različne foraminifere in redke alge. V zgornjem delu profila opisujeta v apnencu pogostejše giroplevre, miliolide in foraminiferi Rhapydionina liburnica in Rhipidionina liburnica. Med pomembnejšimi fosili omenjata še vrsto Montcharmontia apenninica, Discorbis (sensu Bignot 1972), Bolivinopsis sp., Miliolidae (Quinqueloculina sp., Triloculina sp., Spiroloculina sp.), Thaumatoporella parvovesiculifera in ostrakode.

Opis profila pri Vremskem Britofu z nekaterimi novimi podatki se ponovno pojavi dve



Sl. 4. Tretji horizont z giroplevrami.
Fig. 4. The third horizon containing Gyropleura.

leti kasneje (Pavlovec 1981a). Avtor poudarja, da so horizonti z giroplevrami ena od značilnosti vremskih plasti.

Istega leta omenjata profil pri Vremskem Britofu Hötzl in Pavlovec (1981). Menita, da so tu najbolje razgaljene vremske plasti, saj profilom v drugih krajih manjka spodnji oziroma zgornji del, ponekod pa so prekinjeni zaradi tektonike.

V zvezi s problemom foraminifernih združb je leta 1981 omenjeni profil predstavila tudi Drobne. Omenja predvsem foraminiferni vrsti Rhapydionina liburnica in Rhipidionina liburnica ter med plastmi apnenca vložke premoga. Da se v maastrichtijskih apnencih iz okolice Vremskega Britofa pojavljajo dva ali več horizontov z školjkami iz rodu Gyropleura, ter da so med temi horizonti foraminifere Rhapydionina liburnica, poročata še Drobne in Pavlovec (1991). Zadnja objava opisa profila pri Vremskem Britofu z nekaterimi novimi pogledi glede avtohtonosti oziroma alohtonosti giroplever, je iz leta 1991 (Pavlovec & Drobne).

Profila Škocjanske jame ni do sedaj nihče opisal. Geologijo bližnje okolice Škocjanskih jam je nekoliko podrobneje opisal le Gospodarič (1983). V svoji razpravi daje večji poudarek speleogenezi Škocjanskih jam, vendar omenja vremske plasti kot skladnate in drobnoskladnate apnence s plastmi premoga. Uvršča jih v zgornji maastrichtij in morda danij. Osnovni geološki podatki za ta prostor pa so v Tolmaču za list Trst (Pleničar, Polšak & Šikić 1973) in Ilirska Bistrica (Šikić & Pleničar 1975) ter na Osnovnih geoloških kartah listov Trst (Pleničar, Polšak & Šikić 1969) in Ilirska Bistrica (Šikić, Pleničar & Šparica 1972).

OPISI PROFILOV

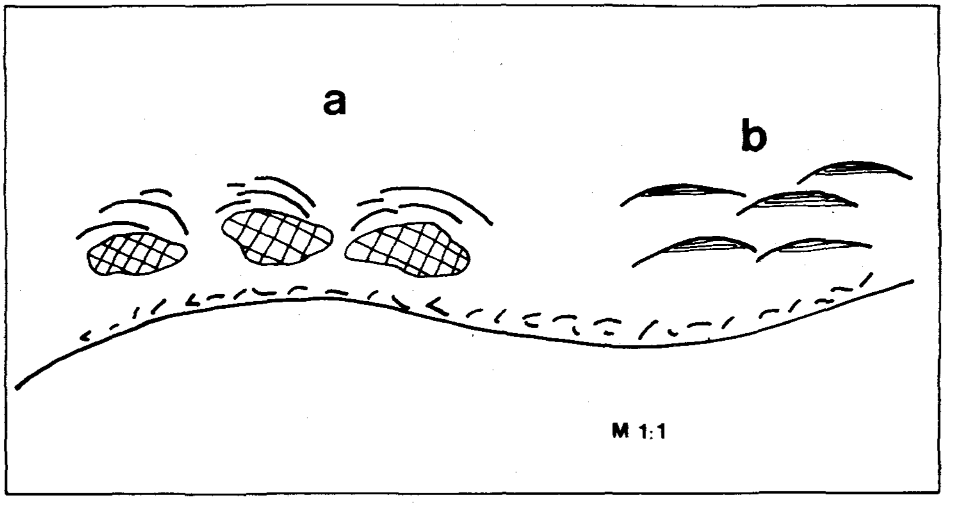
PROFIL VREMSKI BRITOF

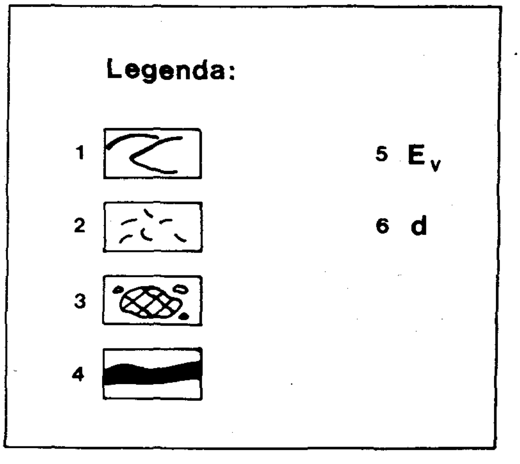
UVOD

Profil je bil leta 1979 (Hötzl & Pavlovec) odkrit v dolžini okrog 130 m, debelina plasti je bila okrog 50 m. Zaradi zaraščanja in rušenja sten cestnega useka je danes mogoče videti le še slabih 40 m (sl. 2). Horizonti z giroplevrami se pojavljajo v skupni dolžini 84 m in ta del sem tudi natančno opisal. Vpad plasti je večinoma 140/30.

Kljub več opisom okolice Vremskega Britofa se do sedaj ni še nihče podrobno ukvarjal s horizonti z giroplevrami in s položajem lupin giroplever ter njihovih odlomkov.

Pri nadaljnem opisu bom govoril le o bolj poznanem rodu Gyropleura, čeprav so po mnenju Pavlovca in Pleničarja iz leta 1983 v horizontih tudi školjke iz rodu Apricardia. V svoji razpravi pa Pleničar (1992) jasno navaja, da se pojavljajo v vremskih plasteh poleg giroplever tudi aprikardije in sicer vrsta (Apricardia pachiniana Sirna), ki je značilna za zgornji senon.





Sl. 5. Odsek tretjega horizonta z giroplevrami z intraklasti (a) in dežnikasto poroznostjo (b). Legenda: 1-dobro ohranjene lupine giroplever, 2-razlomljene lupine giroplever, 3-intraklasti, 4-močno bituminozna kamnina, 5-relativna vrednost energije vode, 6-relativna debelina horizonta z giroplevrami (v cm).
Fig. 5. A section of the third horizon containing Gyropleura with intraclasts (a) and shelter porosity (b). Legend: 1 - well preserved Gyropleura shells, 2 - broken Gyropleura shells, 3 - intraclasts, 4 - very bituminous rock, 5 - relative value of water energy, 6 - relative thickness of Gyropleura horizon (in cm).

LEGA PROFILA VREMSKI BRITOF

Profil Vremski Britof leži 3,5 km jugovzhodno od Divače v cestnem useku ceste Divača - Ribnica severno od vasi Vremski Britof v dolini reke Reke.

HORIZONTI Z GIROPLEVRAMI

V profilu Vremski Britof je 19 horizontov z giroplevrami (sl. 3), ki sem jih označil z od spodaj navzgor zaporednimi številkami od 1 do 19.

1. giroplevrski horizont

Debelina horizonta se spreminja od 5 do 8 cm. V tem horizontu so skoraj same cele lupine, velike večinoma do 3 cm; odlomkov, med katere štejem vse razlomljene dele lupin, je izredno malo, lateralno pa ponekod lupine in odlomki izginejo. Večinoma sta v sedimentu obe školjčni lupini skupaj. Pod in nad horizontom z giroplevrami ni drugih makrofosilov. Horizont z giroplevrami se ostro začne in pravtako konča. V spodnjem delu horizonta z giroplevrami leži nekoliko več lupin vzporedno druga nad drugo in tesno druga ob drugi. Lupine so verjetno zaradi pritiskov v sedimentu precej sploščene. Proti vrhu horizonta z giroplevrami je sploščenih lupin vse manj. Tudi nesploščenih lupin giroplever in njihovih odlomkov je tam manj. Postopno je navzgor vse več celih in lepo ohranjenih posamičnih lupin giroplever, ki se ne dotikajo med seboj, kot je to v nižjih delih horizonta.

2. horizont

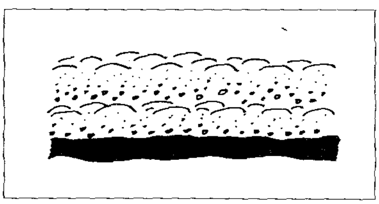
Ta horizont leži 70 cm nad prvim. Debel je 15 cm. V njem so večinoma razlomljene lupine giroplever. Celih lupin je po približni oceni največ 5%. Horizont z giroplevrami ima v spodnjem in zgornjem delu ostro mejo. V spodnjem delu horizonta je precej večjih (10 mm) zaobljenih delcev kamnine, katere uvrščam med intraklaste. Njihovo število se lateralno hitro spreminja.

Spodnja površina drugega horizonta z giroplevrami je na nekaterih delih valovita in kaže na takratno podlago, na katero so bile lupine giroplever prenešene. Lateralno so ponekod celo do 4 cm velike vdolbine v nekdanjem morskem dnu, katere so zapolnjene z lupinami. Ker so vdolbine v drugem horizontu le lokalne anomalije, je potrebno poudariti, da je v splošnem spodnja ploskev horizonta z giroplevrami bolj ali manj ravna in gladka do rahlo valovita.

Po celotnem drugem horizontu z giroplevrami so lupine giroplever v glavnem enakomerno razporejene. Izjema sta le najnižji in najvišji del, debela po 0,5 cm, kjer so lupine giroplever pogostejše. Horizont ima tako v vertikalnem preseku dva ekstrema v pojavljanju lupin giroplever. V sredini horizonta ležijo večji in manjši delci lupin giroplever v smeri plasti. Tam je tudi več celih lupin giroplever, ki jih je ponekod celo več kot odlomkov.

3. horizont

Med drugim in tretjim horizontom z giroplevrami je 45 cm sivega mikritnega apnenca brez giroplever. Debelina tretjega horizonta je 17 cm. Spodnja površina horizonta je precej neravna, množina lupin giroplever pada od spodnjega proti zgornjemu robu horizonta. Proti vrhu horizonta je več drobcev (deli lupin, manjši od 5 mm) lupin (sl. 4), ki končno postopno izginejo. Tretji horizont z giroplevrami torej nima tako razporejenih lupin kot drugi horizont



Sl. 6. Odsek četrtega horizonta z giroplevrami. Legenda pri sl. 5.
Fig. 6. A section of the fourth horizon containing Gyropleura. Legend at Fig. 5.

z giroplevrami. Tam, kjer se število giroplever navzgor zmanjšuje, opazimo številne dele v kamnini, kjer giroplever sploh ni ali so zelo redke.

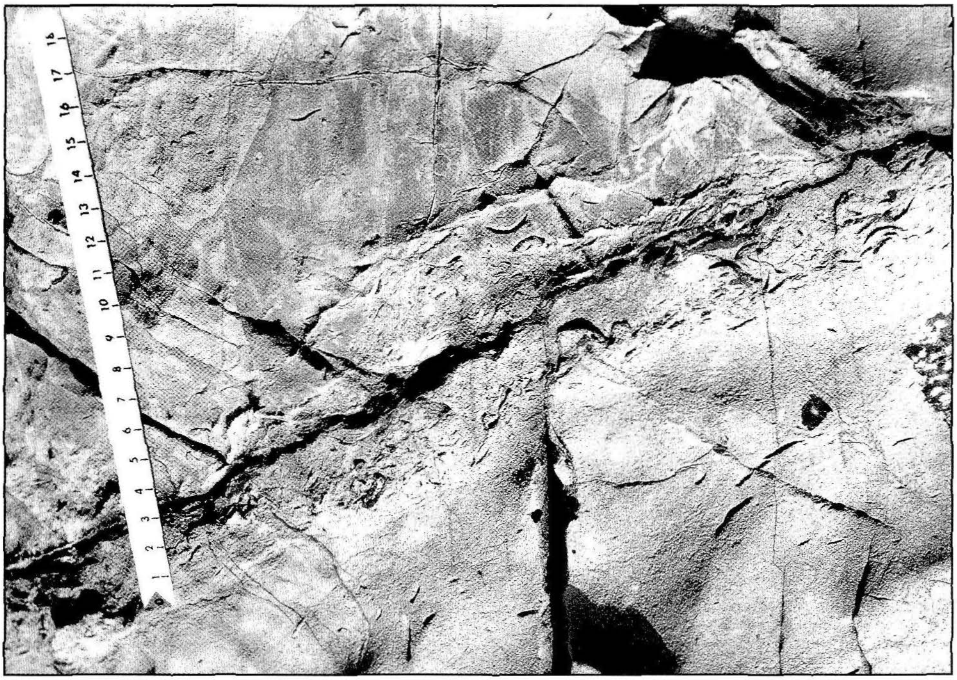
Na bazi horizonta je 1 do 2 cm debel pas kamnine, v katerem so giroplevre izredno nakopičene. Lupine ležijo ena na drugi in so vzporedne s plastmi. 50 do 60 % lupin giroplever, velikih od 1 do 2 cm, je celih ali malo poškodovanih. Področja z redkimi giroplevrami imajo dvojen značaj (slika 5):

a) Polja vsebujejo intraklaste, na katerih ležijo lupine giroplever;

b) Pod lupinami opazujemo jasno izraženo dežnikasto poroznost (sl. 5).

4. horizont

Četrti horizont je 2,90 m nad tretjim in je debel 9 cm. Za četrti horizont je značilno, da so giroplevre v dveh tankih polah nad 8 cm debelo močno bituminozno plastjo (sl. 6). Pri obeh tankih polah z lupinami giroplever izgleda, da sta bili odloženi na zgornjo površino dveh sedimentacijsko različnih apnenčevih delov plasti. Prvo, 2 cm debelo polo, ki leži na močno bituminoznem horizontu, sestavljajo drobni intraklasti, drugo pa drobnozrnat mikritni sediment, v katerem se navzgor manjša velikost zrn.



Sl. 7. Peti horizont z giroplevrami.
Fig. 7. The fifth horizon containing Gyropleura.

5. horizont

Peti horizont z giroplevrami leži 35 cm nad četrim horizontom in je debel 6 cm (sl. 7). Spodnja ploskev petega horizonta z giroplevrami je zelo valovita, tako da variira navzgor in navzdol za okrog 4,5 cm. Vdolbine oziroma kotanje na nekdanji morski podlagi so zapolnjene tako z drobirjem lupin giroplever kot s celimi lupinami.

Drobci lupin giroplever so nad vdolbinami razporejeni v zelo tankih (0,5 cm) nakopičenjih (v horizontu makroskopsko izgledajo kot debelejše črte), ki so vzporedni s plastnatostjo (sl. 8). Med drobci so tudi redkejše cele lupine, ki imajo debelejše stene od drobcev.

6. horizont

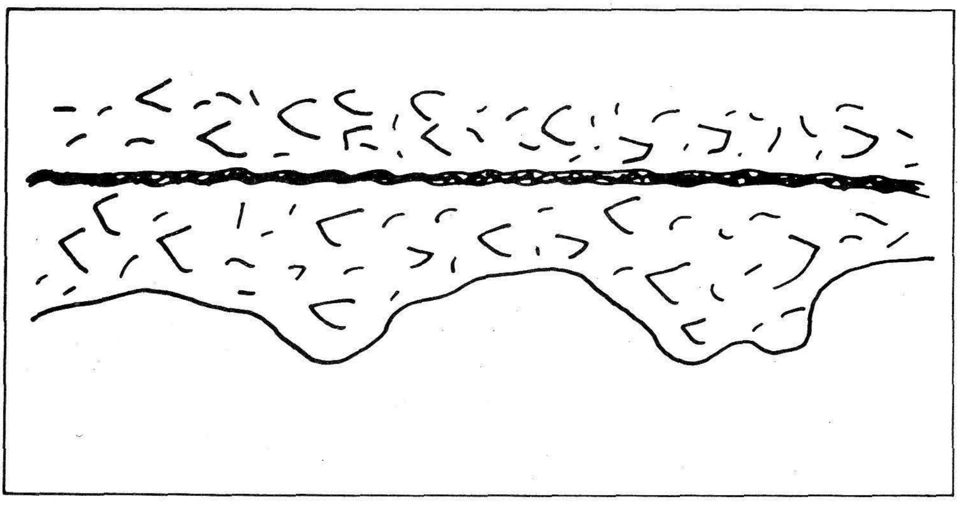
Med petim in šestim horizontom z giroplevrami je 105 cm apnenca brez lupin giroplever. Šesti horizont z giroplevrami je debel 7 cm.

V najnižjih 2 cm horizonta so redki odlomki lupin giroplever, ki so se vsedli na rahlo valovito površino morskega dna. Množina odlomkov se po horizontu lateralno ponekod močno spreminja. Med lupinami v sedimentu ni intraklastov ali plastiklastov. Sledi 3 cm debel del horizonta, v katerem je do približno 85% celih lupin giroplever.

Delu horizonta s celimi lupinami sledi do 2 cm debel del horizonta s številnimi pomešanimi celimi lupinami in njihovimi odlomki.

7. horizont

Med šestim in sedmim horizontom je 11,80 m apnenca brez giroplever. Sedmi horizont je debel 7 cm in leži v profilu 4,60 m nad točko 26 iz profila, ki sta ga opisala Hötzl in Pavlovec (1979).



Sl. 8. Odsek petega horizonta z giroplevrami z valovito spodnjo ravnino. Legenda pri sl. 5.
Fig. 8. A section of the fifth horizon containing Gyropleura with ondulated lower plain. Legend at Fig. 5.

Pod sedmim horizontom je 20 cm bituminoznega mikrita s homogeno sestavo, v katerem je nekaj stilolitnih šivov. V njem sem in tja opazimo redke dendrite. Fosilnih ostankov v mikritni plasti ni.

Številne giroplevre se v sedmem horizontu pojavijo nenadoma. V tem horizontu dobimo večinoma cele lupine giroplever, nekaj je tudi odlomkov. Zdrobljenih lupin ni.

Takoj nad horizontom z giroplevrami so v 30 cm debelem apnencu številne miliolide, ki jih nad doslej opisanimi horizonti z giroplevrami nisem opazil. Navzgor sledi mikritni apnenec brez fosilov. V njem so številni stilolitni šivi.

Nad in pod sedmim horizontom z giroplevrami je apnenec veliko bolj temen, skoraj črn in bolj bituminozen kot v samem horizontu z giroplevrami.

8. horizont

Mikritnemu apnencu brez fosilov sledi navzgor osmi horizont z giroplevrami, ki je oddaljen od sedmega 7,40 m in je debel od 13 do 16 cm. Bočno opazimo na kratke razdalje manjše spremembe debeline. Večina lupin giroplever je velika okrog 4 cm. Zelo lepo je izražena spodnja valovita površina horizonta, ki predstavlja nekdanje morsko dno (sl. 9). Navzgor in navzdol odstopa za nekaj centimetrov.

Osmi horizont z giroplevrami se začne z 1 cm debelo polo nakopičenih lupin giroplever,

Sl. 9. Osmi horizont z giroplevrami.
Fig. 9. The eight horizon containing Gyropleura.

ki v sedimentu ležijo tako, da so z daljšo osjo vzporedne s plastnatostjo. Cele lupine giroplever so dobro ohranjene, njihovi odlomki pa imajo ostre robove.

Zanimivo je tudi to, da je v zgornjem delu horizonta večina lupin giroplever dobro ohranjenih in v se druga druge ne dotikajo. Med seboj so oddaljene vsaj en centimeter.

Podobno, kot pri šestem, so tudi v tem horizontu z giroplevrami jasno ločeni trije tipi vsedanja lupin giroplever (sl. 10):

a) V kotanjah oziroma nekakšnih vdolbinicah, globokih od 3 do 5 cm, ležijo v različnih smereh nakopičene lupine giroplever, ki kotanje popolnoma zapolnjujejo;

b) Na bolj ali manj ravnem delu nekdanjega morskega dna so se vsedale lupine giroplever in kjer je horizont z giroplevrami debel nekaj centimetrov; ta del horizonta z giroplevrami hkrati v enaki debelini prekriva tudi zapolnjene kotanje;

c) Na dvignjenih delih nekdanjega morskega dna lupin giroplever skoraj ni. Zanimivo je, da ležijo lupine giroplever v sedimentu vedno tako, da je njihova daljša os vzporedna s plastnatostjo.

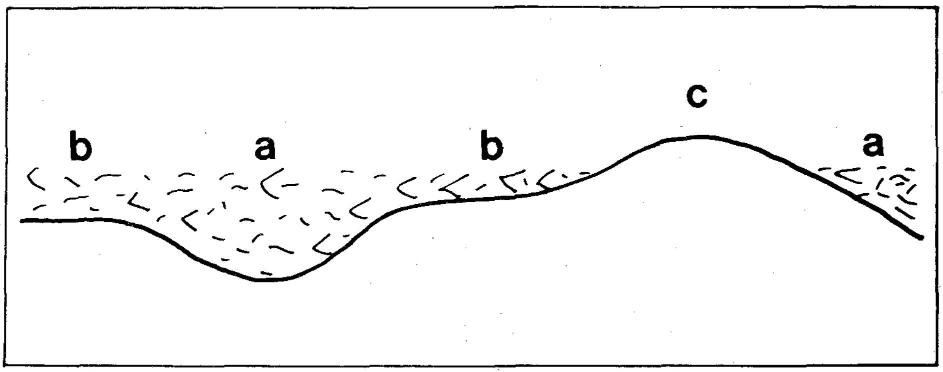
9. horizont

Med osmim in devetim horizontom z giroplevrami je 40 cm apnenca brez g. Debelina devetega horizonta je okrog 5 cm. Spodnja meja je zelo neizrazita, saj se začne postopoma z redkimi drobnimi odlomki lupin giroplever. Višje v horizontu je sicer odlomkov lupin giroplever več, vendar ne presežejo velikosti 1 cm.

Deveti horizont z giroplevrami je zanimiv zato, ker se prvič v horizontih z giroplevrami pojavijo tudi rapidionine.

10. horizont

Deseti horizont z giroplevrami je pri točki 30, v profilu Hötzla in Pavlovca (1979). Med devetim in desetim horizontom z giroplevrami je 40 cm apnenca brez g. Zaradi izredne nagrmadenosti sem nanešenih lupin giroplever je 6 cm debel deseti horizont z giroplevrami popolnoma črne barve in diši po bitumnu. Spodnji dve tretjini horizonta vsebujeta drobce



Sl. 10. Tri področja vsedanja lupin giroplever. Legenda pri sl. 5.
Fig. 10. Three areas of the Gyropleura shells deposition. Legend at Fig. 5.

lupin giroplever, velikih nekaj milimetrov. Vmes so redke miliolide. V zgornji tretjini horizonta z giroplevrami dobimo skoraj cele lupine. Pod desetim horizontom z giroplevrami je rjav do temnorjav apnenec z miliolidami in redkimi rapidioninami.

Takoj nad njim je svetlejši, temnosiv apnenec z redkimi odlomki giroplever in z maloštevilnimi rapidioninami, ki postanejo po petih do decetih centimetrih zelo številne.

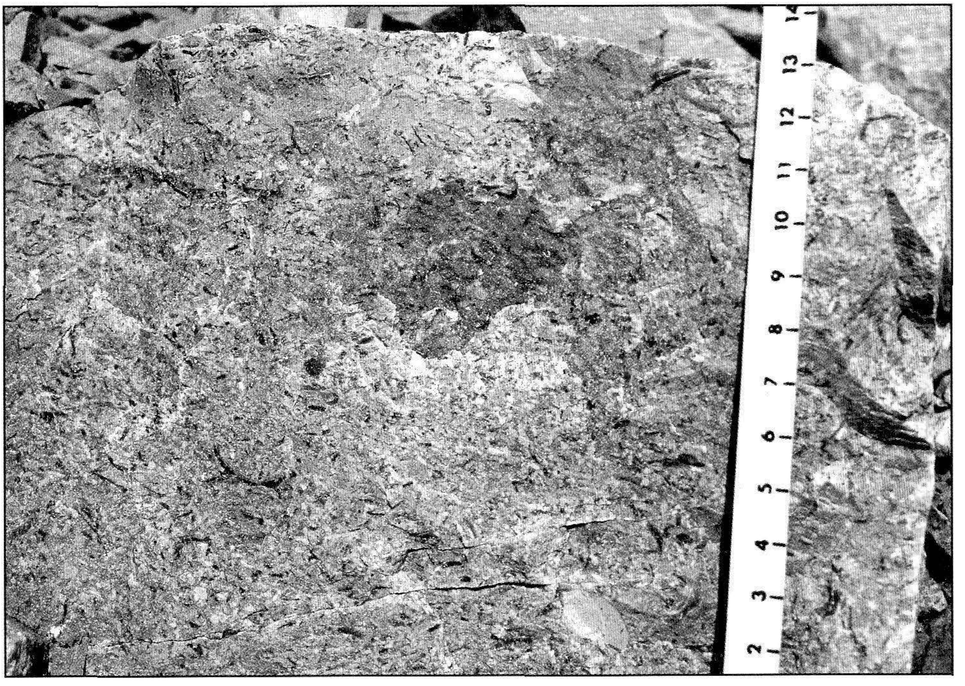
11. horizont

Med desetim in enajstim horizontom z giroplevrami ležijo posamezne cele lupine giroplever in posamezni intraklasti, kar je sicer v profilu Vremski Britof redkost.

Enajsti horizont z giroplevrami je 12 cm debel, temnorjav do črn, močno bituminozni apnenec, v katerem so nakopičene lupine giroplever, pomešane z njihovimi odlomki. Srednji del horizonta vsebuje redkejše cele lupine giroplever.

12. horizont

Dvanajsti, 4 cm debel horizont z giroplevrami, se začne 10 cm nad enajstim horizontom. Večinoma zaradi pritiskov sploščene in zdrobljene lupine giroplever ležijo v črnem bituminoznem sedimentu. Horizont z giroplevrami v zgornjem delu hitro preide v svetlosiv do temnosiv apnenec z redkimi miliolidami in rapidioninami.



Sl. 11. Zelo zdrobljene lupine giroplever.
Fig. 11. Very broken Gyropleura shells.

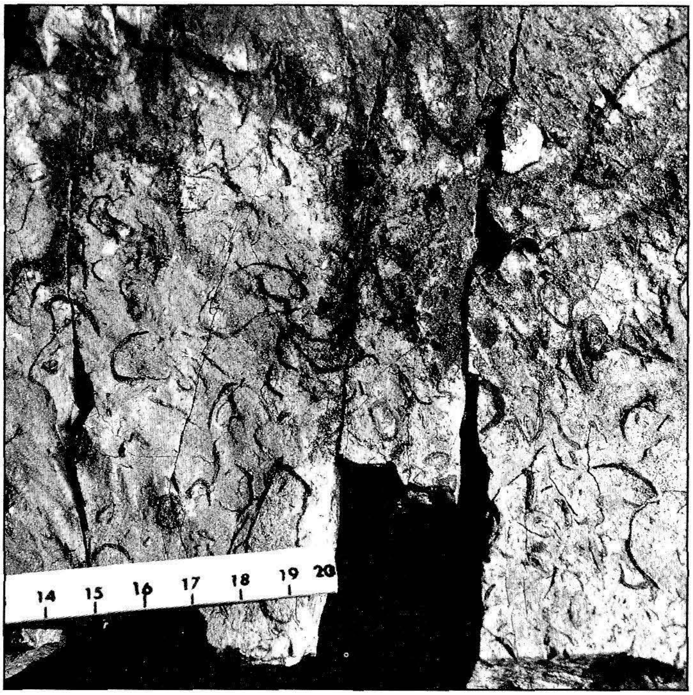
13. horizont

Med dvanajstim in trinajstim, 12 cm debelim horizontom z giroplevrami, je 50 cm apnenca brez giroplever in drugih fosilov.

Mikrosparitni apnenec pod trinajstim horizontom z giroplevrami hitro preide v bolj debelozrnat apnenec s številnimi rapidioninami in odlomki ter drobirjem giroplever. Celih lupin giroplever v tem horizontu ni. Po celotnem horizontu so giroplevre enakomerno razporejene. Drobci lupin giroplever so znotraj trinajstega horizonta z giroplevrami razvrščeni v 1 cm debelih pasovih. Horizont se konča brez izrazitih prehodnih delov. Nad njim je mikrosparitni apnenec.

14. horizont

35 cm nad trinajstim je 11 cm debel štirinajsti horizont mikritnega apnenca z giroplevrami. Ima podobne značilnosti kot drugi horizont z giroplevrami. Ob spodnjem in zgornjem robu je v debelini 3 cm veliko nakopičenih celih lupin in odlomkov giroplever. V sredini horizonta so cele lupine redkejše in se le izjemoma dotikajo med seboj. Takšna razporeditev lupin giroplever v horizontu se ponekod bočno delno spreminja. V srednjem delu horizonta so tri, zaradi velike koncentracije lupin giroplever, temne proge. Rapidionin v tem horizontu nisem opazil.



Sl. 12. V sedemnajstem horizontu z giroplevrami so večinoma cele lupine.
Fig. 12. Within the 17^{th} horizon containing Gyropleura the whole shells predominate.

Štirinajsti horizont z giroplevrami preide navzgor v 40 cm debel, skoraj bel apnenec brez giroplever.

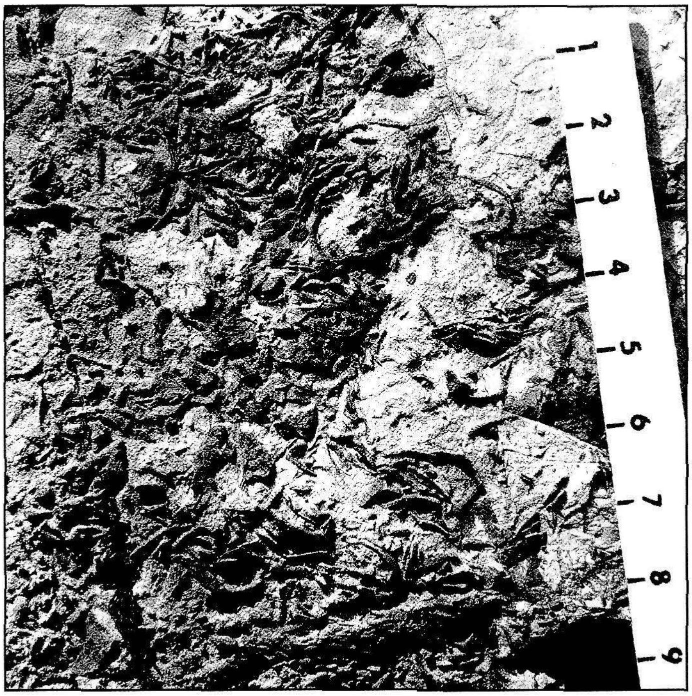
15. horizont

Razdalja med štirinajstim in petnajstim horizontom z giroplevrami je 15 cm. Tri centimetre debel horizont s celimi lupinami giroplever in njihovimi odlomki se pojavi brez postopnega prehoda in v vrhnjem delu prav tako preide v svetlosiv mikrosparit s posameznimi *miliolidami*.

16. horizont

Med petnajstim in šestnajstim horizontom z giroplevrami je 85 cm svetlosivega apnenca z redkimi miliolidami in rapidioninami. Debelina šestnajstega horizonta je 90 cm. 5 do 10 cm pod šestnajstim horizontom število rapidionin hitro narašča in je v apnencu tik pod začetkom horizonta največje. Množina rapidionin ostane enaka ali se še nekoliko poveča v spodnjem delu šestnajstega horizonta, v katerem so skoraj izključno drobci in odlomki lupin giroplever (sl. 11). Tu je rapidionin toliko, da so skoraj kamnotvorne.

Proti vrhu šestnajstega horizonta z giroplevrami se množina zdrobljenih lupin giroplever postopno zmanjšuje, zmanjšuje pa se tudi količina rapidionin. Na koncu šestnajstega



Sl. 13. Izsek devetnajstega horizonta z giroplevrami.
Fig. 13. A section of 19th horizon containing Gyropleura.

horizonta, razen redkih izjem, izginejo tudi rapidionine. Takrat pa nastopijo v večjem številu miliolide, ki jih je prej skupaj z rapidioninami manj.

17. horizont

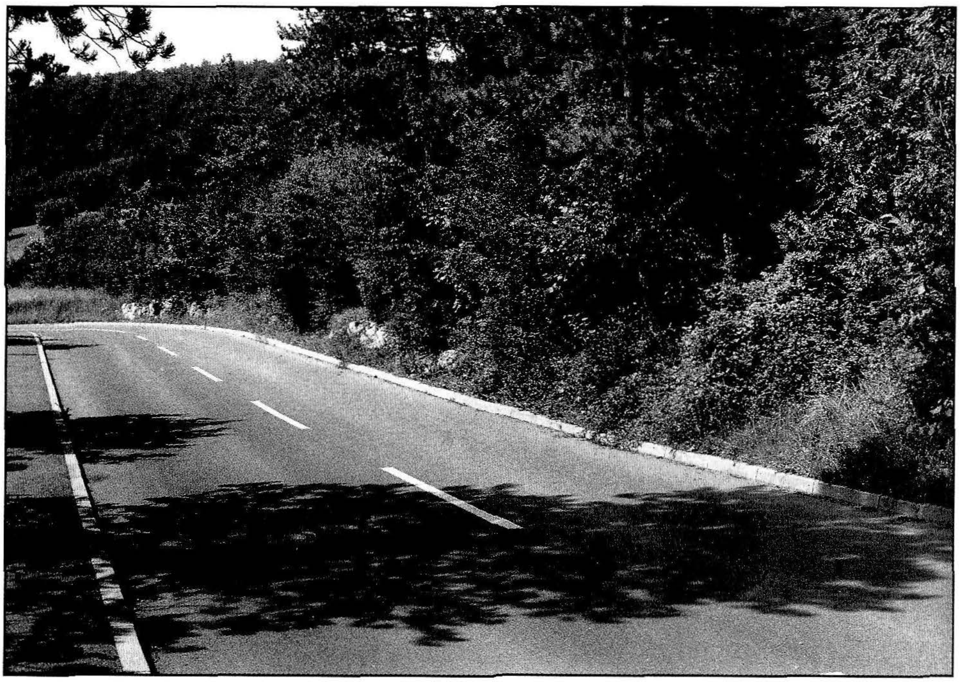
Med šestnajstim in sedemnajstim horizontom z giroplevrami je 45 cm apnenca 35 cm debel sedemnajsti horizont se začne in konča z neizrazito mejo. V njem so večinoma cele lupine giroplever (sl. 12). V srednjem delu horizonta so med posameznimi drobci lupin giroplever tudi redke rapidionine, ki jih je nekoliko več le v zgornjem delu sedemnajstega horizonta, kjer drobci lupin giroplever prevladuje nad celimi lupinami. Rapidionin od tu naprej v profilu Vremski Britof ni več.

18. horizont

Osemnajsti, 5 cm debel horizont z giroplevrami, je 170 cm nad sedemnajstim. Horizont vsebuje enakomerno pomešane cele lupine giroplever in njihove odlomke.

19. horizont

Devetnajsti horizont je 180 cm nad osemnajstim. Debel je 20 cm in ima podobne lastnosti kot osemnajsti horizont z giroplevrami (sl. 13).



Sl.14. Profil Škocjanske jame.
Fig. 14. Škocjanske jame profile.

PROFIL ŠKOCJANSKE JAME

UVOD

Po Geološki karti krasa Škocjanskih jam (Gospodarič 1983) in drugih podatkih (Gospodarič 1984) sem izbral del, v katerem je zajetih večji del vremskih plasti. Profil sem označil kot Škocjanske jame (sl. 14).

LEGA PROFILA ŠKOCJANSKE JAME

Profil Škocjanske jame leži v neposredni bližini upravne zgradbe Škocjanskih jam HTG v povprečno manj kot 1 m visokem useku poti med cesto, ki povezuje Matavun z regionalno cesto Divača - Kozina in upravno zgradbo Škocjanskih jam HTG. To je na skrajnem severovzhodnem delu Osnovne geološke karte SFRJ, list Trst, v merilu 1:100 000 (Pleničar, Polšak & Šikić 1969). Profil Škocjanske jame se začne tam, kjer je po Gospodaričevi karti (1983) začetek maastrichtijskih plasti in se konča tam, kjer je na tej karti maastrichtijske plasti prehajajo v spodnjepaleocenske.

OPIS PROFILA ŠKOCJANSKE JAME

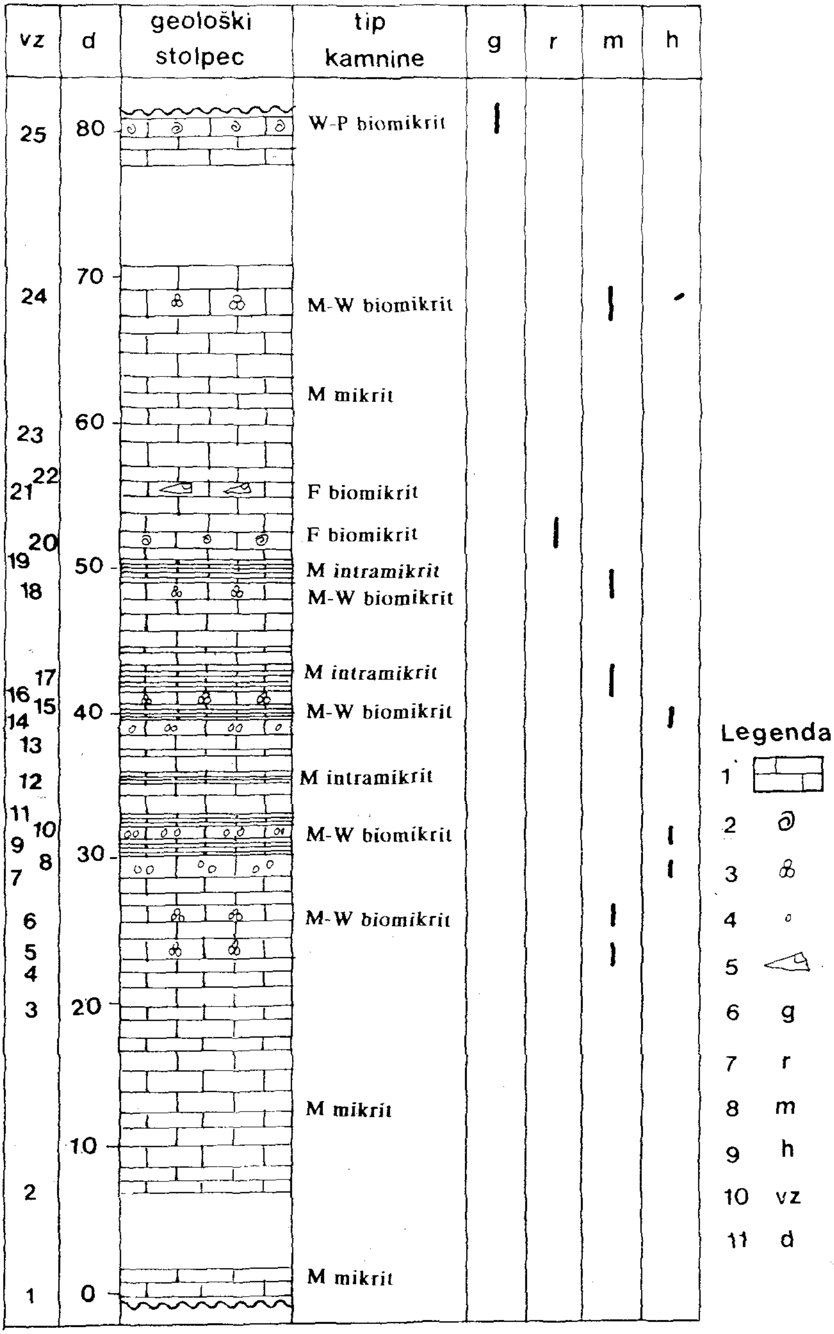
Profil Škocjanske jame je dolg 160 m. Zaradi delne pokritosti v spodnjem in zgornjem delu lahko debelino plasti le ocenimo na približno 80 m (sl. 15). V profilu se izmenjujejo večinoma zelo bituminozni lamelirani in nelamelirani apnenci različnih debelin. Fosili so v profilu redki, saj je v spodnjem delu le en horizont z oogoniji haracej, v zgornjem delu pa so v okrog dva metra debelih plasteh posamezni rudisti. V zgornjem delu profila je en horizont z giroplevrami. Vpad plasti v profilu se spreminja med 190/30 in 200/30.

Plast 1 (0 m)
Spodnjih 28 m profila je slabo razgaljenih. Na začetku profila v plasti 1 je temnorjav do črn mikritni in rahlo bituminozni apnenec brez fosilov.

Plasti 2 (7,5 m), 3 (20 m) in 4 (23 m)
Med plastmi 2 in 4 je mikrosparitni apnenec svetlo siv, ponekod deloma zdrobljen in rahlo dolomitiziran. Tudi v teh plasteh ni fosilov.

Plasti 5 (24,5 m) in 6 (26,5)
V spodnjem delu (24,5 m) svetlosivega mikrosparitnega apnenca so posamezne miliolide. Pri 26,5 m je 10 cm debel horizont s posameznimi miliolidami. Apnenec je mikritnega tipa, temnorjav, bituminozen in močno prekristaljen.

Plast 7 (28 m)
V plasti 7 je apnenec temnorjav in ne vsebuje fosilov.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Plasti 8 (29 m) in 9 (31,5 m)

Apnenec je v tem delu profila mikrosparitnega tipa, svetlorjav in rahlo bituminozen. V plasti 8 so v nekaj centimetrih zelo redki nepoškodovani oogoniji haracej.

Plast 10 (32,5 m)

V plasti 10 leži na 10 cm debelem stromatolitnem apnencu 8 cm debel horizont mikritnega apnenca z oogoniji haracej Meje med stromatolitnim tipom apnenca in mikritnim apnencem z oogoniji haracej je ostra, vmes ni bilo prekinitve sedimentacije. Horizont s haracejami prehaja v 15 cm debel horizont svetlorjavega lameliranega apnenca brez fosilov.

Plast 11 (33 m)

Apnenec je drobno laminiran. Posamezne bolj ali manj ravne in med seboj vzporedne lamine, ki jih sestavljajo drobni, 1 do 2 mm veliki intraklasti in plastiklasti, so debele do 2 mm. Dolomitizirani apnenec ne vsebuje fosilov.

Plast 12 (35,5 m)

Drobno vzporedno laminiran (debelina lamin je od 1 do 2 mm) stromatolitni apnenec (LLH-stromatoliti) preide pri točki 12 v nelaminiran homogen in gost mikritni apnenec brez fosilov. Logan, Rezak in Ginsburg (1964) razlikujejo dva osnovna tipa stromatolitov, ki se kažeta tudi v profilu Škocjanske jame:

-LLH-stromatoliti ("Laterally Linked Hemispheroids"), ki se v sedimentu kažejo kot ravne do rahlo nagubane in s cementom bogate lamine;

-SH-stromatoliti ("Stacked Hemispheroids") imajo med seboj deloma ločene valovito oblikovane skorje.

Plast 13 (37 m)

V plasti 13 je nekaj deset centimetrov drobno lameliranega stromatolitnega svetlo do temnorjavega apnenca tipa "LLH". Lamine se na prepereli površini izredno lepo vidijo. Apnenec ne vsebuje fosilov.

Plasti 14 (39 m) in 15 (39,5 m)

Mikritni apnenec je med plastema 14 in 15 svetlorjav in nelaminiran. V njem so posamezne haraceje ter stilolitni šivi, razporejeni v vseh smereh.

V plasti 15 postane apnenec zopet izrazito laminiran (LLH-stromatoliti) in kodrav. Stromatoliti imajo značaj deloma LLH-stromatolitov, deloma SH-stromatolitov.

Sl. 15. Geološki stolpec profila Škocjanske jame. 1-apnenec, 2-giroplevre (rudisti), 3-miliolide, 4-oogoniji haracej, 5-polži, 6-giroplevre 7-rudisti, 8-miliolide, 9-haraceje, 10-vzorec, 11- debelina (m).

Fig. 15. Geological column of the Škocjanske jame profile. 1 - limestone, 2 - Gyropleura (rudists), 3 - milliolides, 4 - oogonia of Haracea, 5 - mollusks, 6 - Gyropleura, 7 - rudists, 8 - milliolides, 9 - Haracea, 10 - sample, 11 - thickness (in m).

Plast 16 (41 m)

Vzporedno laminirani apnenec hitro preide v nelamelirani temnorjav do črn apnenec z številnimi miliolidami. Horizont z miliolidami je debel 30 cm, sediment pa je vseskozi enak. Nad horizontom z miliolidami je 50 cm črnega, deloma razpokanega bituminoznega apnenca brez fosilov. Razpoke so zapolnjene z debelokristalastim kalcitom in so razporejene v nepravilni mreži.

Plast 17 (41,5 m)

Apnenec je v plasti 17 drobno laminiran. Lamine so med seboj oddaljene 1 mm. Debelina tega "LLH stromatolitnega" apnenca je 1 m.

Plast 18 (47,5 m)

Znotraj plasti 18 so v 16 cm debelem horizontu temnorjavega apnenca miliolide. Ta apnenec prehaja navzgor v lamelirani apnenec.

Plast 19 (51 m)

Apnenec je drobno laminiran. Lamine so vzporedne s plastnatostjo (značilni LLH-stromatoliti). Drobna laminiranost se lepo vidi na prepereli površini (sl. 16). Iz kamnine izstopajo zlasti svetlejše lamine.

Sl. 16. Drobna laminiranost v plasti devetnajst.
Fig. 16. Thin laminae within the 19th layer.

Plast 20 (52 m)

V plasti 20 se pojavljajo rudisti.Sledimo jih tudi nad plastjo 20 v skupni debelini 2 m. M. Pleničar je določil vrsto Bournonia vionceky. Rudisti so v temnorjavem apnencu zelo redki, saj je na površini 1 m^2 največ 5 njihovih predstavnikov ter nekaj odlomkov lupin. *Rudistni apnenec je mikritnega tipa, homogen in ni laminiran, deloma je prekristaljen.*

Plast 21 (56 m)

Svetlorjavi apnenec debel 40 cm, vsebuje posamezne polže, ki jih je še manj kot rudistov. Višina prekristaljenih hišic polžev je do 2 cm. V tem delu profila so plasti apnenca debelejše kot drugod (od 40 do 60 cm).

Plast 22 (56,5 m)

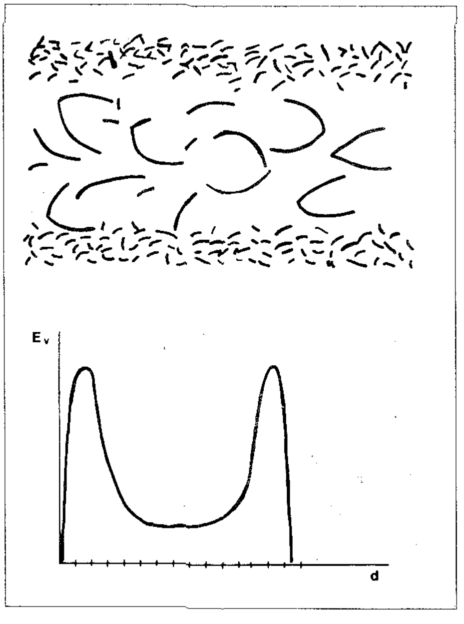
Pri 56. metru (plast 22) profila je svetlorjavi gosti apnenec z briozoji, velikimi do 6 mm. Povprečna velikost osebkov je okrog 3 mm. Briozoji so razporejeni v več do 5 cm debelih horizontih, so vzporednih s plastnatostjo. V tanjših, do 2 cm debelih horizontih so briozoi še posebno številni.

Plast 23 (58 m)

Temnorjavi bituminozni mikritni apnenec ne vsebuje fosilov.

Plast 24 (68 m)

Na 68. metru (plast 24) je rahlo prekristaljen, svetlorjav apnenec z miliolidami.



Sl. 17. Število lupin giroplever je približno enako v spodnjem in zgornjem delu horizonta. V sredini horizonta je lupin manj; tip B (zgoraj), diagram energije vode med sedimentacijo (spodaj). Legenda pri sl. 5.

Fig. 17. The number of Gyropleura shells is approximately equal in the lower and upper part of the horizon. In the middle of the horizon there are less shells; type B (up), diagram of the water energy during the sedimentation (down). Legend at Fig. 5.

Plast 25 (80 m)
Zadnja plast v profilu (plast 25) vsebuje do 4 cm debel horizont z giroplevrami. V tem horizontu so zelo številni odlomki školjčnih lupin, veliki nekaj milimetrov. Zapolnjujejo nekakšne vdolbine oziroma razpoke, ki so se verjetno na morskem dnu ustvarile med sedimentacijo. Smer zapolnjenih vdolbin in razpok je zelo različna, večkrat je celo pravokotna na plasti. Nad in pod horizontom z giroplevrami dobimo v mikritni osnovi posamezne do 5 mm velike odlomke lupin.

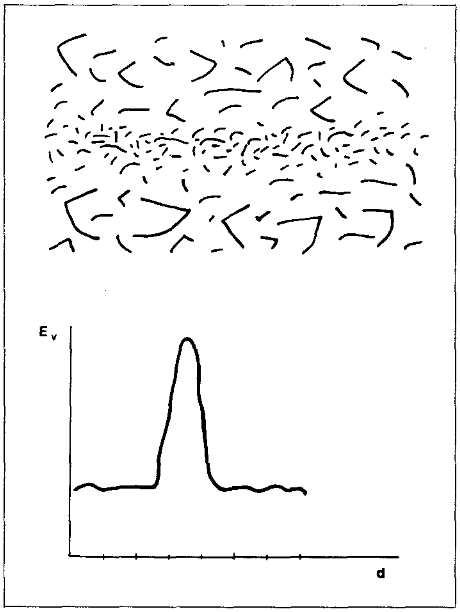
PALEOEKOLOŠKA OPAZOVANJA

PALEOGEOGRAFSKE IN PALEOEKOLOŠKE ZNAČILNOSTI LIBURNIJSKE FORMACIJE

Plasti liburnijske formacije so nastajale od maastrichtija do thanetija (Pavlovec & Drobne 1991). Pleničar, Polšak in Šikić (1973) pišejo, da je prostor Slovenskega Primorja ob koncu krede zajelo laramijsko gubanje. V nastale sinklinale je v daniju in paleocenu transgrediralo morje. Po Šikiću in Pleničarju (1975) so v tem delu pri koncu krede znaki splošnega dviganja ozemlja. Na prehodu krede v terciar pa je morsko dno večkrat osciliralo.

Po sedimentaciji plasti z rudisti, je sledila regresija, zaradi katere so v Sloveniji začele nastajati vremske plasti Pavlovec 1981c).

Podobno opisuje zgodovino nastajanja tega dela ozemlja Buser (1973). V zgornjem senoniju so se nekateri deli Tržaško - Komenske planote dvignili iz morja. V senoniju in



Sl. 18. Največ lupin giroplever je v sredini horizonta in manj v spodnjem in zgornjem delu; tip C (zgoraj), diagram vode med sedimentacijo lupin (spodaj). Legenda pri sliki 5.
Fig. 18. The most of Gyropleura shells are in the middle of the horizon and less in its lower and upper part; type C (up), diagram of water during the shells sedimentation (down). Legend at Fig. 5.

paleocenu so se pogosto menjavali morski, brakični in sladkovodni pogoji sedimentacije.

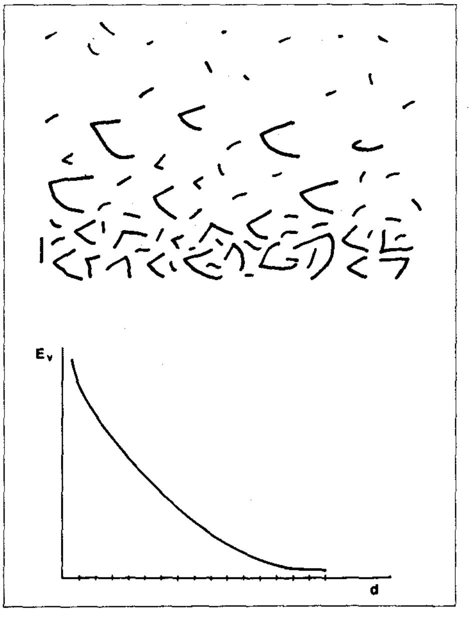
Sedimenti liburnijske formacije naj bi se po Stachejeveih (1872) predstavah usedale v bližini zelo razčlenjene obale. Morje naj bi bilo deloma brakično , med lagunami pa naj bi bili estuariji in ločena obalna jezera Stache 1889). Z upoštevanjem pojavljanja koskinolin in miliolid se Cita (1955) bolj navdušuje za epikontinentalni kot kontinentalni nastanek liburnijskih plasti.

Breče in boksiti liburnijske formacije, ki so na več mestih po Primorski, kažejo na takratno regresijo morja, ki naj bi bilo plitvo s krajevnimi kopninami. V morskih lagunah in deloma v sladkovodnih jezerih se je sedimentacija liburnijske formacije vršila brez večjih vmesnih tektonskih premikov (Pleničar 1961). Na koncu krede je prišlo sicer do dviganja, ki pa je imelo značaj epirogenetskh in ne orogenetskih procesov (Pleničar 1970).

Pri sladkovodnih plasteh liburnijske formacije se je Stache (1889) opiral na polže, plasti premoga in haraceje. Vse tri značilnosti vremskih in kozinskih plasti se v številnih plasteh in horizontih pojavljajo v raziskanih profilih. Za polže je Pavlovec (1963a) izrazil dvom, da bi bili sladkovodni. Hamrla (1959) je prišel do zaključka, da so premogi nastajali tudi v limnično-brakičnem okolju. Nekateri mislijo, da je bil kras v času odlaganja liburnijske formacije že dobro razvit (Hamrla 1959; 1960) in da zato ne moremo pričakovati številnih tekočih voda, ki bi polnile obalna jezera (Pavlovec 1963a).

Po Nortonovih conah je Rhapydionina liburnica, ki se v profilu Vremski Britof pojavlja v več horizontih, najvažnejši fosil maastrichtijskih vremskih plasti (Drobne et al. 1988) in je daleč najpogostejša v coni A, kjer naj bi bila globina morja do približno 9 m in temperatura morja od 21°C do 31°C (Pavlovec 1963a).

Glede na podatke K. Drobne in sodelavcev (1988; 1989), so se vremske plasti v okolici



Sl. 19. Število lupin giroplever se v horizontu postopno manjša od spodnjega proti zgornjemu robu horizonta; tip D (zgoraj), diagram vode med sedimentacijo lupin (spodaj). Legenda pri sl. 5.
Fig. 19. The number of Gyropleura shells in the horizon progressively diminishes from lower to upper horizon's part; type D (up), diagram of water during the shells sedimentation (down). Legend at Fig. 5.

profila Dolenja vas, ki kaže podobnosti z v tej nalogi opisanimi profili, odlagali na mirnem in plitvem zatišnem šelfu z nizkim energijskim indeksom (1-2). Takšno okolje naj bi bilo enotno na širšem prostoru slovenskega dela Zunanjih Dinaridov.

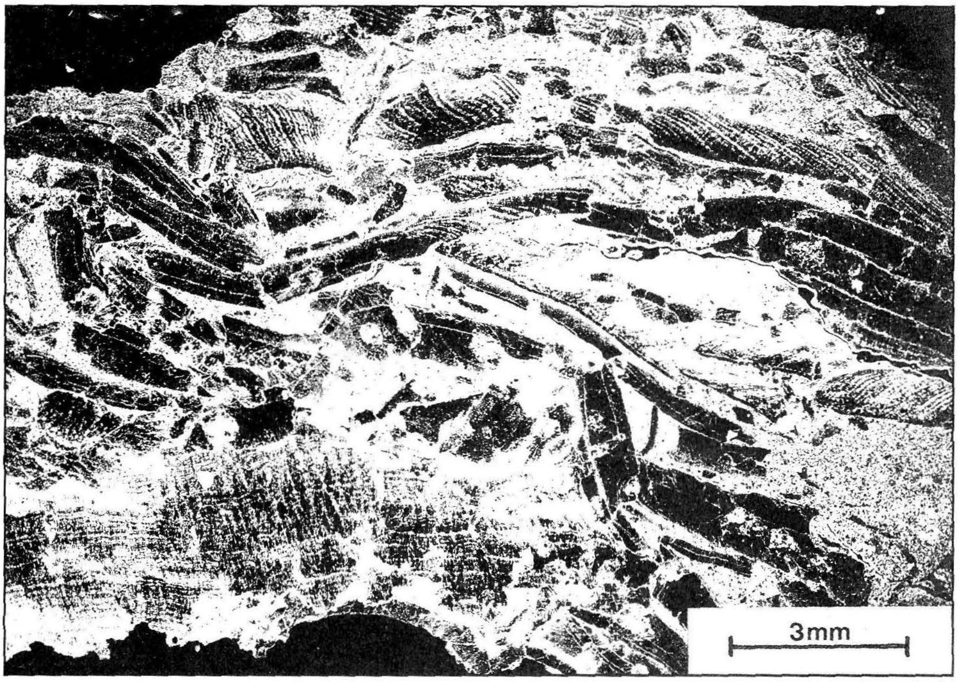
Torej, po novejših raziskavah niso plasti liburnijske formacije v celoti morske ali v celoti sladkovodne. Nad vremskimi plastmi so apnenci s številnimi haracejami. Ti apnenci kažejo na bližino sladkovodnega ali brakičnega okolja (Pavlovec, 1981c).

VREMSKE PLASTI

TIPI HORIZONTOV Z GIROPLEVRAMI

Glede na pojavljanje lupin giroplever v preiskanih profilih razlikujem več tipov horizontov z giroplevrami.

1. Glede na vertikalne razlike v nastopanju lupin giroplever in njihovih odlomkov v horizontu sem določil pet tipov:



Sl. 20. Lupine giroplever so v horizontih večinoma tako številne, da se dotikajo med seboj.
Fig. 20. The Gyropleura shells are so numerous within the horizon that they touch each other .

Tip A: število lupin giroplever se v horizontu postopno veča od spodnjega proti zgornjemu robu horizonta;
Tip B: število lupin giroplever je približno enako v spodnjem in zgornjem delu horizonta z giroplevrami. V sredini horizonta je lupin giroplever manj (sl. 17);
Tip C: Največ lupin giroplever je v sredini horizonta in manj v spodnjem in zgornjem delu (sl. 18);
Tip D: število lupin giroplever se v horizontu postopno manjša od spodnjega proti zgornjemu robu horizonta. (sl. 19);
Tip E: število lupin giroplever je približno enako po vsem horizontu.

2. Glede na ohranjenost lupin giroplever v horizontu sem ločil tri tipe:
Tip 1: Večinoma cele lupine giroplever;
Tip 2: Cele lupine giroplever in njihovi odlomki;
Tip 3: Večinoma odlomki lupin giroplever.

Sl. 21. V večini horizontov so lupine giroplever razlomljene in zdrobljene.
Fig. 21. In most of the horizons the Gyropleura shells are broken or fragmented.

INTERPRETACIJA HORIZONTOV Z GIROPLEVRAMI

Pleničar (1961) piše o hamidnih školjkah, kamor s tega področja uvršča samo rod Gyropleura. Živele naj bi od spodnjega dela zgornje krede do najmlajšega senona. V zadnjem času so geologi (Pavlovec & Pleničar 1983) mnenja, da niso vse školjke, ki jih danes dajemo v rod Gyroplevra iz tega rodu, kar je predvideval že Pavlovec (1963a). Zaradi slabe ohranjenosti so domnevali (Pavlovec & Pleničar 1983), da jih je vsaj del iz rodu Apricardia ali še iz drugih rodov. Danes je znano, da se aprikardije (Apricardia pachiniana Sirna) v vremskih plasteh resnično pojavljajo (Pleničar 1992).

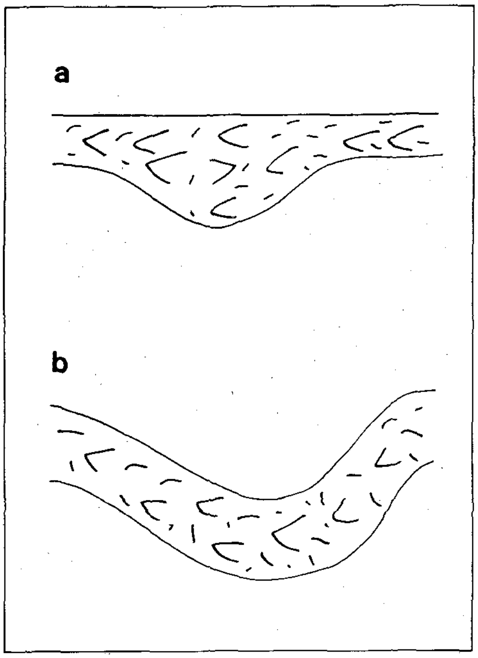
O avtohtonosti oziroma alohtonosti lupin giroplever so bila mnenja deljena, saj nekateri avtorji zagovarjajo avtohtonost, drugi alohtonost. (cf. Pleničar 1961; Pavlovec & Drobne 1991).

Sl. 22. Pod lupino giroplevre so v sparitnem cementu različni bioklasti.
Fig. 22. Below the Gyropleura shells various bioclasts are found in sparitic cement.

Že po prvih raziskavah sem se v večini primerov nagibal k tanatocenozi giroplever. To pomeni, da življenjsko okolje giroplever in aprikardij ni bilo na mestu, kjer jih najdemo danes. Hamidne školjke iz rodu Gyropleura in Apricardia so najverjetneje živele v mirni vodi, v plitvinah, zakopane v mulj (Pleničar, ustno sporočilo). Ta možnost ustreza tudi dejstvu, da kljub temu, da nekateri primerki lupin izgledajo izredno debeli (nekaj mm), so v povprečju še vedno tanjši od lupin školjk, ki so in še živijo v vodi z večjo energijo. Od slednjih bi namreč pričakoval debelejše lupine. Zunanja površina lupine je tudi brez dodatnih ojačitev (reber in podobno), kar navadno kaže na mirno življensko okolje.

Primarnega nahajališča giroplever do danes še ne poznamo. Lupine giroplever so prinašali na mesto, kjer jih danes najdemo občasni vodni sunki, ki so imeli po mojem mnenju izvor v hujših nevihtah ali daljših neurjih. Valovi so lupine giroplever nakopičili (sl. 20) v zatišnem delu sedimentacijskega bazena. O podobnih dogajanjih v recentnih karbonatnih bazenih med drugimi pišejo tudi Ginsburg & Hardie (1975) in Schneider (1975). Ta ugotovitev se sklada tudi z dejstvom, da med horizonti ni lupin giroplever, saj bi v nasprotnem primeru lahko med horizonti z giroplevrami pričakovali vsaj nekaj lupin giroplever. Torej obstaja velika verjetnost, da so opisani horizonti tanatocenoza. Po prepričanju Ogorelca se v recentnih zatišnih obrežnih delih bazenov lahko med nevihtnimi obdobji odloži tudi po več deset centimetrov sedimenta.

Lupine rodu Gyropleura, ki jih je Pleničar (1961) izoliral iz sedimenta, niso zaobljene, torej ne kažejo znakov transporta in naj bi bile avtohtone. Vendar je takrat opisal samo dva horizonta z giroplevrami, medtem ko ni našel tudi po več deset centimetrov debelih



Sl. 23. Vse vdolbine nekdanjega morskega dna, globoke nekaj centimetrov, so zapolnjene z odlomki lupin in bolj ali manj celimi ostanki lupin. Nad zgornjim robom vdolbin pa je horizont z lupinami giroplever povsod enako debel, kot da vdolbin pod njim sploh ne bi bilo.

Fig. 23. All the niches of the former sea floor, some centimeters deep, are filled up by the fragments of shells and more or less whole rests of the shells. Above the upper margin of the niches the horizon with Gyropleura shells is evenly thick giving the impression that there are no hollow below it.

horizontov, polnih odlomkov in drobcev lupin giroplever. Tak tip horizontov namreč prevladuje v profilih Vremski Britof in Škocjanske jame.

Celih lupin giroplever (tip 1) je v horizontih z giroplevrami (na primer prvi, drugi, sedemnajsti horizont) zelo malo (okrog 5%). Kjer dobimo cele lupine se večinoma med seboj ne dotikajo (floatstone). Med školjkami ni drugih fosilov. Ker so lupine dobro ohranjene in sta večinoma obe lupini skupaj, je najverjetneje, da jih je na mesto sedimentacije prinesel počasen, umirjen vodni tok. Vendar bi kljub temu pričakovali med školjkami ostanke drugih organizmov, ki so živeli v takratnem plitvem morju, na primer alge, foraminifere in drugo. Pri tem pa ne smemo povsem izključiti možnosti, da so giroplevre tipa 1 poginjale in situ in so zaradi le rahlega valjenja po morskem dnu ostale bolj ali manj nepoškodovane. V enem ali drugem primeru sklepam na umirjeno sedimentacijo.

V večini horizontov so lupine giroplever razlomljene in zdrobljene (tip 3) (sl. 21), kar

Sl. 24. Horizonti so večinoma navzdol in navzgor ostro omejeni.
Fig. 24. Downwards and upwards the horizons are usually sharply delineated.

kaže na močne vodne tokove in valove, ki so s seboj nosili lupine giroplever in jih na poti drobili. Velikost razlomljenih delov lupin giroplever je pri večini horizontov nekaj milimetrov in največkrat ne preseže en centimeter.

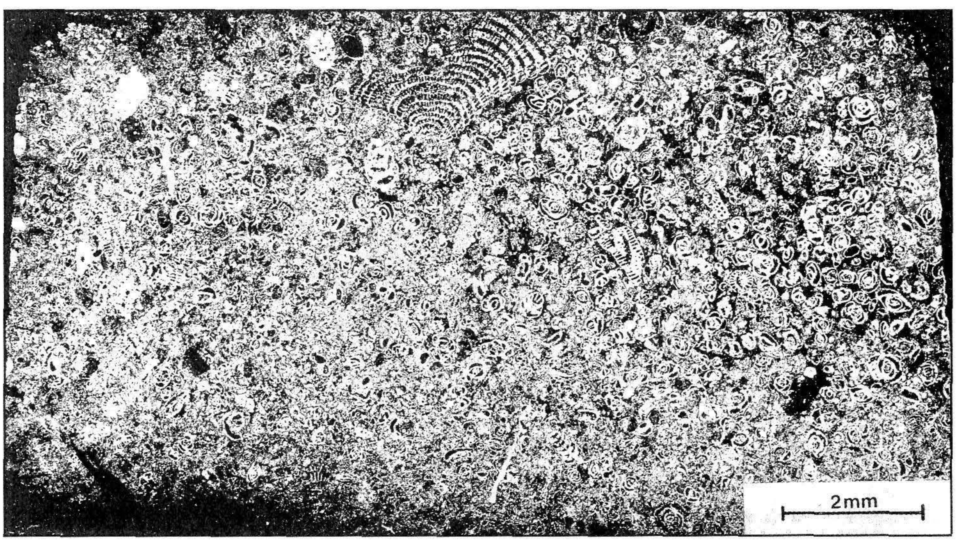
Takšna stanja lupin giroplever je mogoče pojasniti najmanj na dva načina:

1. Lupine giroplever so se zdrobile ob daljšem transportu in so padale na morsko dno razlomljene.

Velike količine drobirja lupin giroplever v nekaterih horizontih so lahko posledica večje energije vode v kateri so se lomile lupine.

2. Lupine giroplever so v nekaterih horizontih (na primer drugi horizont z giroplevrami) relativno tanjše (1 mm) od lupin v prvem horizontu z giroplevrami in je morda to vzrok za močno lomljenje lupin. V tem primeru ni potrebno misliti na daljši transport. Hkrati je potrebno vedeti, da so lupine giroplever velike od 2 do 4 cm. Za trdnost je gotovo pomemno razmerje debelina lupin : velikosti lupin.

V prostoru med lupinami giroplever so ponekod delci sedimenta, veliki tudi do nekaj centimetrov. To so intraklasti ter plastiklasti, ki so jih gibanje vode ali vodni tok nanesli v plitvejše vdolbine na morskem dnu. Vdolbine so izoblikovane v mikritni osnovi, ki je pomešana z odlomki lupin giroplever. Prav tak sediment obdaja in prekriva intraklaste. Ker so v horizontih z giroplevrami in intraklasti navzgor intraklasti vse manjši, sklepam, da je takšno sedimentacijo horizontov z giroplevrami najbrž potrebno pripisati pojemajočemu vodnemu toku. Ta je s svojo energijo najprej s seboj prenašal intraklaste in drobil lupine, v končni fazi pa je že zdrobljene lupine giroplever v suspenziji le še odložil.



Sl.25. En primerek B generacija vrste Rhapydionina liburnica, ki se ne pojavlja med lupinami giroplever. Prevladujejo miliolide.

Fig. 25. One specimen of B generation of Rhapydionina liburnica species which does not occur among the Gyropleura shells. Milliolides prevail.

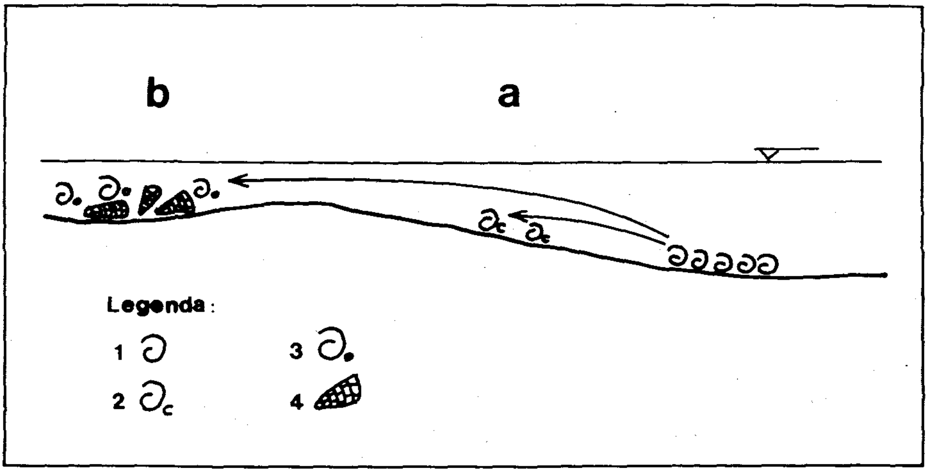
Večina horizontov (tipi A, B, E, 2 in 3) z giroplevrami ima ostro zgornjo mejo. Lupine giroplever naenkrat izginejo, spremembe v sedimentu pa ni. Na zgornjem robu horizonta cele lupine in njihovi odlomki ne ležijo vzporedno s plastnatostjo. Po njihovi legi sodeč so bili navpično in poševno zapičeni v sediment. Najverjetneje so se v mehko blato zapičili med premetavanjem po morskem dnu zaradi povečane energije vode. Ker imajo cele lupine giroplever in njihovi odlomki v zgornjem delu horizonta z giroplevrami ostre robove, menim, da lupine giroplever v tem horizontu niso preživele daljšega transporta.

V primeru (predvsem tretji horizont z giroplevrami, tip D2), ko so posamezne lupine giroplever, ki se med seboj ne dotikajo, s konveksno stranjo obrnjene navzgor in je pod njimi interni sediment (sl. 22), kaže stanje na manjšo energijo vode, saj bi lupine giroplever sicer odplavilo ali bi jih vodni tok nagrmadil drugo na drugo.

Glede na gost, temnorjav do črn bituminozni mudstone okrog lupin giroplever in glede na orientacijo lupin predpostavljam, da je bila sedimentacija precej mirna. Zdi se, da je bila energija vode nizka, vendar s stalnim gibanjem, na kar kaže tudi rahlo izpran mikritni cement. Ker predpostavljam, da so lupine giroplever na mesto sedimentacije prišle bolj ali manj cele, bi zaradi stalnega gibanja vode na mestu tudi lahko prišlo do (dodatnega) drobljenja lupin giroplever na mestu sedimentacije.

Ponekod so med drobci tudi posamezne cele lupine (tip 2), ki imajo debelejše lupine kot v drobcih. Pri tem se postavi vprašanje, ali drobci niso razlomljene lupine juvenilnih primerkov, starejše debelejše lupine pa so ostale cele.

Možno je, da v takšnih horizontih z giroplevrami ni igral važne vloge samo način (različna energija vode) nakopičenja lupin, temveč trdnost lupin; transport lupin giroplever z nevihtnimi valovi je bil lahko sorazmerno počasen in so se pri tem razlomile le naključne



Sl. 26. Možen transport lupin giroplever med sedimentacijo.
Fig. 26. A possible transport of Gyropleura shells during the sedimentation.

šibkejše lupine, lahko pa je bilo kopičenje lupin giroplever hitro in so se vse lupine, debelejše in tanjše, lomile enako.

Možnost, da bi bili na področju, od koder so bile lupine giroplever prinešene, samo občasno ugodni pogoji za razvoj giroplever in bi takrat prišlo do hiperprodukcije organizmov, zavrača med drugim značilnost šestega horizonta z giroplevrami. Vse vdolbine nekdanjega morskega dna, globoke nekaj centimetrov, so zapolnjene z odlomki lupin in bolj ali manj celimi ostanki lupin. Nad zgornjim robom vdolbin pa je horizont z lupinami giroplever povsod enako debel, kot da vdolbin pod njim sploh ne bi bilo (sl. 23).

Če bi giroplevre živele na mestu, kjer jih najdemo fosilizirane, bi bil horizont z giroplevrami vsaj približno enakomerno debel tako v vdolbinah kot tam, kjer teh ni. V šestem horizontu pa kotanje ne vplivajo na debelino horizonta z giroplevrami, saj je zgornja meja tega horizonta popolnoma ravna oziroma vzporedna s plastnatostjo. To nedvomno dokazuje, da so bile giroplevre vsaj nekoliko prenešene.

V osmem horizontu z giroplevrami je lepo izražena spodnja meja, ki predstavlja nekdanje morsko dno. To predstavlja enega tipičnih primerov obrežnega dela morja, kjer pod vplivom valov in vodnih tokov pride do erozije morskega dna. S takšno razlago se strinja tudi B. Ogorelec.

Johnson in Baldwin (1986) pišeta, da naj bi erozijske površine (kot je v našem primeru na sliki 9), ki "presekajo" enakomerno plastnatost, nastale v času kratkotrajnih valov ali tokov z visoko energijo vode kakor tudi med daljšo periodo vetrovnega, nevihtnega vremena. Ista avtorja sta mnenja, da je v pogojih povečane energije vode kot tudi spremembe smeri vodnega toka erodiran vrhnji, nevezani del plasti. Pri tem voda odnese del materiala, ki ga lahko kasneje odloži na istem mestu ali v neposredni bližini. Erozijska sled pa v kamnini ostane.

Glede na te podatke in v skladu z razmišljanjem o transportu in sedimentaciji lupine giroplever v šestem horizontu z giroplevrami predvidevam, da so bili med sedimentacijo osmega horizonta podobni paleoekološki pogoji. Valovanje oziroma vodni tok, s katerim so prihajale na prostor sedimentacije lupine giroplever, je bil nekoliko šibkejši, kot je bil med sedimentacijo šestega horizonta z giroplevrami, saj je med lupinami le malo njihovih drobcev. Lupine v šestem in osmem horizontu so enako orientirane, kar kaže, da so bile bolj ali manj mirno odložene na takratno morsko blato.

Prenos materiala v krajših časovnih obdobjih opisujeta tudi Johnson in Baldwin (1986). Tako med drugim omenjata "facies sedimentov, ki so nastali pretežno pod vplivom plimskih tokov" ("Tide-dominated offshore facies"), ter "facies sedimentov, ki so nastali pretežno pod vplivom valov , viharjev ter neviht" ("Wave- and storm-dominated offshore facies").

V prvem primeru, ki ga navajata zgornja avtorja, bi zaradi sorazmerno počasnejšega sedimentiranja pričakoval dobro sortiranost lupin giroplever in njihovih odlomkov, ki so najrazličnejših velikosti. Prav tako bi pričakoval sortiranost sedimenta po velikosti, v katerem so lupine giroplever. Ker večinoma takšnih lastnosti v kamnini ne opazim, se moja predvidevanja skladajo z drugim primerom, ki ga navajata Johnson in Baldwin (1986). Avtorja govorita o nesortiranih nanosih materiala z valovi in tokovi, kar povzročijo vetrovi ob nevihtah in viharjih.

Kljub temu, da glede na sediment predvidevamo, da je bilo okolje sedimentacije lupin giroplever plitvo (najverjetneje do 10 m) in da je bilo v takšnih globinah tudi njihovo življenjsko okolje, naj navedem podatek, da tip nevihtnih valov lahko s svojo bazo seže celo v globino 30 m (Seneš 1988).

Po Johnsonu in Baldwinu (1986) se z nevihtnimi valovi prenaša material v gostih suspenzijah. Pri profilu Vremski Britof je bilo to drobnozrnato karbonatno blato, ki so ga valovi skupaj z lupinami giroplever dvigali s plitvega morskega dna. Sediment, ki ga danes dobimo med lupinami giroplever je večinoma mikritnega tipa.

Ista avtorja (1986) pišeta, da takšni pogoji trajajo sorazmerno kratko v primerjavi z "nenevihtno" sedimentacijo, vendar lahko pričakujemo zaradi višje energije vode v zelo kratkih časovnih obdobjih znantne debeline sedimenta. Glede na recentna opazovanja smo skupaj z Ogorelcem, Pavlovcem in Pleničarjem podobno ugotovili tudi na terenu ob pregledu posameznih horizontov z giroplevrami.

Horizonti s številnimi odlomki lupin giroplever so navzgor in navzdol ostro omejeni (na primer prvi, drugi , peti, dvanajsti, trinajsti in štirinajsti horizont z giroplevrami. Sl. 24). Le v posameznih horizontih je postopen prehod iz apnenca brez giroplever v horizont z giroplevrami(deseti, sedemnajsti in osemnajsti horizont z giroplevrami). Posameznih lupin giroplever v apnencu med horizonti, razen redkih izjem, ni. To so osnovni dokazi za alohtonost lupin giroplever.

LAMINITI V PROFILU ŠKOCJANSKE JAME

Da je bilo v času sedimentacije vremskih plasti zelo plitvo okolje sedimentacije, pričajo tudi znatne debeline dolomitiziranih laminitnih apnencev v profilu Škocjanske jame. Številni avtorji (Laporte 1975; Read 1975; Hoffman 1975; Wanless 1975) menijo, da se v laminitnih apnencih anorganske lamine največkrat izmenjujejo z laminami, ki so ostanki delovanja modrozelenih cepljivk. To domnevam tudi za laminitne apnence v profilu Škocjanske jame. Glede na raziskave recentnih morskih plitvin (Monty 1967) naj bi laminitne stromatolitne skorje nastajale na medplimskem (intertidal) kot tudi na nadplimskem področju (supratidal), redkeje pa v nekoliko globljem (subtidal) in od valov zaščitenem okolju.

Do izmenjave organskih in anorganskih lamin je prišlo zaradi preplavljanja modrozelenih cepljivk na področju medplimske ravnice (intertidal) v času plime in sušitvijo med oseko (Gabelein & Hoffman 1969). Najverjetneje je bilo to področje blago nagnjene morske obale, na kateri je bil občasno močan vpliv plime in oseke. Na takšno okolje sedimentacije opozarja tudi Tišljar (1987). Med oseko je bila na medplimski ravnici omogočena rast modrozelenih cepljivk, med plimo pa je voda tja nanesla tanjše ali debelejše plasti drobnozrnatega materiala. Okolje med nastajanjem stromatolitnih skorij je bilo torej izjemno plitvo in za življenje mnogih organizmov neprimerno. Tudi v nekaterih odsekih profila Škocjanske jame, kjer sem našel stromatoliten tip sedimenta, ni drugih fosilov.

Zaradi izhlapevanja morske vode ter zato hitre litifikacije se stromatoliti relativno lahko ohranijo (Tišljar 1987). Ker organsko snov zamenja cement, se trate modrozelenih cepljivk ne ohranijo. S propadom cepljivk nastanejo v sedimentu votline, ki jih kasneje zapolni kalcitni cement. Na ta način se v kamnini, kjer so bile nekoč cepljivke, kaže le fenestralna zgradba.

RHAPYDIONINA LIBURNICA V PROFILU VREMSKI BRITOF

A in B obliki vrste Rhapydionina liburnica se pojavljata v več horizontih v profilu Vremski Britof (Drobne 1981). Zanimivo je, da B generacije ni v horizontih s številnimi odlomki in drobci lupin giroplever (sl. 25). Pravtako se v bližini horizonta z giroplevrami rapidionine ne pojavljajo v večjem številu. Med šestim in sedmim ter med sedmim in osmim horizontom z giroplevrami, kjer je rapidionin veliko, ni giroplever, ki bi tvorile horizont. Rapidionine se zopet v večjem številu pojavijo med osmim in devetim horizontom. Rapidionine in lupine giroplever se v sedimentu med šestim in osmim horizontom pojavljajo ločeno; enkrat ene drugič druge.

V nekaterih primerih (na primer šestnajsti horizont z giroplevrami) so lupine giroplever skupaj z rapidioninami. V tem primeru rapidionine številčno prevladujejo nad giroplevrami. Lupine giroplever so med rapidioninami le kot odlomki in drobci, celih lupin med rapidioninami ni. Prav tako niso odlomki giroplever med rapidioninami nakopičeni niti v nekaj centimetrov debelih horizontih, temveč so nepravilno razporejeni po vsem horizontu z rapidioninami A generacije. Zato domnevam, da gre za povezavo pri odnosu rapidionine : odlomki lupin giroplever.

Možne razlage za razmerje med lupinami giroplever in rapidioninami je naslednje.

a) Vodni tok in valovanje sta lupine giroplever iz življenskega položaja nosila proti obali, kjer so živele rapidionine (Fleury 1970; 1979), vendar sta jih odložila pred biotopom z rapidioninami (sl. 26, položaj A). Zaradi kratkega transporta so lupine giroplever ostale bolj ali manj nepoškodovane, celih lupin giroplever in rapidionin pa skupaj ne najdemo.

b) Druga možnost je ta, da so lupine giroplever tokovi ali valovanje prenesli v zatišne plitvine oziroma lagune z rapidioninami, ki naj bi bile bolj oddaljene od sedimentacije celih lupin giroplever (slika 26, položaj B). Zaradi daljšega transporta v plitvejše in mirnejše okolje so lupine giroplever pretrpele hujše lomljenje in drobljenje, sedimentirale pa so se skupaj z rapidioninami. Nahajališče lupin giroplever je torej tudi v tem primeru tanatocenoza. V času, ko voda ni prenašala lupin giroplever v prostor z rapidioninami, so tam nastajali horizonti z rapidioninami, v katerih ni lupin giroplever.

SKLEPI

Osnovni namen raziskave je bil proučevanje okolja sedimentacije plasti z giroplevrami in aprikardijami v vremskih plasteh.

Pri tem sem prišel do naslednjih ugotovitev.

1. Številne školjke iz rodu Gyropleura, Apricardia in morda še druge školje so v apnencih vremskih plasti na drugotnem mestu.

2. Giroplevre so živele v plitvi vodi nedaleč od obale. Na drugotno mesto so jih prinesli valovi in tokovi, ki so jih povzročila neurja in nevihte.

3. Odsotnost rapidionin v horizontih z giroplevrami potrjuje trditev, da so bile lupine nametane proti obali, saj so rapidionine živele v izrazito lagunskem okolju. Na plitvo okolje sedimentacije kažejo tudi laminiti.

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PALEOECOLOGICAL PROPERTIES OF THE VREME BEDS IN THE VICINITY OF ŠKOCJANSKE JAME

Summary

INTRODUCTION

From paleoecological and partly biostratigraphical point of view two profiles of Vreme beds (the lower part of the Liburnian formation) from the immediate vicinity of Škocjanske jame cave system are treated: the profile Vremski Britof and the profile Škocjanske jame.

In the Vreme beds I carefully studied the layers containing Gyropleura and Apricardia and the mode of the shells and their fragments appearance within the particular horizons. Thus I wished to get the paleoecological data, to solve the question of their primarity or secondarity respectively. In some parts of Vreme beds there are besides the Gyropleura and Apricardia numerous Foraminiferans and Algae.

THE PROFILE VREMSKI BRITOF

In 1979 the profile Vremski Britof was discovered (Hötzl & Pavlovec 1979) of about 130 m long, the layers being about 50 m thick. Due to vegetation growth and roadcut breaking down only some 40 m may be seen today. The horizons with Gyropleura appear in the total length of 84 m and this part I described in more detail. The dip of strata is 140/30 mostly.

In spite of several descriptions of the Vremski Britof vicinity we are lacking the detailed study of Gyropleura and Apricardia horizons and the location of the shells or their fragments.

In continuation I shall write about better known genus of Gyropleura, although, according to the opionion of Pavlovec and Pleničar (from 1983) in these horizons the shells of Apricardia exist as well. Pleničar (1992) in his treatise distinctly quotes that in the Vreme beds there are besides Gyropleura the Apricardia too, namely the species (Apricardia pachiniana Sirna) characteristic for the Upper Senonian.

In the profile Vremski Britof there are 19 horizons containing Gyropleura.

THE PROFILE ŠKOCJANSKE JAME

Since now nobody has described the profile in Škocjanske jame. The detailed geology of the Škocjanske jame vicinity was studied by Gospodarič (1983) only. In his treatise the spelegenesis of Škocjanske jame is more accentuated, nevertheless he mentions the Vreme beds as bedded and thin-bedded limestones containing some coal layers.

The Škocjanske jame profile is 160 m long. As it is partly covered in lower and upper part it thickness may be evaluated to 80 m approximately. Very bitumunous laminated and non-laminated limestones of various thickness alternate within the profile. The fossils within the profile are scarce, in lower part there is one horizon only containing oogonia of Haracea, and in upper part there are in about two meters thick beds single rudists. In the upper profile's part there is one horizon containing Gyropleura. The dip of strata within the profile changes between 190/30 to 200/30.

PALEOGEOGRAPHICAL AND PALEOECOLOGICAL PROPERTIES OF THE LIBURNIAN FORMATION

The layers of the Liburnian formation, where the both profiles lie, were developing from the Maastrichtian to the Thanetian (Pavlovec & Drobne 1991). Pleničar & Polšak & Šikić (1973) write that the area of the Slovene Littoral was subdued to the Laramian folding at the end of the Cretaceous. The sea transgressed into existing sinkline in the Danian and the Paleocene. According to Šikić & Pleničar (1975) there are in this part the indications of the general uplifting of the area at the end of the Cretaceous. At the transition of the Cretaceousa to Tertiary the sea floor frequently oscillated.

After the sedimentation of the layers with rudists the regression followed which is the cause of the Vreme beds origin in Slovenia (Pavlovec 1981c).

Similar description of the past of this part of the area is provided by Buser (1973). In the Upper Senonian some parts of the Trieste - Komen plateau uplifted from the sea. In the Senonian and in the Paleocene sea, brackish and fresh water conditions of sedimentation frequently alternated.

The breccias and bauxites of the Liburnian formation found on numerous places in the Littoral show the then sea regression which is supposed to be shallow with local lands. In the sea lagoons and partly in fresh water lakes the sedimentation of the Liburnian formation went on without remarkable intermediate tectonic displacements (Pleničar 1961). However at the end of the Cretaceous the uplifting occurred having the character of epirogenetic and orogenetic processes (Pleničar 1970).

According to the recent researches the Liburnian formation layers are not entirely marine nor entirely fresh water. Above the Vreme beds there are the limestones with numerous Haracea. These limestones indicate the vicinity of fresh or brackish water environment (Pavlovec 1981c).

THE INTERPRETATION OF THE HORIZONS CONTAINING GYROPLEURA

Pleničar writes about Chamidae shells and from this area he ranks among them the Gyropleura genus only. They are supposed to live since lower part of the Upper Cretaceous to the youngest Senonian. In the last time the geologists (Pavlovec & Pleničar 1983) believe that all the shells which today are classified to Gyropleura genus do not belong to it as it was supposed by Pavlovec (1963a) already. Due to bad preservation it was presumed

(Pavlovec & Pleničar 1983) that one part at least belongs to Apricardia genus or to other genera even. Today it is known that Apricardia (Apricardia pachiniana Sirna) really appears in the Vreme beds (Pleničar 1992).

The opionions about the autochthonous or allochtonous origin of the Gyropleura shells were shared, as some authors argue for autochthonous and the others for allochtonous origin (cf. Pleničar 1961; Pavlovec & Drobne 1991).

After the first researches already in most cases I was inclined towards the tanatocenosis of Gyropleura. It means that the living space of Gyropleura was not on the same spot where they are found today. The most probably the Chamide shells of Gyropleura genus lived in calm, shallow water burried into silt (Pleničar, oral communication). This possibility corresponds to the fact that although some samples of the shells are rather thick (some mm) in average they are thinner than the shells which lived and still live in the water with higher energy. Of the last we would namely expect thicker shells. The external shells surface does not have any additional strengthenings which usually indicate a calm life environment.

Till now we do not know the primary finding site of Gyropleura. The Gyropleura shells were transported to the place where they are found today by seasonal water pushes having their origin, according to my opionion in storms or longer lasting tempests. The waves accumulated the shells on leeward side of the sedimentary basin. Similar events in the recent carbonate basins are described by Ginsburg & Hardie (1975) and Schneider (1975). This statement corresponds to the fact that among the horizons there are no Gyropleura shells and if the case would be the opposite at least some of them must have been found. Hence a probability exists that the described horizons belong to tanatocenosis. Referring to the B. Ogorelec conviction in the recent leeward places of the coastal parts of the basins during the storms several ten centimeters of the sediment may be deposited.

According to appearance of Gyropleura shells in the studied profiles several types of the horizons containing Gyropleura are distinguished.

1. Referring to vertical stratification of Gyropleura shells and their fragments appearance, five types are distinguished:

Type A: The number of Gyropleura shells within the horizon progressively increases from lower towards the upper margin of the horizon;

Type B: The number of Gyropleura shells is approximately the same in the lower and the upper part of the horizon but in the middle there are less of shells;

Type C: The most of Gyropleura shells are in the middle of the horizon and less in the upper and lower parts;

Type D: The number of Gyropleura shells within the horizon progressively diminishes from lower towards the upper margin of the horizon;

Type E: The number of Gyropleura shells is approximately the same all over the horizon.

2. Referring to preservation of Gyropleura shells within the horizon three types are distinguished:

Type 1: Mostly complete articulated Gyropleura shells;

Type 2: Complete Gyropleura shells and their fragments;

Type 3: Mostly fragments of Gyropleura shells

LAMINITES IN THE PROFILE OF ŠKOCJANSKE JAME

Considerable thickness of dolomitized limestones in laminae within the profile of Škocjanske jame indicates that during the time of the Vreme beds deposition the sedimentary environment was extremely shallow. Several authors (Laporte 1975; Read 1975; Hoffman 1975; Wanless 1975) believe that in these limestones the anorganic laminae the most frequently alternate with laminae which are the rests of the blue-green algae (cyanobacteria). The same is supposed for the laminated limestones in the Škocjanske jame profile. Referring to recent researches of sea shoals (Monty 1967) the laminated stromatolitic crusts originated at intertidal or even supratidal areas and rarely in deeper subtidal environment, protected against the waves.

CONCLUSION

The basic goal of this research was to study the sedimentary environment of the Gyropleura and Apricardia layers within the Vreme beds.

1. Numerous shells of Gyropleura and Apricardia genus and maybe some other shells too are found within the Vreme beds at the secondary site.

2. Gyropleura lived in shallow sea not far from the coast, and have been transported to their secondary site by current action caused by storms and tempests.

3. The absence of Rhapydionina within the Gyropleura horizons confirms the statement that the shells were thrown towards the coast as Rhapydionina lived in lagoon environment. The laminae indicate the shallow sedimentary environment too.

Translated by Maja Kranjc

BARON HERBERSTEIN ON THE CERKNICA KARST LAKE - A PHANTOM BOOK OF THE 16TH CENTURY?

BARON HERBERSTEIN O CERKNIŠKEM JEZERU - NEOBSTOJEČA KNJIGA IZ 16. STOL.?

TREVOR R. SHAW

Abstract UDC 551.44 (091)

Shaw, Trevor R.: Baron Herberstein on the Cerknica Karst Lake - a Phantom Book of the 16th Century?

De admirandis rebus naturae by Sigmund von Herberstein, cited as a published source in Valvasor (1689), can nowhere be traced. An apparent reference to it by Wernher (1551) proves to refer only to a verbal report. It is concluded that Valvasor, or his collaborator Francisci, was confused by the inclusion of Wernher's De admirandis Hungariae aquis as an appendix in Herberstein's Rerum Moscoviticarum commentarij without any prominent statement of its authorship.

Key words: karstology, history of karstology, Cerkniško jezero, Herberstein S., Valvasor J. W., G. Wernher

Izvleček UDK 551.44 (091)

Shaw, Trevor R.: Baron Herberstein o Cerkniškem jezeru - neobstoječa knjiga iz 16. stol.

Dela "De admirandis rebus naturae" Sigismunda von Herbersteina, ki ga navaja Valvasor (1689) med svojimi tiskanimi viri, ni mogoče zaslediti. Wernherjeva (1551) navedba se nanaša najbrž le na ustno poročilo. Avtor meni, da je Valvasorja, ali njegovega sodelavca Franciscija, zavedlo dejstvo, da je Herbersteinovemu delu "Rerum Moscoviticarum comentarij" priključeno kot dodatek Wernherjevo delo "De admirandis Hungariae aquis" brez opazne navedbe avtorja.

Ključne besede: krasoslovje, zgodovina krasoslovja, Cerkniško jezero, Herberstein S., Valvasor J. W., G. Wernher

THE BOOK CITED

When Georg Wernher (1551) described the intermittent karst lake of Cerkniško jezero in Slovenia, he acknowledged Sigmund von Herberstein as the source of his information. Nearly 140 years later Valvasor's Die Ehre dess Herzogthums Crain (1689) lists among the sources used De admirandis rebus naturae by Herberstein. So it has always been assumed that such a book must exist. What is this publication? What does it say? And where is it to be found?

In the first volume of Valvasor's Die Ehre... is a 12-page "Verzeichniss aller derer Scribenten...", acknowledging publications used in the preparation of the book. The list was probably prepared by Valvasor's collaborator and editor, Erasmus Francisci (Baraga 1990), but this does not diminish its authority. The entry reads "Sigmund Freyherr von Herberstein de Admirandis Rebus Naturae" (Fig. 1).

As is common throughout the list, the date and place of publication are not given. In his text it is described as a little book ("Buchlein") and also as being "in Quarto", i.e. with its sheets folded into four leaves and so of smaller height than the folio volumes of Die Ehre ... Thus the book being described had evidently been examined.

Georg Wernher's *De admirandis Hungariae aquis hypomnemation* (1551) includes a four-page description of Cerkniško jezero, and states that "Sigismund in Herberstein" provided the information. A modern English translation of this description, made by the late G. F. Pullen, a professional Latin scholar and translator and published as an appendix by Shaw (1979), renders this acknowledgement as "... I will describe it from what you yourself have written".

Both Wernher's book and Valvasor's refer in some detail to the caves, sinks and underground streams associated with the lake and both provide maps of it. It was tantalizing to wonder what of this information was derived from Herberstein and whether he had recorded any other facts about these karst phenomena.

An intensive search was started for a copy of the original publication. Bearing in mind Wernher's reference in 1551, and Herberstein's birth in 1486, it seemed likely that the book must have appeared between about 1510, when Herberstein was 24 years old, and 1551. Furthermore Herberstein's other books were published from 1549 onwards, suggesting a date later rather than earlier in this period.

THE BOOK NOT FOUND

The existence of Herberstein's De admirandis rebus naturae as a printed book became less and less likely as the search continued. Enquiries showed that no copies exist in the national libraries of Austria, the Czech Republic, France, Great Britain, Hungary or Slovenia, nor in the Bodleian Library or the college libraries in Oxford, the library of the Royal Society, the Danish Royal Library, the Schleswig-Holsteinische Landesbibliothek in Kiel, the libraries of the Evangelisches Predigerseminar in Wittenberg or the Erdgenössische Technische Hochschule in Zürich, nor in Valvasor's own library (now in Zagreb). Neither this title or any similar one is recorded in the National Union Catalogue (covering libraries in USA) or in the bibliographies of Moller (1774), Ebert (1821) or Stillwell (1970). It is of particular significance that it is not included in the comprehensive Herberstein bibliography of Krones (1871). Moreover Pochlin (1803), although he does list it, gives Valvasor's reference as the sole authority.

It was not uncommon in the 16th century for a short piece of writing on one subject to be published as part of a larger book or as an appendix to a book on a quite unrelated subject. But searching showed that this was not so in this case; De admirandis rebus naturae was not contained in any of Herberstein's other books.

Thus its non-existence as a printed book seems almost conslusive. There still remains the possibility of its existing, or having existed once, in manuscript only. This can never be disproved, but the European libraries listed above, which are among the most likely to hold such material, all report that they are not aware of such a manuscript. Extensive searches of catalogues of manuscripts have similarly failed to reveal its presence.

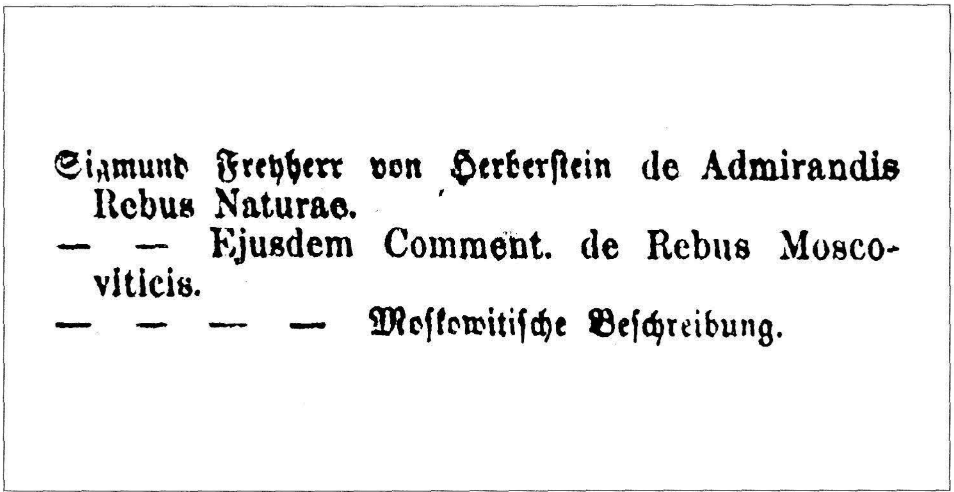
Sigmund Freyherr von Herberstein de Admirandis Rebus Naturae.
— — Ejusdem Comment. de Rebus Moscoviticis.
— — — — Moscowitische Beschreibung.

Fig. 1 - The reference to Herberstein's work, in Valvasor's book (1689, 1: (xliv))
Sl. 1: Navedba Herbersteinovega dela v Valvasorjevi knjigi (1689, 1: XLIV).

HERBERSTEIN THE MAN

Baron Sigmund (or Sigismund) von Herberstein (Fig. 2) was born in the castle at Vipava (Slovenia) on 23 August 1486 and died in Wien on 28 March 1566 (Eyriès 1817; Major 1851; Bergstaesser 1969; Sitar 1987). Although of German family he spoke Slovene. He studied law, became a soldier and fought against the Turks, and then from 1516 undertook diplomatic missions from the German court to Russia, Poland, Denmark, Turkey and elsewhere in Europe. The resulting travels provided materials for books, which seem to have

Fig. 2 - Sigmund von Herberstein, aged 61, in 1548. An engraving by Augustin Hirschvogel (reproduced by permission of the Staatliche Graphische Sammlung, München)

Sl. 2: Sigmund von Herberstein 1548, star 61 let, po gravuri Augustina Hirschvogla (objavljeno z dovoljenjem Staatliche Graphische Sammlung, München).

been renowned for their accuracy. One on Russia, which he visited in 1517 and 1526, is the best known, running into at least 19 editions in four languages.

Herberstein's birthplace, Vipava, is only 32 km from the Cerknica lake but, as his work as a diplomat took him to other countries, his native land seems not to feature in his books.

WHAT WERNHER REALLY SAID

Wernher dedicated his book De admirandis Hungariae aquis hypomnemation to Herberstein, and it has a foreword in the form of a letter from Herberstein to him encouraging him to publish and referring to his own experiences of springs but without mentioning Cerknica. In introducing his remarks on the Cerknica lake (Fig. 3) and writing as if addressing Herberstein, Wernher's actual words were "...de tuo sermone describam...". "Sermo" normally refers to speech, so his phrase is best translated as "I will describe from what you yourself have said" or "... told me". Thus Pullen's version, "I will describe it from what you yourself have written", hitherto the accepted English translation, is imprecise and misleading.

There is thus no reason, from what Wernher wrote, to expect to find a published description by Herberstein of the Cerknica lake. But we are left with the fact that Valvasor (1689), or his co-author Francisci, refers definetely to De admirandis rebus naturae as one of his sources. From this alone one might suspect that Herberstein did indeed write about the lake, possibly published after Wernher had used his verbal information in his own book, or perhaps left only as an unpublished manuscript. Or could the Valvasor reference have been an error?

WHAT VALVASOR REALLY SAW

The important question remains: what was it that Valvasor or Francisci was citing as De admirandis rebus naturae? There is no evidence of a completely spurious work being named

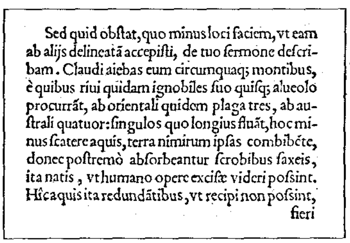
Sed quid obſtat, quo minus loci faciem, vt eam
ab alijs delineatã accepiſti, de tuo ſermone deſcri-
bam. Claudi aiebas eum circumquaq; montibus,
è quibus riui quidam ignobiles ſuo quiſq; alueolo
procurrãt, ab orientali quidem plaga tres, ab au-
ſtrali quatuor: ſingulos quo longius fluãt, hoc mi-
nus ſcatere aquis, terra nimirum ipſas combibẽte,
donec poſtremò abſorbeantur ſcrobibus ſaxeis,
ita natis, vt humano opere exciſæ videri poſsint.
Hîc aquis ita redundãtibus, vt recipi non poſsint,
fieri

Fig. 3 - Wernher's acknowledgement, on lines 2 and 3, of Herberstein as the source of his information (Wernher 1551, f. 17b)

Sl. 3: Wernherjeva navedba, v 2. in 3. vrstici, Herbersteina kot vir informacij (Wernher 1551, f. 17 b).

elsewhere among the sources listed; nor would it have served any purpose. Errors in transcription were not rare at that time, but unless some other publication was known to Valvasor and his colleague that could have been erroneously recorded under that title, one is left to conclude that a manuscript account of the lake by Herberstein did once (and perhaps still does) exist. It is relevant, though, that none of the other authorities listed in the "Verzeichniss aller derer Scribenten" of Die Ehre... appear to have been unpublished.

But there is a possible, even probable, way in which Valvasor's list of sources could, with a little careless copying, have produced "De admirandis rebus naturae" from a well-known book which does exist.

Wernher's De admirandis Hungariae aquis hypomnemation (note the somewhat similar title) exists in several editions. As a separate publication it appeared in 1551 (Hungarian bibliographies show an edition of 1549, but no copy has been traced). This 1551 edition is of quarto size and contains only 20 leaves, so it is similar in appearance to the "Buchlein ... in Quarto" descibed in Die Ehre ... In additon, it was included (apparently without the map of the lake) as an appendix in several, but not all, editions of Herberstein's Rerum Moscoviticarum commentarij. In Latin it was published with the editions of 1556, 1557 and 1571, and a German translation formed part of the 1563 and 1567 editions of the German version, Moscoviter wunderbare Historien. It appeared also, with the map, in Broniowski's book of 1595.

In none of these editons was Wernher's name prominent on the title page and in the editions of 1556 and 1571 it did not appear there at all. Although his name was present in the title block of the poem, so was Herberstein's as the person to whom it was sent. It would be all too easy for a hurried editor or assistant to record the Wernher appendix under the principal name of the title page. Errors in transcribing the title in haste are also possible; such mistakes are not unknown in the 20th century. Confusion with Wernher's book is not precluded by the fact that Valvasor's list of sources includes also ""Georgius Wernerus de Admirandis Hungariae aquis"; indeed its likelihood is somewhat strengthened as even this otherwise accurate citation spells Wern(h)er's name differently from the way it is written in his book.

CONCLUSION

It has been shown that Wernher (1551) did not in fact refer to Herberstein's having written on the Cerknica lake but only to information obtained from him verbally. Extensive searching has failed to find any evidence of De admirandis rebus naturae by Herberstein existing at all, either printed or in manuscript.

It is therefore concluded that this title, listed among Valvasor's sources as by Herberstein, is in fact an erroneous transcription of Wernher's De admirandis Hungariae aquis hypomnemation which was printed as an appendix in several editions of Herberstein's Rerum Moscoviticarum commentarij.

What did Herberstein's book contain is therefore a meaningless question. What it would have contained, had it been written, would have been similar to what Wernher wrote, for the latter acknowledges that this is described "from what you [Herberstein] yourself have said." Wernher goes into sufficient detail to make it unlikly that he omitted any significant facts.

ACKNOWLEDGEMENTS

I am particularly grateful to Prof. Dr Dieter Lohmeier, Director of the Schleswig-Holsteinische Landesbibliothek, who pointed out that Wernher's text did not in fact refer to a written description of the Cerknica lake by Herberstein; he also verified the holdings of the Danish Royal Library. W. Rudolf Reinbacher, of USA, took the Herberstein problem to heart and suggested contacts in several major libraries in Germany and Switzerland. Alan J. Clarke, Deputy Librarian of the Royal Society, and Erika Schulz of the library of the Evangelisches Predigerseminar in Wittenberg also made helpful suggestions. As always, the services of the British Library in London were indispensable. I thank also all those other libraries that reported their holding of Herberstein's Moscow book containing the Wernher text, and their non-holdings of his supposed De admirandis rebus naturae. The National Library of Hungary advised on the status of the commonly-cited 1549 edition of Wernher's book. The National and University Library of Slovenia told me of two important bibliographies.

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BARON HERBERSTEIN O CERKNIŠKEM JEZERU - NEOBSTOJEČA KNJIGA IZ 16. STOL.?

Povzetek

Ko je G. Wernher (1551) opisal Cerkniško jezero, je omenil S. von Herbersteina kot svojega informatorja. Skoraj 140 let kasneje Valvasor v svoji Die Ehre des Herzogthums Crain (1689) navaja med objavljenimi viri Herbersteinovo delo De admirandis rebus naturae. Torej se je vedno domnevalo, da ta knjiga mora obstajati. To delo bi moralo biti tiskano med leti 1510 in 1551, raje bliže 1550. Avtor je iskal po številnih knjižnicah in zbirkah dokumentov, a knjige ni našel, niti ni to delo v obliki dodatka objavljeno v kaki drugi Herbersteinovi knjigi. Iz tega izhaja sklep, da ta knjiga ni bila tiskana. Avtor domneva, da je Valvasor napačno prepisal vir - Wernherjevo delo De admirandis Hungariae aquis hypomnemation - ki je tiskano v dodatku nekaterih izdaj Herbersteinovega dela Rerum Moscoviticarum comentarij brez posebne navedbe Wernherjevega imena kot avtorja.

THE BONEWELL SPRING (ENGLAND) IN VALVASOR'S "DIE EHRE DESS HERZOGTHUMS CRAIN" (1689) - THE AUTHOR'S SOURCES

IZVIR BONEWELL (ANGLIJA) V VALVASORJEVI "SLAVI ... (1689) - AVTORJEVI VIRI

TREVOR R. SHAW

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Izvleček UDK 551.44 (091)

Shaw, Trevor R.: Izvir Bonewell (Anglija) v Valvasorjevi "Slavi ... (1689) - avtorjevi viri

Bonewell (Bone Well ali Boney Well), ki ga omenja Valvasorjev sodelavec Erazem Francisci v Die Ehre dess Herzogthums Crain, je izvir iz apnenca, ki je naplavljal kosti žab. Avtorjev vir, J. C. Becmann, ga navaja po knjigi Britannia (izdaja 1607) angleškega topografa Williama Camdena.

Ključne besede: krasoslovje, kraška hidrologija, kraški izvir, zgodovina krasoslovja, Anglija, Bonewell.

Abstract UDC 551.44 (091)

Shaw, Trevor R.: The Bonewell Spring (England) in Valvasor's "Die Ehre dess Herzogthums Crain" (1689) - the author's sources

The Bonewell (Bone Well or Boney Well), referred to by Valvasor's collaborator, Erazem Francisci, in Die Ehre dess Herzogthums Crain, is a limestone spring from which frog bones used to be washed out. The author's stated source, J. C. Becmann, obtained his information from the 1607 edition of the book Britannia by the English topographer William Camden.

Key words: karstology, karst hydrology, karst spring, history of karstology, England, Bonewell.

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In reviewing karst phenomena in parts of the world outside Slovenia, Die Ehre dess Herzogthums Crain (Valvasor 1689) refers to "Der Beinlein, Brunn in Engeland":

In einer Englischen Provintz Herford-Shire bey Richards Castle (oder dem Schloss Richardi) findet man einen Brunnen welchen die Innwohner the Bonewell, (die Bein = Quelle) zu nennen pflegen; selbiger schwimmt voller Beinlein welche denen so man in den Fröschen findet nicht ungleich sehen und wann man sie gleich alle heraus nimt so ersetzt sie doch der folgende Tag wieder in voriger Menge. (a)

(a) J. C. Bechmannus, Historia Orb. Terr. Part 1. Cap III 4

In the English county of Herefordshire, near Richards Castle one finds a spring which the local people call the Bonewell; the same flows full of small bones which are not dissimilar to what one finds in frogs and when they are all taken out it replaces them the following day in the same quantity.

This passage is one of the several in Valvasor's book, providing background for phenomena in Slovenia, that were written by his collaborator and editor Erazem Francisci (Baraga 1990).

What is this spring? How did knowledge of it reach Valvasor? And were bones really present in the water?

THE SPRING

The spring known as the Bone Well or Boney Well is about 5 km south-west of the town of Ludlow at latitude 52°19'43" N and longitude 2°45'48" W, more conveniently located by the National Grid Reference, SO 481703 (Fig. 1).

Richard's Castle, now ruined and all but disappeared, is one of the earliest castles in England, being built about 1050 AD. The village near it is also called Richard's Castle.

The standard account of springs in the county of Herefordshire (Richardson 1935) describes the Bone Well as "a strong overflow spring from the top of the Aymestry Limestone where it disappears beneath the [impervious]... Upper Ludlow beds" of the Upper Silurian period. Richardson also states that "From the collecting chamber near the spring the Manor House, Batchcott, the rectory and church are supplied by gravitation. A pipe also leads to Moor Park and several cottages." All these are shown on the map (Fig. 1) and most of them are many centuries old or have replaced older building on the same sites. The spring is now usually known as Boney Well, as printed in the official maps of the Ordnance Survey since the 19th century.

The volumetric output of the spring is not known, but the National Rivers authority has authorized the use "of a maximum of 2250 gallons (10,23 m^3) per day and not more than 821,250 gallons (378,5 m^3) in any calendar year for domestic and agricultural use on the estate" (Abstraction Licence No. 18/54/ 9/5; Catherine Bason of the National Rivers Authority, pers. comm.). The present landowner, Sir Humphrey Salwey, states that the spring currently supplies seven house and is also used for providing water for livestock.

VALVASOR'S SOURCES

As Francisci (in Valvasor 1689) acknowledges, his immediate source was a book by Johann Christoph Becmann. This was first published in 1673, and the extract below is taken from the 2nd edition of 1680. The description there, and in the 3rd edition of 1685, is almost word for word the same as the text in Valvasor's book, except for being written in Latin. It is not known which edition Francisci used.

In Herford-shire, Provincia Angliae prope Castellum Richardi, Richards Castle, Fons est Fons Ossium, the Bonewell, communiter dictus, qvod Ossiculis fluat, iis qvae in ranis sunt non dissimilibus, qvibus etiam, si examinantur omnia, seqventi die eadem copia scatet.

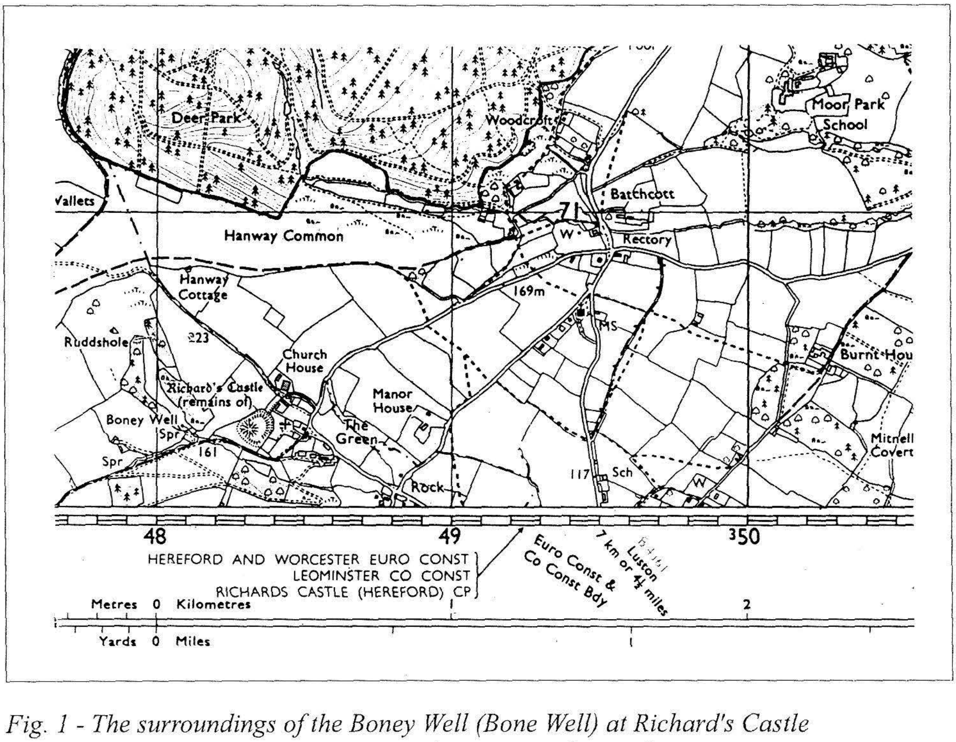

Fig. 1 - The surroundings of the Boney Well (Bone Well) at Richard's Castle
Sl. 1: Lega izvira Boney Well (Bone Well) pri Richard's Castle.

In the English county Herefordshire, near Richards Castle, a spring is commonly called the Bonewell, because small bones flow out from it, to which those of frogs are not dissimilar, which if they are all [removed &] examined, gush out the next day just as abundantly.

Becmann, in turn, undoubtedly derived his basic description from Britannia of William Camden, a pioneering topographical survey of the British Isles first published in 1586 and the source of very many subsequent descriptions of places in England. Valvasor does include "Camdenus" (no date) in the list of works consulted but, as has been seen, it was Becmann's book that was acknowledged as the source of the Bonewell information.

When Britannia was first published, the text concerning the Bone Well was as follows:

Richards Castle... Sub quo natura quae nusquam magis quam in aqua miraculis ludit, fonticulum eduxit pisciculoru ossiculis semper scatentem, quamuis subinde exhauriantur, vnde Bone Well vocitatur.

Mentioning fish bones only. However Camden continued to modify and add to the book until 1607, in which year the much enlarged 6th edition was issued. Here it is that the alternative of frog bones is first mentioned:

Sub hoc, natura quae nusquam magis quam in aqua miraculis ludit, fonticulum eduxit pisciculorum (vel vt putant ranularum) ossiculis semper scatentem, quamuis subinde exhauriantur, vnde Bone Well vocitatur.

Fig. 2 - The Bone Well about 1833 (reproduced from Murchison 1839, p. 250). The date is deduced from information in Thackray (1978)
Sl. 2: Bone Well okoli 1833 (reprodukcija iz Murchisona 1839, str. 250). Letnica je določena po navedbah v Thackrayovem delu (1978).

A contemporary English translation is that of Philemon Holland (Camden 1610):

Beneath this castle, Nature, who no where disporteth her selfe more in shewing wonders, then in waters, hath brought fourth a pretie well, which is alwaies full of little fish bones, or as some thinke, of small frog-bones, although they be from time to time drawne quite out of it, whence it is commonly called Bone well.

A more easily understandable translation is the one by Bishop Edmund Gibson (Camden 1695):

Beneath this Castle, Nature (which no where sports her self more in shewing wonders than in the waters) hath brought forth a little Well, which is always full of small fish-bones (or as others think, small frog-bones) notwithstanding it is ever now and then emptied and clear'd of them; whence 'tis commonly call'd Bone-Well.

OTHER DESCRIPTIONS OF THE BONE WELL

Brief reference was made to the Bone Well in Michael Drayton's topographical poem Polyolbion first published in 1612:

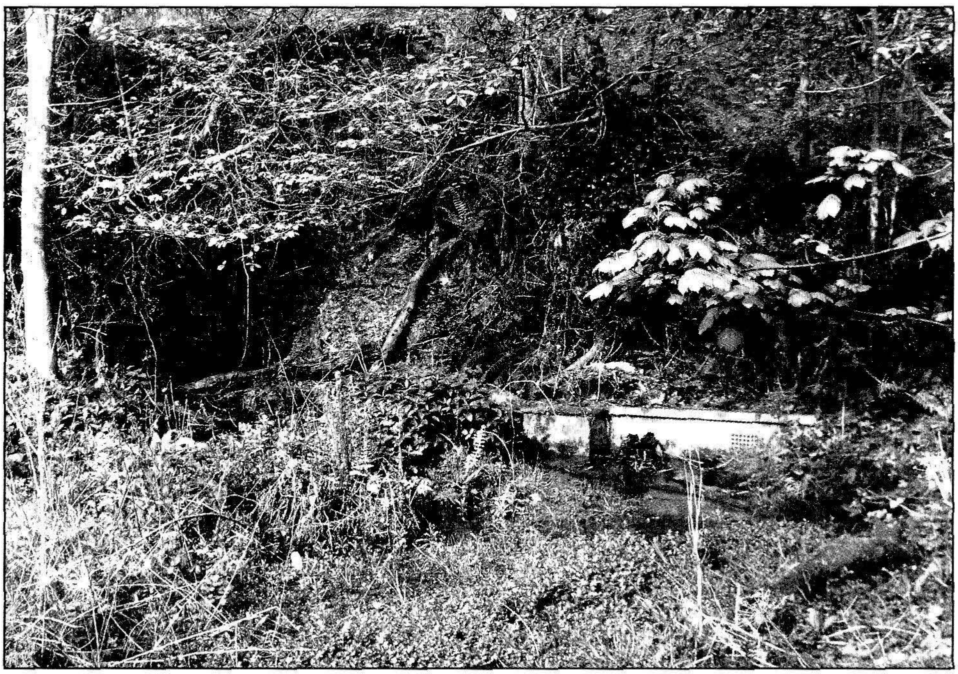

Fig. 3 - The Bone Well photographed on 30 April 1993. The collecting chamber made of brick can be seen
Sl. 3: Slika Bone Wella posneta 30. aprila 1993. Viden je zbiralnik iz opeke.

... with strange and sundry tales, Of all their wondrous things; and not the least, of Wales; Of that prodigius Spring (him neighbouring as he past) That little Fishes bones continually doth cast.

Although not containing sufficient information to be Becmann's source, this reference to the spring is an early example of how, once a place of phenomenon had been described by Camden, it appeared again and again in later literature, in England and elsewhere, no matter how small its real importance. Many, including the Bone Well, continued to attract attention because of their curiosity value.

It is not surprising that local guide books to the region noticed the spring. One of the earliest of these (Anon. 1811) adds the fact that the appearance of the frogs' bones "happens at two particular seasons of the year only, viz. March and September" and the writer supposed that "the coldness of the water first killed the frogs, and then destroyed and dissolved the flesh".

The distinguished geologist Sir Roderich Impey Murchison (1839) had a small box of bones from the spring examined and they were identified as being exclusively of frogs, with no fish bones at all. The illustration reproduced here as Fig. 2 is taken from Murchison's book and the place is hardly changed today except that it is overgrown with vegetation (Fig. 3). He writes:

The water issues from one of the joints before described, and as this joint is doubtlessly connected with many other similar open cracks, which ramify through the higher slopes of the ridge, we can easily comprehend how the minute bones or frogs or even of mice, living and dying on the adjacent hills, should from time to time be washed down through connecting fissures and discharged at the first natural source wide enough to afford them egress; their occasional issue depending on floods, sudden thaws, and such causes.

EXPLANATION OF THE BONES

Wolfgang Zeuner (pers. comm.), a geologist living in the area, agrees that "Murchison was right. The explanation is that frogs got into fissures further upstream and died, and in times of flood, i. e. spring and autumn, their clean bones were washed down and settled out. Nowadays there ae not enough frogs, sadly, so no bones despite an adequate water flow".

The present writer collected two very small bones from just outside the overflow of the collecting chamber in April 1993. Although they could have come from elsewhere, the spring is their most likely source. They were identified at the Natural History Museum in London (A. P. Currant, pers. comm.) as a very small bird femur and a fragment of a limb bone, possibly a femur, of a small mammal about the size of a Short Tailed Field Vole (*Microtus agrestis*) or Wood Mouse (*Apodemus sylvaticus*).

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IZVIR BONEWELL (ANGLIJA) V VALVASORJEVEM DELU "DIE EHRE DESS HERZOGTHUMS CRAIN" (1689) - AVTORJEVI VIRI

Povzetek

Opis kraškega izvira Bonewell, ki ga opisuje Valvasorjev sodelavec Erazem Francisci v Die Ehre dess Herzogthums Crain, je takorekoč neposredni prevod odlomka iz dela J. C. Becmanna Historia Orb. Terr. (1673), ta pa ga je povzel po knjigi Britannia (izdaja 1607) angleškega topografa Williama Camdena.

Izvir Bonewell je jugozahodno od mesta Ludlow (Herefordshire), pri vasi Richard's Castle, ki ima ime po enem najstarejših angleških gradov. To je relativno močan (do 10,23 m^3 dnevno) prelivni kraški izvir, zajet za nekaj posestev, za župnišče in nekaj kmetij. Ime je dobil po tem, da, kot navajajo stari viri, voda nanaša koščice žab - če se jih pobere iz vode, jih voda takoj spet nanese. Znani geolog R. I. Murchinson (1839) je zbral koščice in jih določil kot žabje. Tudi današnji raziskovalci se strinjajo s tem, da so se žabe zalezle v razpoke ob vodi navzgor in ko so poginile, je voda nanašala njihove obeljene kosti. Žal danes ni več toliko žab in voda njihovih kosti ne nanaša več.

DEJAVNIKI OBLIKOVANJA JAMSKE SKALNE POVRŠINE

THE FACTORS INFLUENCING ON THE FORMATION OF THE CAVE ROCKY SURFACE

TADEJ SLABE

Izvleček UDK 551.442 (497.12)

Slabe, Tadej: Dejavniki oblikovanja jamske skalne površine

Speleogenetski dejavniki, ki oblikujejo skalni relief kraških votlin, se odražajo tudi na njegovi površini. Skalna površina je zato pogosto pomembna sled oblikovanja in razvoja votlin. Vodni tokovi zaradi raztapljanja in mehanskega brušenja kamnine ustvarijo gladko, razeno in obtolčeno površino. Skala je pogosto gladka tudi pod drobnozrnato naplavino, drobno pa jo členi kondenzna vlaga in biogeni dejavniki. Pomembna spoznanja prispeva proučevanje skalne površine s pomočjo elektronskega vrstičnega mikroskopa. Pod velikimi povečavami so površine, ki so pri opazovanju s prostim očesom gladke, lahko raznovrstno, toda značilno drobno hrapave. Takšna je tudi mehansko zglajena površina in skala oblikovana pod drobnozrnato naplavino. Na nehomogeni kamnini je težje razbrati procese njenega oblikovanja. Površina odraža predvsem sestavo kamnine.

Ključne besede: kraška votlina, skalni relief, skalna oblika, skalna površina, Slovenija, kraško ozemlje

Abstract UDC 551.442 (497.12)

Slabe, Tadej: The factors influencing on the formation of the cave rocky surface

Speleogenetical factors influencing on rocky relief of the karst caverns reflect on its surface too. This is why the rocky surface is frequently an important clue of formation and development of the caves. Water creates either by the dissolution or mechanical polishing smooth, abrased or bruised surface. The rock is frequently smooth below the fine-grained sediments, it is thinnly etched by condense humidity or biogenic factors. The study by electronic microscope contributes important knowledge. Aided by great magnifications the surfaces seemingly smooth with a naked eye, are diversely, characterictically etched in detail. Such is also mechanically polished surface and rock below the fine-grained sediments. The processes of such formation are much more difficult to be viewed on the unhomogeneous rock. The surface reflects the lithology mostly.

Key words: karst cave, rocky relief, rocky feature, rocky surface, Slovenia, karst area

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Pri proučevanju oblikovanja in razvoja jamskega skalnega reliefa, sestavljenega iz raznovrstnih skalnih oblik, pozornost posvečam tudi njihovi površini. Gladkost in hrapavost skalne površine sta posledici lastnosti in učinkovitosti dejavnikov, ki v različnih hidroloških pogojih povzročajo procese na kamnini in odnašajo njihove proizvode. Kamnina skalnega oboda rovov s svojo sestavo, skladovitostjo in pretrtostjo odloča o nastanku različnih skalnih oblik in vpliva na njihovo oblikovanje in površino.

Skalno površino lahko opišemo kot gladko ali hrapavo, bodisi, da jo opazujemo s prostim očesom ali povečano. Pod velikimi povečavami elektronskega vrstičnega mikroskopa so skorajda vse skalne površine vsaj deloma hrapave. To je posledica zrnate sestave karbonatnih kamnin. Skalna površina je sprana, ko dejavniki, ki delujejo nanjo, odnašajo proizvode procesov, ali pa je preperela. Takšna je, ko jo prekriva mehka plast deloma raztopljene kamnine.

Skalno površino in način njenega oblikovanja sem skušal predstaviti že v poročilih o proučevanju posameznih jamskih skalnih oblik. Z novimi dognanji dopolnjene in povezane izsledke sem strnil v samostojno poročilo, saj se izkazalo, da je površina jamskega skalnega reliefa pomebna speleomorfogenetska sled.

Površino skalnih oblik je z elektronskim vrstičnim mikroskopom fotografiral V. Segala (Oddelek za geologijo, Montanistika).

Delo poteka v okviru projekta Nastanek in oblikovanje kraških votlin, ki ga denarno omogoča Ministrstvo za znanost in tehnologijo Republike Slovenije.

VIRI O PROUČEVANJU SKALNE POVRŠINE

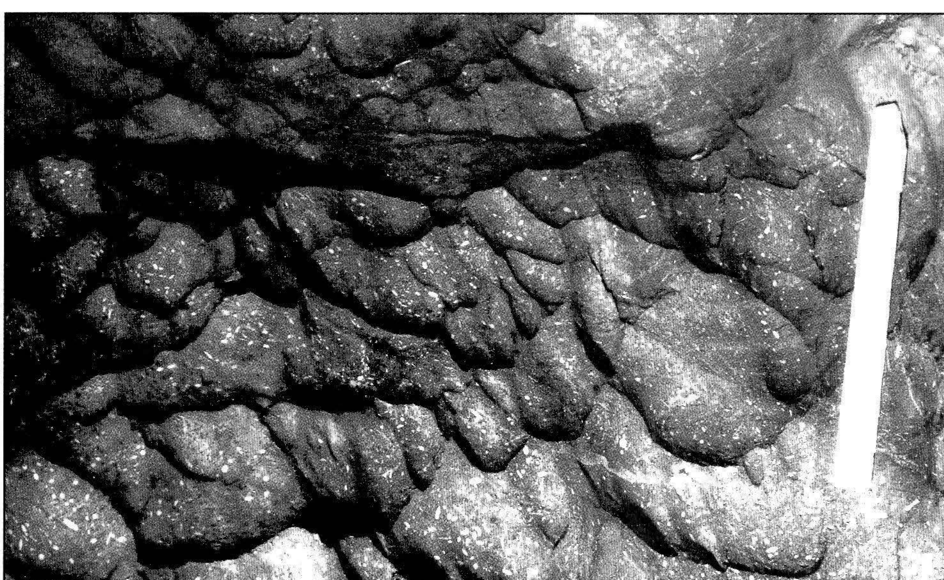
Pogosto so omenjene posamezne značilnosti skalne površine kot posledice litoloških značilnosti ali različnih dejavnikov, ki oblikujejo kamnino. Nisem pa zasledil celovitega pregleda tovrstnih izsledkov.

Pomen litoloških značilnosti pri oblikovanju skalne površine, reliefa skalne površine kot ga imenuje Renault (1958, 27) je izpostavilo več speleologov. Renault (1958, 27) je naštel fosile, leče roženca in žile kalcita, ki štrlijo iz sten. Površino, prepredeno z žilami kalcita, ki štrlijo iz sten v pravokotni mreži, poimenuje z angleškim izrazom boxwork, če pa so kalcitne žile razvrščene vzporedno, jih imenuje francosko palletes. Boxwork je leta

1942 opisal Bretz. Pri njegovem nastanku je poudaril, poleg značilnosti kamnine, pomen selektivne korozije zaradi stoječe vode. Sweetingova (1972, 78) pravi, da so karbonatna zrna s polinomnimi kristali počasneje topljiva. Ek in Roques (1972, 71) pišeta, da se drobnozrnat kalcit raztaplja hitreje kot tisti, ki je sestavljen iz večjih kristalov. To je posledica večje odpornosti kristalnih ploskev in omrežne energije večjih kristalov. Tudi Trudgill (1985, 76) poudarja velik vpliv litoloških značilnosti kamnine pri razvoju jamskih sten. Različna topljivost posameznih delcev kamnine in ostankov fosilov povzroča lokalno vrtinčenje vodnega toka. Drobne različnosti v topljivosti kamnine določajo mikrotopografijo (Trudgill 1985, 20). Herman in White (1985) sta ugotovila, da je površina dolomita zaradi različno velikih kristalov hrapava. Ford in Williams (1989, 286, 287) sta opisala boxwork na drobno razpokanem dolomitu, v katerem so razpoke zapolnjene s kalcitom. Kasneje se je na kalcitne žile odložil nov kalcit in mreža zato štrli 100 cm iz sten in stropa rova. Couturaud (1989, 38) je ugotovil, da se fosili iz oolitnega apnenca lahko izluščijo, iz mikrokristalinskega pa ne. Zato v prvem nastanejo vdolbinice.

Izpostavljen je tudi pomen dejavnikov in procesov, ki značilno oblikujejo skalno površino.

Trudgill (1979, 33) trdi, da je skalna površina gladka, če jo hitro razjeda tekoča agresivna voda, ki raztopino hitro tudi odnaša. Opiše (Trudgill 1985, 38) tudi glajenje površine zaradi skrajno kislih vod, ki delujejo na apnenec. Dognanja je dokazoval z laboratorijskimi poskusi,



Sl. 1. Fasete na paleogenskem apnencu v Beško ocizelski jami (merilo = 15 cm)
Fig. 1. Current markings on the Paleogene limestone at Beško-Ocizelska jama (scale = 15 cm)

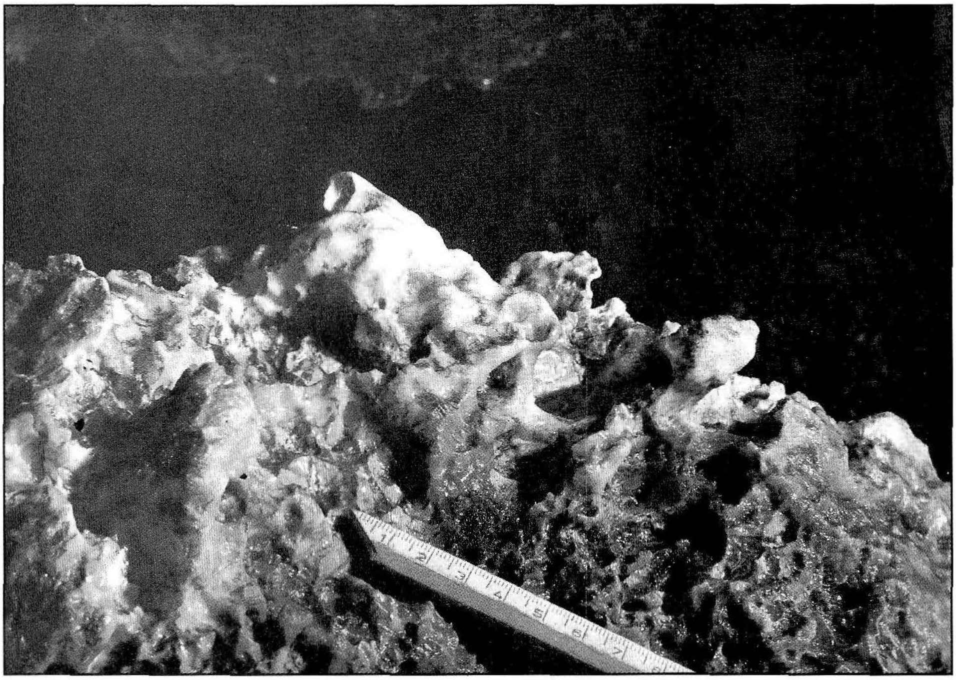
ko je uporabil kisline, in s posnetki skalne površine z elektronskim vrstičnim mikroskopom. Močna reakcija in počasno odnašanje raztopine povzroči gladko površje in obratno razmerje hrapavo. Gams (1963, 10; 1971, 36) že prej ugotavlja, da voda, ki pronica skozi drobnozrnato preperelino, ustvari gladke ploskve homogene kamnine.

Kranjc (1985) je s površine prodnikov razbral zadnji proces njihovega oblikovanja. Gladki so zaradi mehanskega brušenja, hrapavi pa zaradi raztapljanja kamnine. Slednji so v Babji jami starejši. Površino, na kateri se poznajo udarci prodnikov - to so vdolbinice ali pa razbita površina, je opisal Mihevc (1989).

Zaradi kavitacije naj bi bila skalna površina luknjičasta (Cigna 1983, 485). Predlaga (Cigna 1983, 485) mikroskopsko opazovanje izpostavljene skalne površine zaradi morebitno premaknjenih kristalov.

Polzeča voda v subkritičnem turbolentnem režimu oblikuje navpične in gladke stene, saj ob ovirah nastanejo hidravlični skoki, ki pospešijo erozijo (White 1988, 168, 297). Agresivna voda, ki polzi po previsni kamnini, gladi njeno površino (Gams 1962/1963). Voda se namreč težnostno zbira na delcih, štrlečih iz kamnine, ki so zato podvrženi hitrejši koroziji.

Skalno površino značilno členijo tudi biogeni dejavniki. Ti so kemični in fizikalni (Ollier 1984, 10). Epiliptični lišaji povzročijo nastanek gladke površine, endolitični pa se zajedajo



Sl. 2. Površina apnenca v Velikem Hublju
Fig. 2. The limestone surface in Veliki Hubelj

v kamnino in ustvarjajo vdolbinice (Sweeting 1967). Lišaji lahko povzročijo destrukcijo mineralov (Ollier 1984, 55). Trudgill (1985) je z elektronskim vrstičnim mikroskopom ugotovil, da so se v romboidne kristale zajedle alge. Najbolj natančno je posledice lišajev na karbonatnih kamninah razčlenil Viles (1987). Glive povzročajo nastanek vdolbinic, nitasti deli alg pa kanalčkov. Tako mikrotopografijo je imenoval biokras (Viles 1987, 467, 468). Zajede nastanejo med kristali, izvrtine pa tudi v njih. Karbonate napadajo tudi kisline bakterij (Chorley 1984). Pogosta so dela, ki poročajo o vplivu morske bioerozije na karbonatno kamnino. Ta ni predmet tokratnega proučevanja, le metoda, ki sta jo uporabila Palmer in Plewes (1993, 139), bi lahko bila uporabna. Biogene zajede sta zalila s epoksidno smolo in

Sl. 3. Površina konglomerata s fasetami v Smoganici (merilo=15 cm)
Fig. 3. The conglomerate with current markings surface in Smoganica (scale = 15 cm)

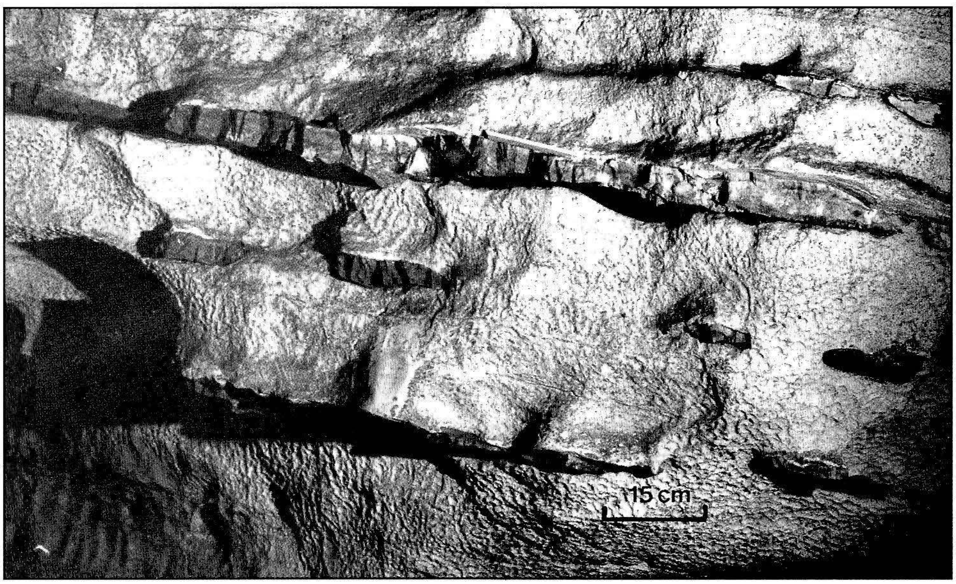
nato raztopila kalcit. Na ta način so lepo razvidne posledice na apnencu in razpoznati je moč njihove povzročitelje.

Pri proučevanju jamskih skalnih oblik sem speleomorfogenetski pomen njihove skalne površine določeval tudi sam (Slabe 1987, 1988, 1989, 1990, 1992, 1993).

OBLIKOVANJE SKALNE POVRŠINE ZARADI OBLIVANJA KAMNINE Z VRTINČASTIM VODNIM TOKOM

Skalni relief kraških votlin najbolj učinkovito oblikujejo vodni tokovi. Zaradi vrtinčenja vode ob hrapavi površini skale nastanejo fasete. Ob stropnih razpokah, zajedah in zaradi vrtinčenja vode ob zoženju ali razširitvi rovov se oblikujejo stropne kotlice, v skalnih strugah vodni tok dolbe draslje, med izrazitimi razpokami nastanejo skalni stebri in noži. Vodni tok raztaplja kamnino in jo mehansko brusi s trdnim tovorom, ki ga prenaša. Površino, ki je izpostavljena vodnemu toku, lahko razdelimo na gladko, razeno in obtolčeno.

Fasete (Slabe 1993, 153) nastanejo predvsem na homogeni kamnini. Njihova površina, še zlasti manjših, je gladka. Iz površine pa lahko štrlijo sparitni kristali, kalcitne žilice, fosili in intraklasti v mikritni osnovi ali pa se vanjo zajedajo vdolbinice, ki so vezane na hitreje topljive dele kamnine ali na drobne razpoke (Slabe 1993, 157). To je posledica različne topljivosti posameznih delov kamnine. V Ocizeljski jami (Slabe 1993, 153), kjer



Sl. 4. Majhne fasete na apnecu iz katerega štrlijo gomolji roženca v Malih jamah Postojnske jame (merilo=15 cm)
Fig. 4. Small current markings on the limestone, the chert nodules protruding, Male jame in Postojnska jama (scale = 15 cm)

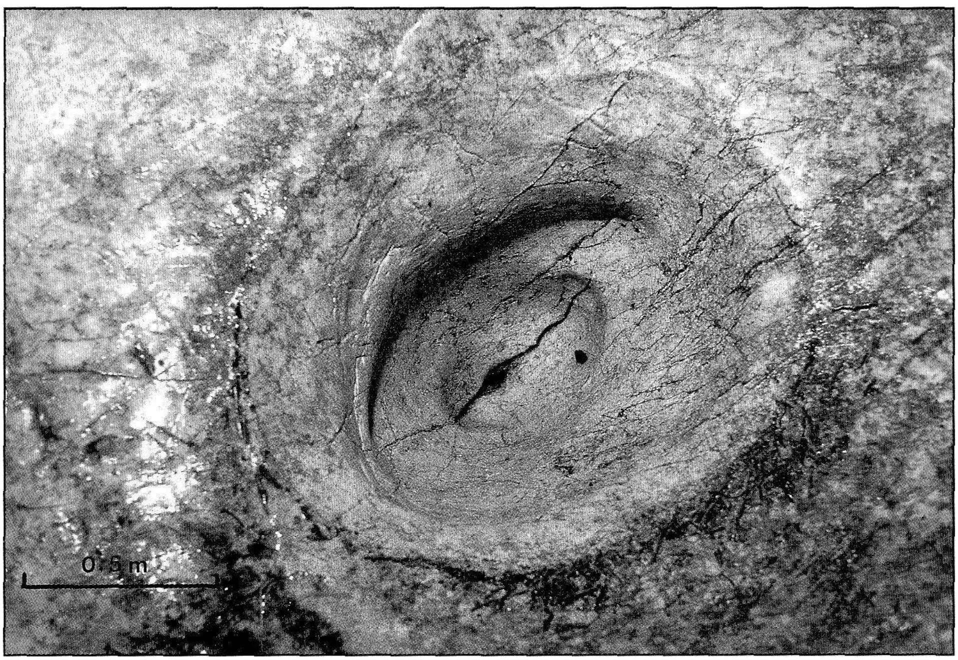
so fasete na paleogenskem apnencu (sl.1), se alveoline, numuliti in orbitoline na površini faset ne odražajo veliko.

Na nehomogeni kamnini, sestavljeni iz različno velikih in topnih delcev, majhne fasete ne nastanejo, večje pa so raznovrstnih oblik (Slabe 1993, 153). V Velikem Hublju je površina prekristaliziranega apnenca hrapava (sl.2). Iz nje štrlijo 1-3 cm veliki sparitni kristali. Na občasno poplavljenem delu stene v Pivki jami so fasete dolge okoli 3 cm, kjer pa štrlijo 1,5 cm iz površine rudisti, faset ni. Tudi v Predjami v Ponorni jami Lokve iz stene štrlijo rudisti. Prek njih je vrezana drobno razčlenjena mreža večjih faset s hrapavo površino. V Križni jami in v Velikem Hublju iz dolomita štrlijo manjši in večji skupki kristalov sparitnega veziva, ki povečuje obstojnost kamnine v vodnem toku. Zato v Križni jami dolomit štrli iz sten. V njegovo površino so zajedene posamezne majhne vdolbinice. Majhne površine krojivega dolomita v Pucovem breznu pa so gladke. Krojivost povzroča, da se kamnina členi v stopničke. V Smoganici so v strugi iz karbonatnega konglomerata fasete (sl.3) le na kosih apnenca, ki so nekajkrat večji od faset. Vezivo, v katerem so manjši kosi apnenca in peščenjaka, je grobo hrapavo in v razčljenjih konicah štrli iz skalne površine. V Podstrešju Male Boke intraformacijsko brečo sestavljajo manjši deli kamnine (1-3 cm premera), vmes pa je trdno sparitno vezivo, ki štrli iz sten. Med sparitnim vezivom so oglate vdolbine, ki so

Sl. 5. Stropna kotlica v apnencu z roženci v Stari jami Predjame (10 cm = 2m)
Fig. 5. Ceiling pocket in limestone with cherts in Stara jama of Predjama (scale = 10 cm = 2 m)

podolgovate ob razpokah. V bližnjem rovu z apnenčastim obodom, kjer so ob visokih vodah podobni hidrološki pogoji, nastanejo fasete. V Lepih jamah Postojnske jame štrlijo med fasetami do 2 cm iz stene podolgovate leče rožcnca (sl.4), katerih površina je nazobčana z ravnimi ali le malo zaobljeni ploskvami.

Od nastanka stropne kotlice zaradi vrtinca v vodnem toku ali povezave z zračnimi mehurji in od sestave ter razpokanosti kamnine je odvisna tudi zglajenost njene površine. Kotlice na homogeni kamnini, ki jo obliva hitrejši vodni tok, imajo gladke obode (Babja jama), na nehomogeni kamnini pa iz njihove površine štrlijo počasneje topni delci kamnine (Matijeva jama) in roženci (sl.5). Njihova površina je razčlenjena tudi ob drobnih razpokah (sl.6). V Rakovem rokavu v Planinski jami visoke vode stisnejo in osamijo zračne mehurje v stropne zajede. Površina plitkih, a dokaj širokih kotlic nima izrazitih znakov vrtinčenja vode in je hrapava. To bi bila lahko posledica kondenzne korozije, ki pa je kotlice verjetno le preoblikovala. Podobno hrapava so tudi dna kotlic v niši Križne jame. Mucke, Völker in Wadevitz (1983) poudarjajo pomen kondenzne korozije v stropnih zajedah, v katerih je ujet zrak. Kondenzacija je mogoča, če je voda toplejša od kamnine. Pogosto se pri razlagi nastanka kotlic omenja pomen plinov s CO_2, ki se v vrtinčastem toku dvigujejo navzgor in pospešujejo raztapljanje. Tudi raztapljanje CO_2 iz zraka, ki je pod velikim pritiskom ujet pod stropom, naj bi povečalo lokalno korozijsko stopnjo (Bögli 1978, 158; Ford & Williams 1989, 298; Cser 1988, 132). Kotlice z ravnim dnom, ki nimajo izrazitih znakov vrtinčenja,



Sl. 6. Stropna kotlica v Ponorni jami Lokve v Predjami (10 cm = 1,5 m)
Fig. 6. Ceiling pocket in ponor cave of Lokva, Predjama (10 cm = 1,5 m)

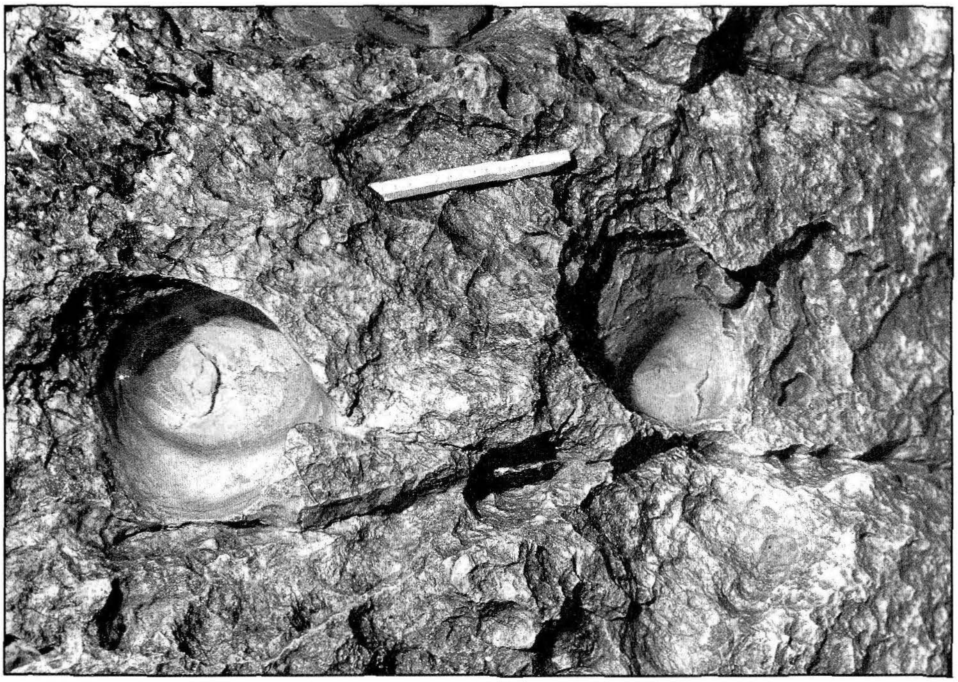
so tudi v Vodni jami v Lozi in v Divaški jami. V času obiska so bila dna kotlic prekrita z gosto mrežo svetlečih kapljic. Te bi lahko zaradi korozije pod njimi vplivale na preoblikovanje starih kotlic. Nastanek kotlic z ravnim dnom Cser in Szenthe (1986, 279) razlagata s premikanjem zračnih mehurjev pod stropom.

Površina draselj je gladka ali pa so na njej tanke raze. Te so v globljih drasljah vodoravne, kar je posledica strujnic v vrtincu. 10-20 cm pas okoli draselj je mehansko zglajen, fasete segajo vse do njihovega roba (Slabe 1989, 86, 87), v Polhovem rovu v Mali Boki (sl.7) pa je brečasta skala grobo hrapava. Obod draselj je v vseh primerih gladek. Takšna je tudi površina draselj, ki so nastale v kremenovem peščenjaku v Smoganici.

Gladki so tudi prodniki, ki prekrivajo dna strug ali pa so v drasljah. Gladka (sl.8) in obtolčena površina sta značilni za večino pritočnih delov strmih, skorajda pravokotno vodnemu toku izpostavljenih ovir v strugah.

Skalne površine, ki jih gladijo hitrejši vodni tokovi, so izpostavljene koroziji in mehanskemu brušenju. Proučil sem jih z elektronskim vrstičnim mikroskopom. Zbruski *kamnine nam omogočajo primerjavo njene sestave in izpostavljene površine.*

Pod večjimi povečavami elektronskega vrtičnega mikroskopa so jasno razvidne razlike v gladkosti skalne površine. Manjše fasete, ki so nastale na biomikritnem apnencu v Križni jami in na biomikrosparitnem apnencu v Škocjanskih jamah (Slabe 1993, 157), so najbolj



Sl. 7. Drasije na breči v Polhovem rovu Male Boke
Fig. 7. Rock-mills in breccia, Polhov rov of Mala Boka

gladke (sl.9). Površina večjih draselj (sl.10) na biomikrosparitnem apnencu v Šumeči jami pa je enakomerno, drobno hrapava po vsem prečnem prerezu. Nekoliko bolj gladka je površina manjših, polkrogelnih talnih kotlic. Drobno hrapava je tudi površina prodnikov (paleogenski biomikrit) v Šumeči jami, zglajenih sten v Babji jami in strmega pritočnega dela izbokline v strugi Vzhodnega rova v Predjami (sl.8). Na povečavah gladkih površin, na katere deluje vodni tok s prodom in peskom, so lepo razvidne raze (sl.11) in manjši kraterji (sl.12). V njih je kamnina zdrobljena. Najbolj izrazito je razčlenjena obtolčena površina, ki pa je razvidna že s prostim očesom (sl.13). Kraterji v njej so globji, kristali različno pretrti in ostro lomljeni. Sestava kamnine se na mehansko zglajenih površinah ne odraža veliko, nekoliko odstopa le rekristaliziran in pretrt biomikriten dolomit v Pucovem breznu.

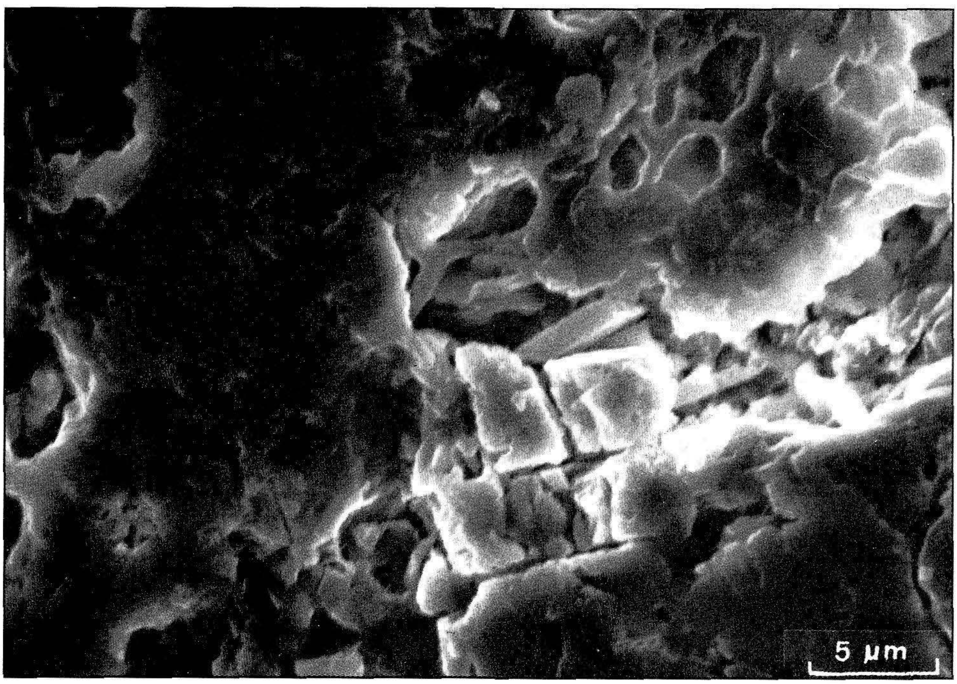
Ugotovimo lahko, da je oblikovanost skalne površine, ki jo nazorno razčlenimo šele pod večjimi povečavami, posledica različnih procesov, ki delujejo nanjo. Zglajena površina manjših faset in manjših kotlic je posledica prevladujočega, pretežno korozijskega delovanja hitrejšega vodnega toka. Vrtinčasto jedro se povsem približa steni in odnaša tudi počasneje topne delce kamnine, ki štrlijo iz nje. Za obe obliki je značilno, da sta v v zatišnih legah (sl.8), odmaknjene od vlečenega vodnega tovora, torej na odtočni strani grbin, zgornjih ploskev skalnih blokov, ali pa višje na steni. Mehansko zglajene površine so pod velikimi

Sl. 8. Gladek pritočni del izbokline v strugi in odtočni s fasetami v Vzhodnem rovu Predjame
Fig. 8. Smooth inflow part of protruding in the river bed and the outflow part with current markings, Vzhodni rov of Predjama

povečavami drobno hrapave zaradi trenja prodnikov in peska ob skalno strugo. Najbolj izpostavljeni deli skalnih blokov in izboklin na dnu struge pa so pogosto obtolčeni. Takšen je tudi strop za ožino v Babji jami (sl.13), kjer hitre visoke vode vrtijo prod.

Skratka, vodni tok praviloma gladi skalno površino bodisi zaradi raztapljanja ali mehanskega delovanja. Kamnina, ki je izpostavljena korozijskemu delovanju hitrega vodnega toka, pa je lahko tudi hrapava, še zlasti, ko jo sestavljajo večji fosili, sparitni kristali, je brečasta ali konglomeratna. Mehansko delovanje vodnega toka, ki prenaša prod in pesek, takšno površino zgladi. Na tako glajeni kamnini so skalni robovi zaobljeni. Ko pa so na skali fasete, ki imajo pogosto gladke površine, in njeni robovi ostri, pa prevladuje proces raztapljanja kamnine. Vsekakor je trditev, da gladko skalno površino oblikuje le mehansko delovanje vodnega toka (Cser 1988, 132), preveč poenostavljena, kar se izraža tudi na mikroskopskih posnetkih. Največkrat so skalne oblike, ki nastanejo v freatičnih razmerah, pretežno korozijske, delež erozije pa se povečuje s približevanjem k hitrim odprtim tokovom.

Tudi onesnaženost voda lahko vpliva na skalno površino. Površina draselj na dnu struge v Škocjanskih jamah je bila prevlečena s tanko plastjo smolnate snovi (sl.14). Kakšna je, nismo uspeli ugotoviti. Težko jo je bilo odstraniti, čeprav smo poskušali z alkoholom in acetonom. Predvidevam, da je ostanek usedline iz onesnažene Reke. V njej so sprijete tudi prinešene diatomeje. V robnih delih struge te prevleke ni bilo. Usedala se je torej predvsem



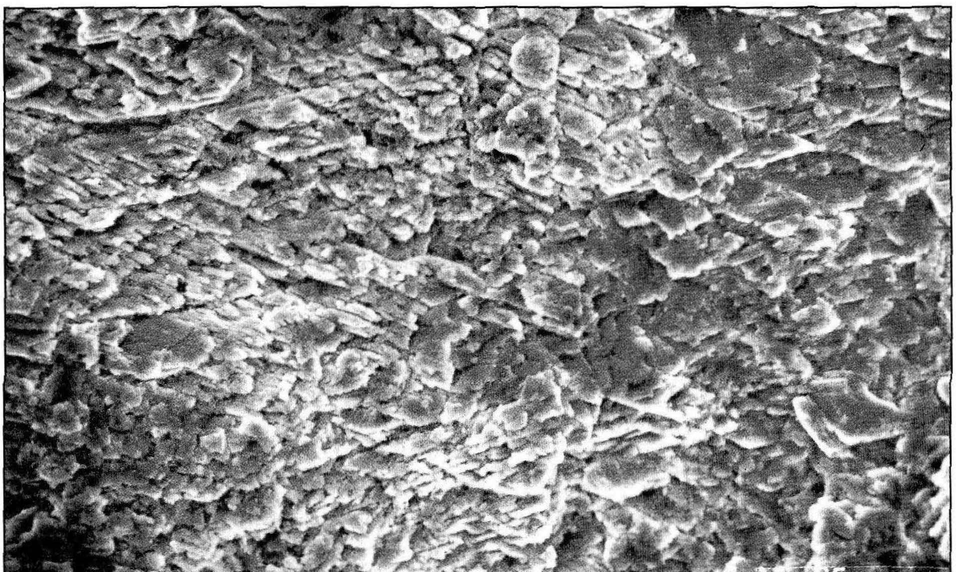
Sl. 9. Površina majhne fasete v Križni jami
Fig. 9. The surface of small scallop, Križna jama

iz nižjih voda. Visoke vode so bolj razredčene in mehansko učinkovite. Lahko pa opazujemo, da v zadnjem času voda oblogo odstranjuje, saj struga ni več sluzasta in spolzka.

POVRŠINA OBNAPLAVINSKEGA SKALNEGA RELIEFA

Površina večine skalnih oblik, ki sestavljajo obnaplavinski jamski skalni relief (Slabe 1992), je, če je opazovana s prostim očesom, gladka. Takšna je površina skalnih oblik, ki so nastale zaradi korozije ob stiku z vlažno drobnozrnato naplavino (podnaplavinske in nadnaplavinske vdolbinice, zajede), ali pa nadnaplavinskih žlebov, ki so nastali zaradi pretakanja vode nad naplavino. Resda, tudi ti so bili pogosto zapolnjeni z naplavino. Na površini manj homogene kamnine pa se lahko odraža njena sestava. Drobne kalcitne žilice sestavljajo "boxwork" (Slabe 1992, 30). Iz kamnine štrlijo večji fosili, silikatni delci, še najbolj hrapava pa je praviloma površina dolomita, ki ga sestavljajo različno veliki kristali, prepredajo pa kalcitne žilice. Gams (1971, 37) je podobno ugotovil za podtalne skalne oblike, ki so nastale na apnencu s fosili in z gostimi žilami rekristaliziranega kalcita. Konveksni deli ostajajo ostri, konkavni pa se zaobljijo (Mowat 1962). Ostre robove imajo kalcitne žile, vdolbinice pa so zaobljene. Nadnaplavinske vdolbinice, katerih obliko narekuje sestava in razpokanost kamnine, lahko dosežejo več cm premera (Slabe 1992, 20).

Lahko gladkost skalne površine povežemo z ugotovitvijo Trudgilla (1979, 38), da močna reakcija in slabo odnašanje razstopine gladita kamnino? Voda je verjetno agresivna tudi



Sl. 10. Površina draslje v Škocjanskih jamah
Fig. 10. Rock-mill surface, Škocjanske jame

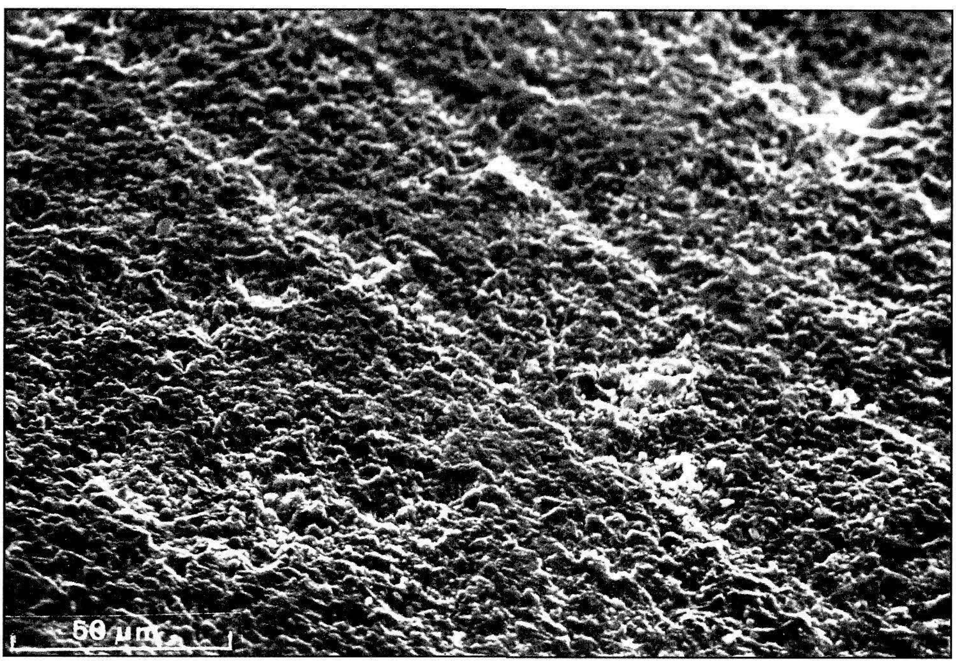
zaradi organskih snovi v naplavini (Slabe 1989, 212). Tudi Gams (1963, 10) ugotavlja, da voda, ki pronica skozi prst, ustvari gladko kamnine pod njo. Predvidevam, da ja gladka površina posledica enakomerne korozije, ki deluje na razmeroma homogeno kamnino. Najprej se raztopijo hitreje topni delci kamnine in tako se povečuje koroziji izpostavljena površina počasneje topnih delcev. Večje nehomogenosti se torej ne izravnajo.

Skalna površina, ki je (bila) prekrita z naplavino, je pogosto preperela. Na njej so netopni ali počasneje topni ostanki kamnine. Preperelost je posledica počasnega odplakovanja proizvodov raztapljanja kamnine.

Pod velikimi povečavami elektronskega vrstičnega mikroskopa so površine obnaplavinskih skalnih oblik, ki so s prostim očesom gladke, drobno hrapave (Slabe 1992, 29) (sl.15). Iz površine štrlijo posamezni večji kristali ali skupki manjših. Drobna hrapavost je posledica zrnate kamnine, ki je podvržena enakomerni koroziji. Tudi manjši vodni tokovi v nadnaplavinskih žlebovih so prešibki, da bi s površine trgali štrleče kristale.

POVRŠINA SKALNEGA RELIEFA, KI GA OBLIKUJE POLZEČA VODA

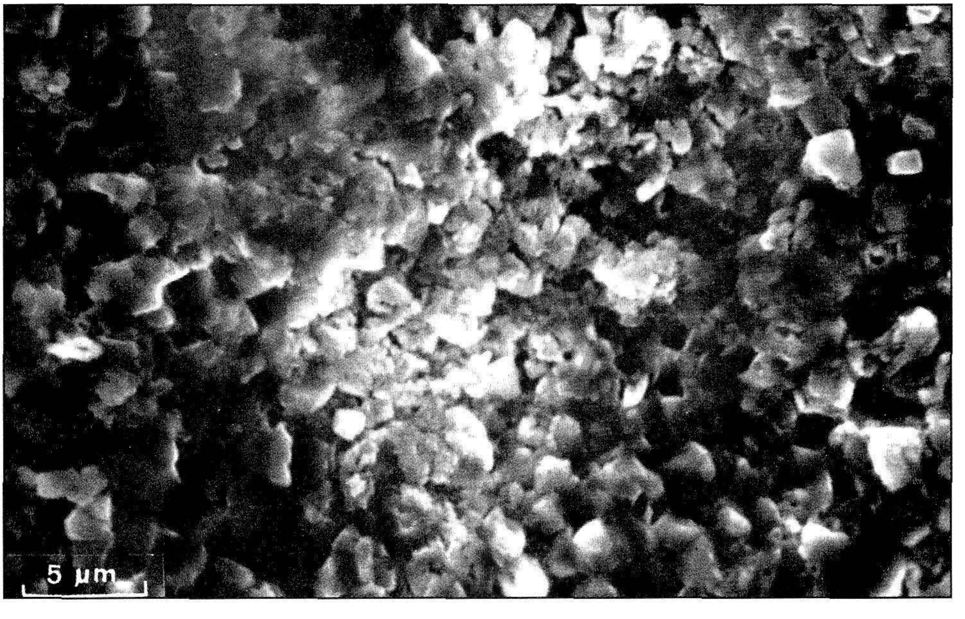
Pri oblikovanju sten brezen je pomembna tudi sestava kamnine, po kateri polzi voda. Iz površine žlebičev v Bazinovi jami pri Podlaških topolih izstopajo kalcitne žilice. V Smoganici



Sl. 11. Raze na erozijsko zglajeni steni
Fig. 11. Abrasion on erosionally polished wall

se stik med grobozrnato in drobnozrnato apnenčasto brečo na oblikah skorajda ne odraža (sl.16), je pa površina prvega bolj hrapava. V jami R3 na Podgorski planoti iz majhnih žlebičev, ki so nastali na paleogenskem apnencu, štrlijo numuliti. Nekateri imajo le še šibka pritrdišča. V podobnih razmerah pa v Breznu pri Škrklovici skalno površino razčlenjujejo assiline. V breznu Morska lilija na Trnovskem gozdu iz stene tudi več cm daleč štrlijo fosili lilij (crinoide). Na stenah brezen v Veliki ledenici v Paradani, ki so ponekod dolomitne ali pa dolomitne in deloma apnenčaste, značilnih oblik, ki bi jih vrezala polzeča voda, ni. Iz dolomita štrlijo oglati kosi kamnine (sl.17). Površina apnenca je bolj gladka in na njej so vdolbinice. Večji skupki kristalov rekristaliziranega dolomita so odpornejši. Tudi v Čo meandru na Kaninu, kjer iz stene štrlijo veliki fosili (sl.18), značilnih sledov polzenja vode ni. V prelomnih conah so nastali ozki in drobnonazobčani roglji, ki štrlijo iz sten (Slabe 1990, 192). Njihovo površino oblikuje tudi krušenje pretrte kamnine. V Ledenici na Dolu je navpična površina skale, ki je homogena in nerazpokana, gladka. To se ujema z Whitovo (1988, 168, 297) razlago nastanka navpičnih sten, ki je povzeta v pregledu literature. Voda s površine tudi trga večje kristale. Pod brezni se pogosto nakopiči drobnozrnat pesek (Zupan & Mihevc 1988).

Oblikovanje stropa s polzečo vodo sem si pomagal razložiti s poskusi na mavcu (Slabe 1990, 180). Skozi kanalčke v mavcu je prenikala voda. Ob ustju na stropu so se razlivale posamezne kaplje in nastala je vdolbinica. Tovrstne kotlice sem opisal pri proučevanju Volčje jame na Nanosu (Slabe 1990, 178). Izluščimo lahko tri značilne površine (Slabe 1990, 181), ki so koncentrično razporejene okrog dotočnega kanalčka. Notranja površina

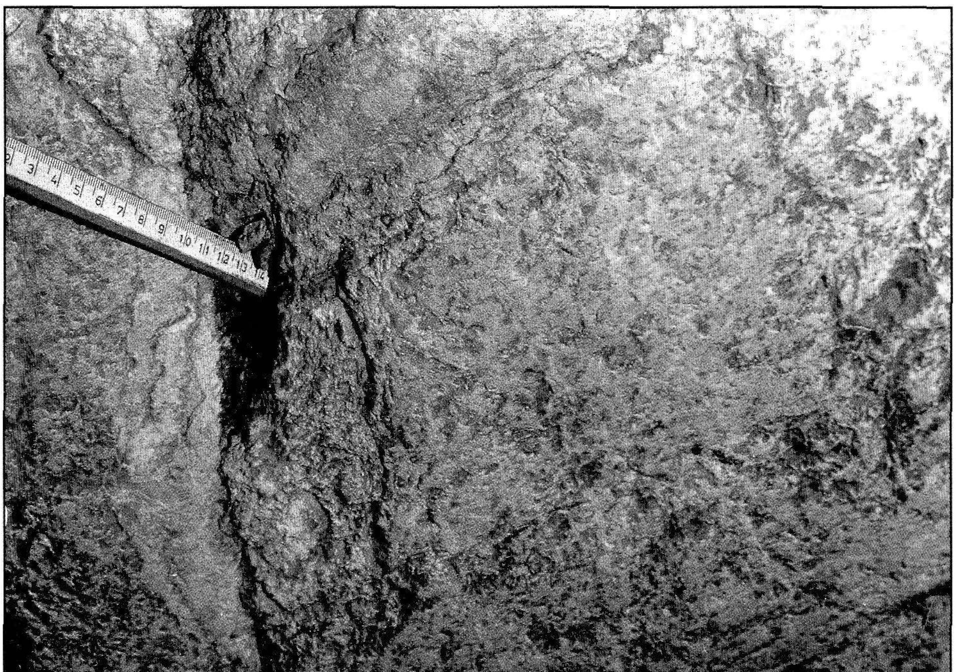


Sl. 12. Krater z zdrobljemini zrni
Fig. 12. Crater with broken grains

kotlice je gladka, saj je bila dokaj enakomerno oblita z vodo. Gladka površina je posledica težnostnega zbiranja vode na štrlečih delcih kamnine in ti so podvrženi hitrejši koroziji. Srednji kolobar je hrapav in koničast. Vodni film, ki ga je oblival, je bil tanjši. Enaka količina vode, kot v prvem primeru, se je razlila preko večje površine. V zunanjo površino so zajedeni različno široki in plitki žlebiči, po katerih se je voda pretakala strnjeno. Oblikovanost površine je predvsem posledica različne količine vode, ki obliva kamnino različne sestave.

Kot lahko opazimo v Volčji jami in Ledenici na Dolu, pa v Kamnešci in Ciganski jami pri Predgrižah, so stropne konice trikotnega prečnega prereza in imajo zaobljene vrhove. Dolge in široke so do 1 cm. Pod vrstičnim mikroskopom (Slabe 1990, 178, 179) so vidne v vdolbinicah med konicami globlje zajede. Na konicah je kamnina manj razčlenjena. Nastanejo zaradi neenakomernega raztapljanja kamnine pod tankim filmom vode, ki se razliva po stropu. Voda se zbira na štrlečih delcih kamnine, kjer pa je že manj agresivna ali pa že odlaga raztopino. Zato se razlika med konicami ter vmesnimi vdolbinicami še povečuje.

Kapljice, ki oblikujejo talne vdolbinice, padajo na njihovo dno in se razpršijo. Obod vdolbinice je zato gladek, površina okoli nje pa zaradi pršenja vode, ki se odbija iz vdolbinice, drobno luknjičasta. To se je pokazalo tudi pri poskusu z mavcem.



Sl. 13. Obtolčena površina stropa za ožino v Babji jami
Fig. 13. Bruised ceiling surface behind the narrowing, Babja jama

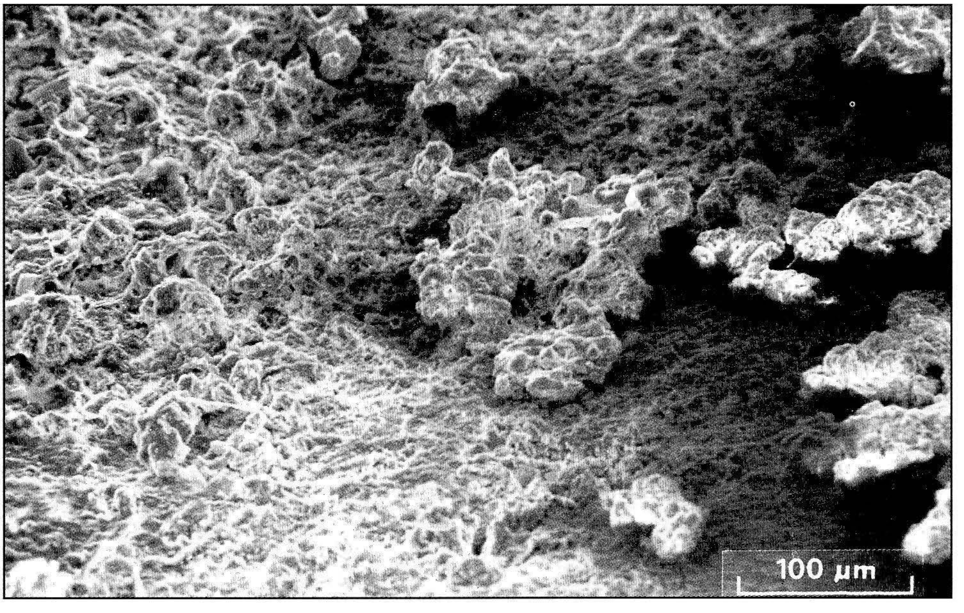
POVRŠINA S KONDENZIRANO VLAGO OBLIKOVANE SKALE

V votlinah, skozi katere kroži zrak, se na skalnem obodu pogosto kondenzira vlaga (Slabe 1988). Kondenzacija zračne vlage je posledica ohlajevanja toplejšega zraka na stiku z mrzlim ali pa oblivanja hladnih sten s toplejšim zrakom. Pri ohlajevanju toplejšega, razmeroma bolj vlažnega zraka, se izloči presežek vlage na skalni obod.

Skalno površino, izpostavljeno koroziji, ki jo povzročo kondenzirana vlaga, s prostim očesom lahko razdelimo na gladko in hrapavo ter preperelo. Pod povečavo vrstičnega mikroskopa je v vseh primerih dokaj hrapava (sl.19), (Slabe 1989, 216). Gladkost in hrapavost površine sta posledici razmerja med učinkovitostjo korozije in odnašanjem raztopine, ki sta pogojeni zlasti s količino vlage, izločene iz zraka, in nehomogenostjo ter razpokanostjo kamnine, na katero se vlaga izloča.

Zaradi počasnega pretoka toplejšega zraka pod stropom rovov nastanejo žlebovi, kotlice in velike fasete. V vhodnem delu Trhlovce je v rovu, ki je že nekoliko odmaknjen pred neposrednimi zunanjimi vplivi, plitek, polkrožen stropni žleb. Njegova površina je bolj grobo hrapava kot okolna skala. Stropne kotlice v začetku vhodnih rovov, kjer je kondenzacija najbolj izrazita, pa imajo gladko površino.

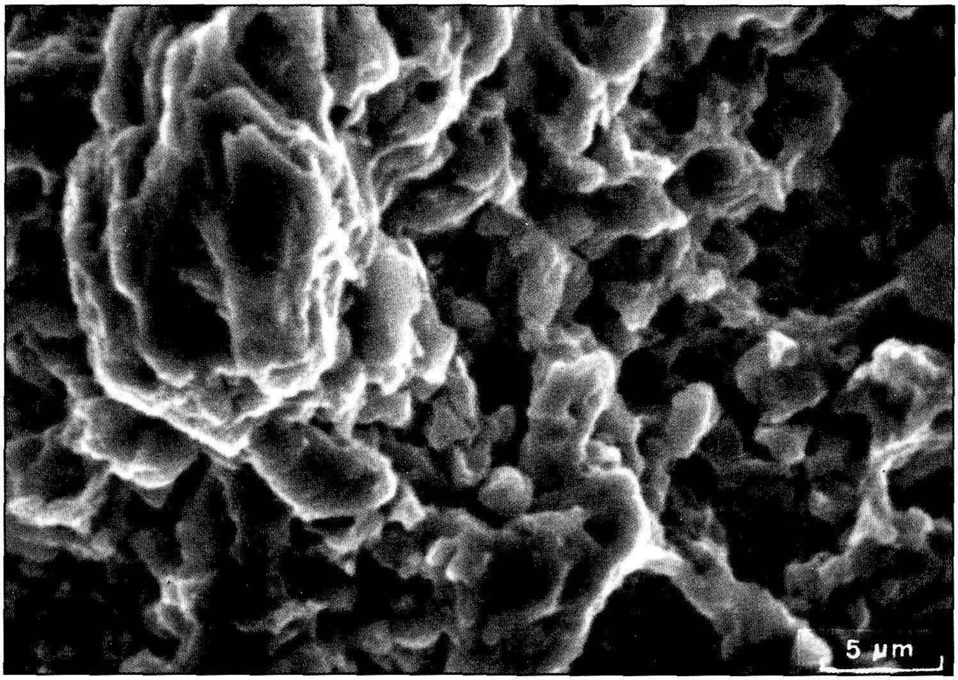
Kondenzirana vlaga pogosto le preoblikuje stari skalni relief. V Komarjevem rovu v Dimnicah smo ugotovili, da zaradi večje količine vlage s površine razmeroma homogenega biomikrosparita in dismikrita odpadajo večji sparitni kristali, ko se hitreje stopi mikritno vezivo (Slabe 1988, 90). Površina je zato gladka. Na delih oboda, kjer je vlage premalo, da



Sl. 14. Smolnata plast na skali v strugi Škocjanskih jam
Fig. 14. Layer on the rock in the river bed, Škocjanske jame

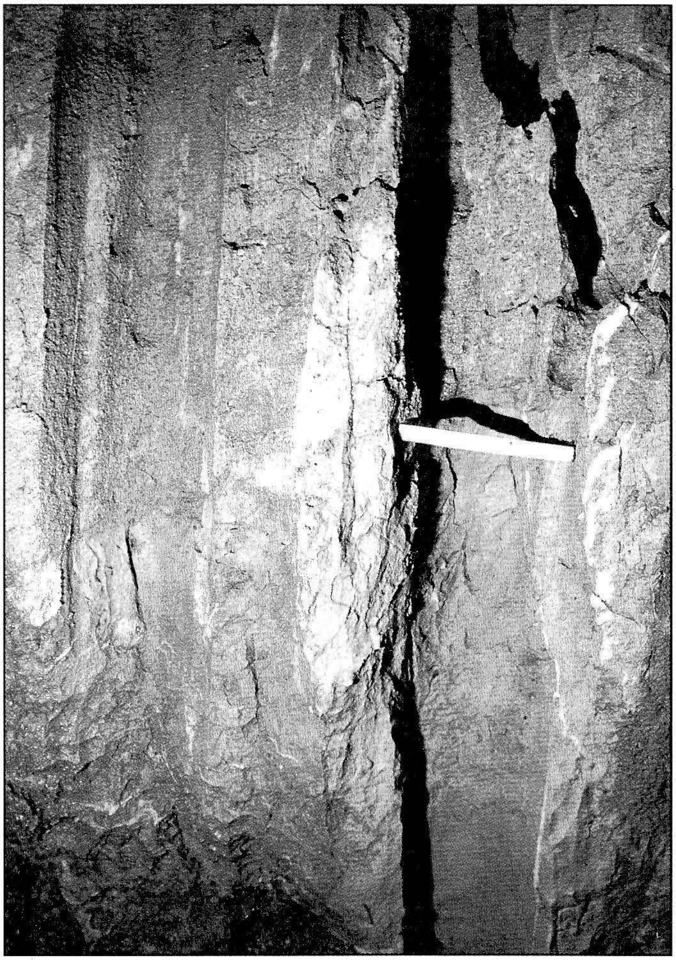
bi raztopila in razločila tesneje povezane skupke sparitnih zrn, nastajajo med njimi drobno razjedene luknjice. Podolgovate vdolbinice so pogoste tudi na drobno razpokanih stenah ali na tanko plastoviti kamnini (Slabe 1989, 214). Na delih kamnine, kjer je bilo kondenzne vlage v Komarjevem rovu še manj, iz mikritne osnove štrlijo zrna sparita. V Medvedjem rovu v Križni jami zaradi šibke kondenzne korozije iz stene štlijo žilice kalcita (boxwork) (Slabe 1989, 214), ki so počasneje topne od okolne mikritne kamnine. Iz stene v vhodnem delu Zadlaške jame štrlijo posamezne večje debelozrnate kalcitne žile. Ob drobnih razpokah gosto pretrtega apnenca v Golobji jami na primorskem kraškem robu in v Križni jami (Slabe 1989, 214) so nastale nekaj mm globoke, podolgovate vdolbinice, prepletene v pravokotno mrežo. Vlage se kondenzira precej, zato hitro odnaša raztopino. Skalo v Golobji jami spira tudi voda, ki občasno prenika skozi tanek strop. Manjše in plitke vdolbine ter drobne razjede na breči Zadlaške jame so vezane na hitreje topne dele kamnine (sl.20). Na stropu so štrline, ki so dolge do 10 cm in nazobčano razčlenjene. So ostanki rekristalizirane, le deloma topne naplavine, ki se je sprijela s karbonatno kamnino in jo zaščitila pred razjedanjem.

Pogosto so površine, ki so izpostavljene kondenzirani vlagi, preperele. Skalo prekriva mehka plast neraztopljene kamnine, ki se ob dotiku razmaže. Takšni primeri so v vhodnem rovu Volčje jame na Nanosu, v Veliki Kozinski, Križni in Ciganski jami. V slednji je preperela plast kamnine debela 3 mm. Iz podpisov in datumov na steni, v katero so bili vrezani s trdim



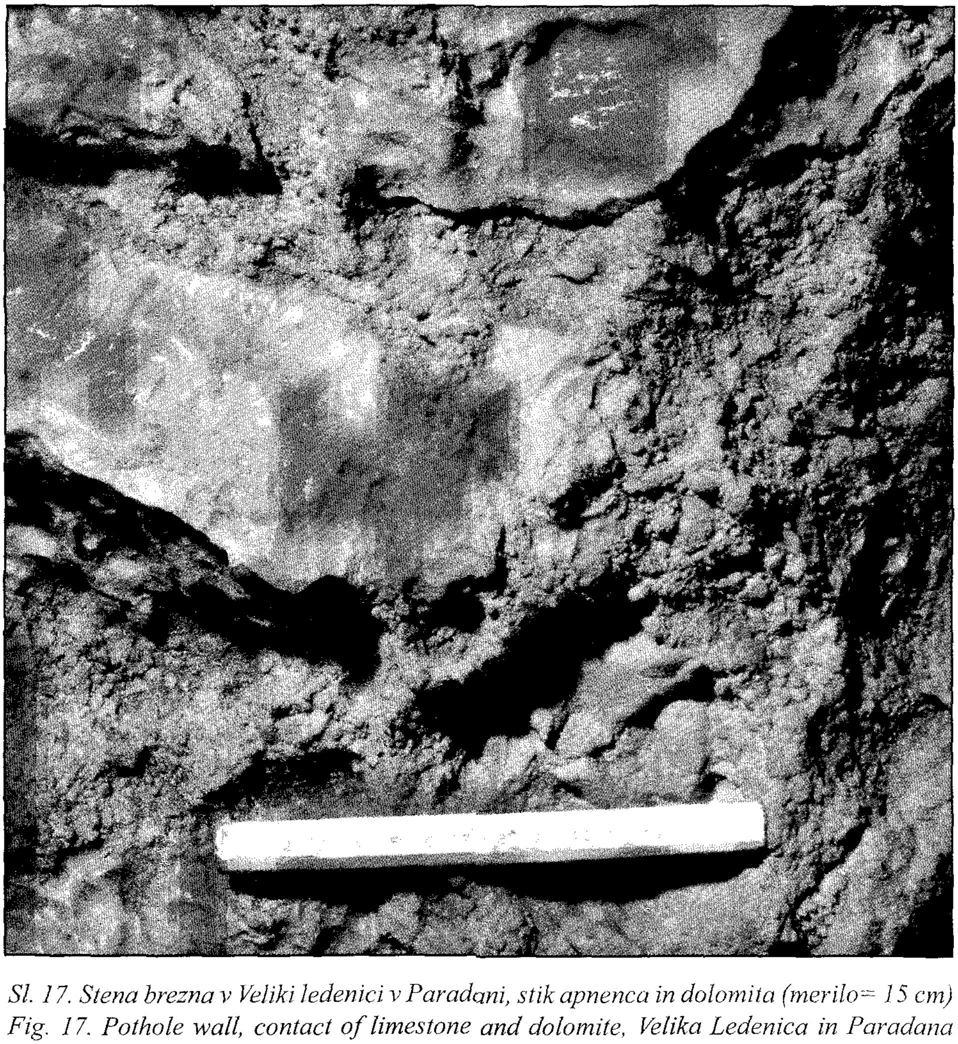
Sl. 15. Podnaplavinska površina pod elektronskim vrstičnim mikroskopom
Fig. 15. Below-sediment surface seen by the ectronic microscope

predmetom v mehko površino leta 1890, sklepam, da je v stotih letih preperel 1 mm skale. Preperela skalna površina ovira dostop vlagi in onemogoča hitrejše razjedanje stene. Apnenec v Volčji jami je 1,5 mm debelo preperel in razčlenjen z luknjičastimi razjedami (Slabe 1990, 181). Dolomitna kamnina v bližini ima le nekaj desetink mm debelo, manj izrazito preperelo površino. Tudi v Veliki Kozinski jami je strop na prehodu v spodnji del jame 3-5 mm debelo preperel. Kondenzacija je šibka. Določili smo količino CaCO3 v kamnini in v prepereli plasti, ki jo prekriva. V kamnini ga je bilo 95,7 % v prepereli plasti pa 2 % več. Vlage je premalo, da bi raztopino sprala. V sušnejšem obdobju voda iz raztopine izhlapeva



Sl. 16. Žlebiči na stiku grobozrnatega in drobnozrantega apnenca v Smoganici (merilo= 15 cm)
Fig. 16. Runnels at the contact of coarse-grained and fine-grained limestone, Smoganica (scale = 15 cm)

in na površju se zato izločajo kristali kalcita. Preperela plast je bila v jami vlažna in se je ob dotiku razmazala. V suhem laboratorijskem zraku pa se je posušila in postala trdnejša. Kalcit je rekristaliziral. Podobnemu procesu sem lahko sledil v Komarjevem rovu v Dimnicah (Slabe 1988, 90). Največ prevleke je bilo na delih stene, kjer se je vlaga kondenzirala redko in je izhlapevanje zato bolj učinkovito.



Sl. 17. Stena brezna v Veliki ledenici v Paradani, stik apnenca in dolomita (merilo= 15 cm)
Fig. 17. Pothole wall, contact of limestone and dolomite, Velika Ledenica in Paradana (scale = 15 cm)

POVRŠINA PODLEDNEGA SKALNEGA RELIEFA

Vdori mrzlega zraka s površja v jamo ohladijo površinsko plast stene in voda, ki polzi po njej, zmrzuje. Ledena obloga se najprej stopi na stiku s steno in jo kratek čas vlaži.

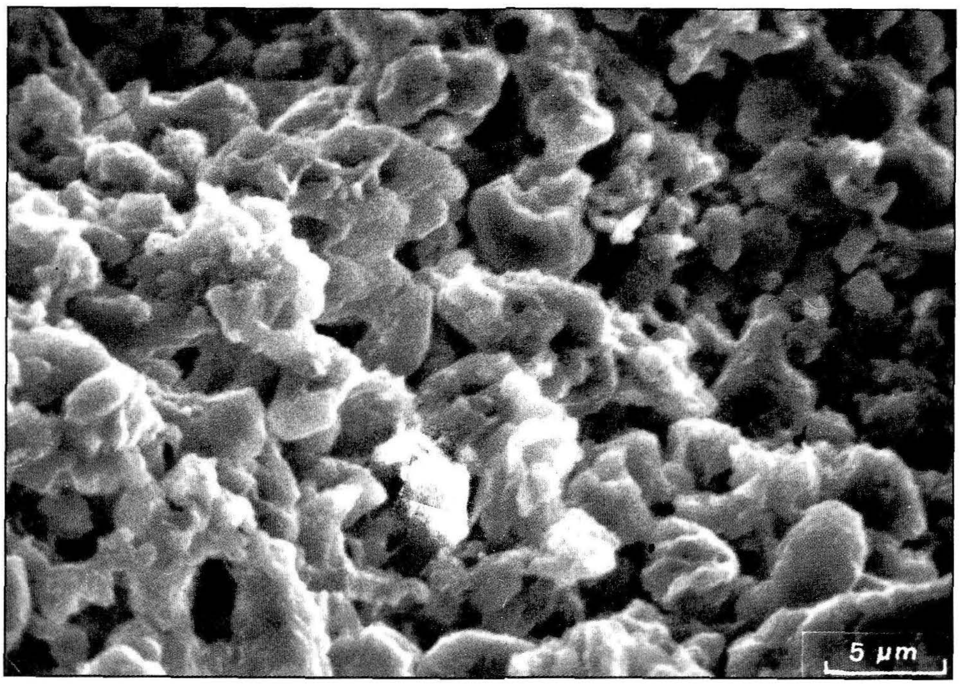
V vhodnem delu Velike ledenice v Paradani, ki je skorajda celo leto obdan z ledom, so stene zaobljene in dokaj gladke. Spodnji del rova, kjer je led najdlje, je nekoliko razširjen in stene ob njem so previsne. Podledne zajede (sl. 21) so posledica enakomerne korozije ob stiku z ledom. Manjše štrline imajo večjo površino izpostavljeno koroziji. Skala je nekoliko vboklo razčlenjena le ob razpokah. Okolna skala, ki je dokaj gosto pretrta, ni pa obdana z ledenimi oblogami, razpada in obod sestavljajo manjše in večje, dokaj ravne ploskve. Pogosto se pod ledom, ki je najbolj debel prav na tleh rovov, preoblikujejo skalni bloki iz oglatih v zaobljene in gladke (Volčja jama). Na stropu vhodnega dela Velike ledenice v Paradani so vdolbinice (sl.22). Predvidevam, da so nastale ob taljenju tanke ledene obloge, ki obda strop rova. Kratkotrajno vlaženje kamnine z manjšo količino vlage je povzročilo raztapljanje najhitreje topnih delcev kamnine.

Sl. 18. Površina brezna v Čo meandru na Kaninu
Fig. 18. Pothole surface, Čo meander, Kanin

BIOGENO RAZJEDENA SKALNA POVRŠINA

Deli stene v vhodnih metrih Volčje jame so poraščeni z lišaji. Skozi vhod prodira svetloba v jamo vzporedno s steno. Skalna površina pod lišaji je razčlenjena v luskinasto se prekrivajoče štrline, ki so usmerjene proti izhodu. V razjedah med štrlinami so lišaji. Predpostavljam, da raztapljanje skale pospešuje tekočina, ki se v kapljicah zadržuje v lišajih na prisojni strani (Slabe 1990, 182). Lišaje, zajedene v apnenec, sem opazoval tudi pod povečavo elektronskega vrtičnega mikroskopa (sl.23) (Slabe 1990, 183). Skozi štrline so nitasti deli lišajev zajedli kanalčke. Pod tanko plastjo lišajev so na stenah vhodnega dela Velikega Hublja nastale vdolbinice (sl.24). Svetloba sije naravnost na steno. Lišaji so verjetno prekrili vso skalno površino in hitreje razjedli bolj topne dele kamnine. Sedaj so ohranjeni v vdolbinicah ter v zajedah ob drobnih razpokah. Kaže, da je to tudi posledica občasnega oblivanja stene z vodnim tokom, ki spira izpostavljene dele kamnine. Koristne bi bile natančnejše analize neposrednega vpliva lišajev na razjedanje kamnine.

V rovu za vhodom v Veliki Hubelj so preoblikovana tudi skalna tla in podorni bloki. Razčlembe, to so posamezne ali sestavljene vdolbinice (sl.25) s površino 1 do 10 cm^2 ter globoke do 3 cm, so zapolnjene z iztrebki jamskih netopirjev. Tudi površina med vdolbinicami je drobno hrapava. Pod iztrebki se raztopijo najprej hitreje topni deli kamnine,



Sl. 19. Površina razjedena s kondenzno vlago
Fig. 19. The surface etched by condense humidity

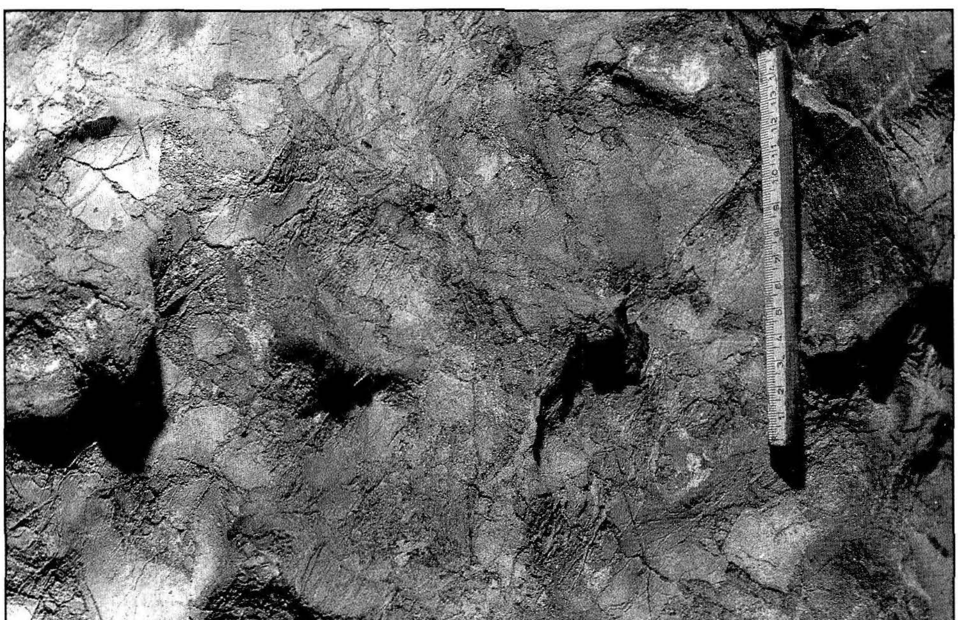
ki se polkrožno poglobijo. Voda, ki jamo občasno zalije, spere izpostavljene dele kamnine, v vboklih pa namoči iztrebke. To povzroči hitrejše raztapljanje kamnine. Razčlembe se poglabljajo in širijo. Ali razjedanje skale povzročajo iztrebki sami, ali pa le večja količina vode, ki se zadrži v njih, ko presahne vodni tok, še nisem ugotovil. Predvidevam, da so podobnega nastanka kot podnaplavinske vdolbinice (Slabe 1992, 24).

V Križni jami v Medvedjem rovu je medvedji obrus (Slabe 1989, 214). To je zglajen del iz stene štrleče kamnine. Okolna skala je razjedena zaradi kondenzirane vlage.

SKLEP

Raznovrstno zrnata sestava karbonatnih kamnin pogojuje oblikovanost njihove površine. Enak dejavnik, ki deluje na različno kamnino ali pa različni dejavniki, ki delujejo na isto kamnino, lahko povzročijo, da je njena površina bolj gladka ali hrapava. Povezave hitrosti procesov in hitrosti odnašanja njihovih proizvodov z gladkostjo površine (Trudgill 1979, 33) je težko posplošiti. Izluščimo pa lahko značilnosti vplivov posameznih dejavnikov na različno kamnino.

Na izrazito nehomogeni kamnini pogosto ne nastanejo skalne oblike. Značilnosti kamnine torej prevladujejo nad učinkovitostjo dejavnikov in površina kamnine je predvsem posledica njene sestave in razpokanosti. Izjema je mehansko brušenje kamnine z vodnim tokom, ki



Sl. 20. Površina s kondezno vlago razjedene breče v Zadlaški jami
Fig. 20. The surface of breccia etched by condense humidity, Zadlaška jama

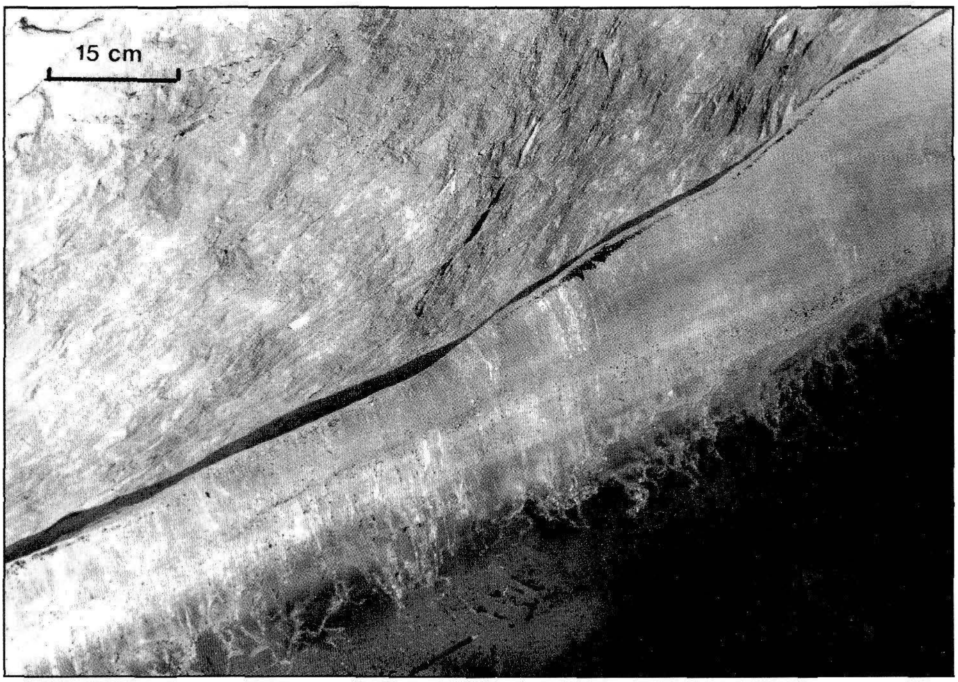
prenaša tovor, s katerim gladi kamnino. Sestava kamnine narekuje tudi površino odlomov, le na premaknjenih blokih apnenca so pogosto tektonske drse.

Na razmeroma homogeni kamnini se oblikuje značilni skalni relief. Njegova površina je odraz različnih dejavnikov, ki ga oblikujejo. Dejavniki povzročajo procese in odnašajo njihove proizvode.

Hitri vodni tokovi, ki ne prenašajo tovora, zaradi izrazite vrtinčaste difuzije povzročajo hitrejše raztapljanje kamnine in odnašanje raztopine. Počasneje topne delce vodni tok tudi odtrga s površine in odnese neraztopljene. Površina majhnih faset in stropnih kotlic na homogeni kamnini je zato gladka bodisi, da jo opazujemo s prostim očesom bodisi pod veliki povečavami. Počasnejši vodni tok lahko na enaki kamnini zapusti bolj hrapavo površino.

Značilno oblikuje skalo vodni tok z mehanskim delovanjem tovora, ki ga vključuje v vrtinčenje. Skalna površina je zglajena, razena ali obtolčena. Toda pod velikimi povečavami so tudi na gladkih površinah, ki so dokaj ravne, jasno razvidne raze in majhni kraterji.

Pogosto je gladka površina obnaplavinskih skalnih oblik. Korozija, ki deluje enakomerno na vso površino, jo gladi, seveda če to dopušča sestava kamnine. Če pa takšno gladko površino proučujemo s pomočjo velikih povečav elektronskega vrstičnega mikroskopa, ugotovimo, da je v drobnem izrazito hrapava. To je posledica razjedanja različno topnih delcev kamnine.



Sl. 21. Površina podledne zajede (1cm = 10 cm)
Fig. 21. The surface of notch below ice (1 cm = 10 cm)

Podobno lahko oblikuje skalo večja količina kondenzirane vlage. Manjša količina takšne vlage pa površino kamnine razčleni v hrapavo. Pod velikimi povečavami elektronskega vrstičnega mikroskopa je površina v vseh primerih drobno hrapava. Za oba dejavnika tako vlago v drobnozrnati naplavini kot korozijo zaradi kondenzirane vlage je značilno večinoma manj hitro raztapljanje kamnine in počasno odnašanje raztopine.

Večja količina polzeče vode, še zlasti, če polzi po stropu, gladi homogeno kamnino. Na izrazito nehomogeno in razpokano kamnino pa nima večjega vpliva.

Svojevrstno je biogeno razjedanje skalne površine. Lišaji povzročijo nastanek luknjičaste in luskinaste površine, ko se zajedajo med kristale. Pod iztrebki netopirjev nastanejo vdolbinice.

Poseben tip je preperela površina. Na takšni površini ostane tanka plast neraztopljene kamnine. Je posledica raztapljanja kamnine zaradi kondenzirane vlaga ali vlage v drobnozrnati naplavini.

Skalna površina je skladna s skalnim reliefom, torej s procesi, ki ga oblikujejo ali pa je posledica njegovega kasnejšega, manj učinkovitega preoblikovanja. Namreč stare skalne oblike, ki jih je vrezal hiter vodni tok in za katere je značilna gladka površina, so bile zaradi spremenjenih hidroloških razmer pogosto obdane z drobnozrnato naplavino ali pa preoblikovane s kondenzno korozijo in biokorozijo. Njihova površina je zato hrapava.

Iz skalne površine lahko razberemo zadnje dejavnike in procese oblikovanja kamnine.

Sl. 22. Podledne vdolbinice v Veliki ledenici v Paradani
Fig. 22. Below ice pockets, Velika Ledenica in Paradana

Dopolni nam dognanja, ki ga nudi poznavanje jamskega skalnega reliefa in je torej lahko pomebna sled razvoja kraških votlin.

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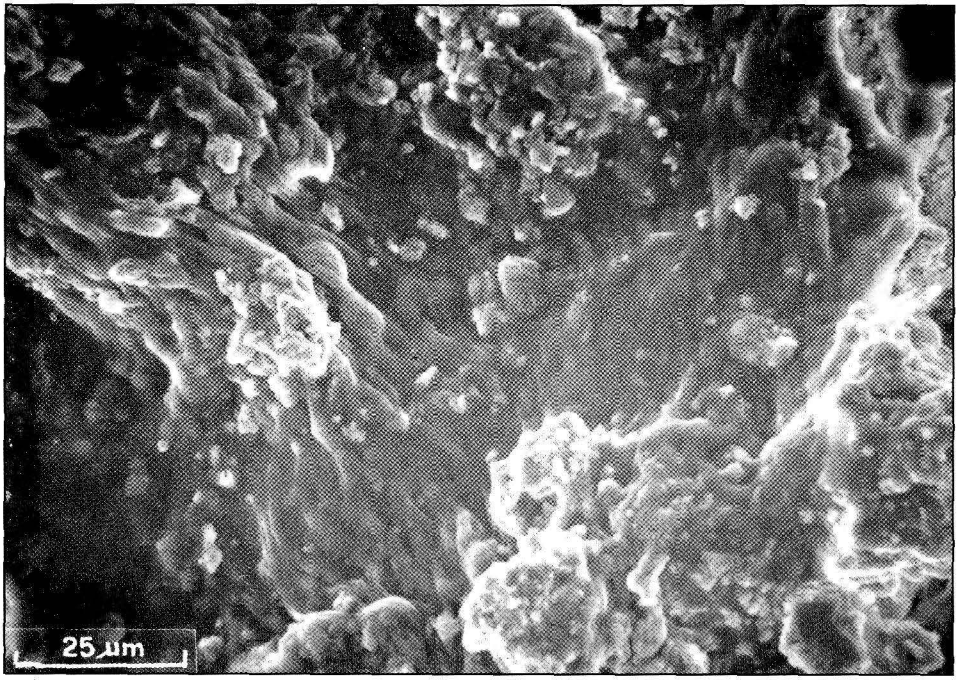

Sl. 23. Lišaji v vhodnem delu Volčje jame na Nanosu
Fig. 23. The lichens in the entrance part of Volčja jama, Nanos

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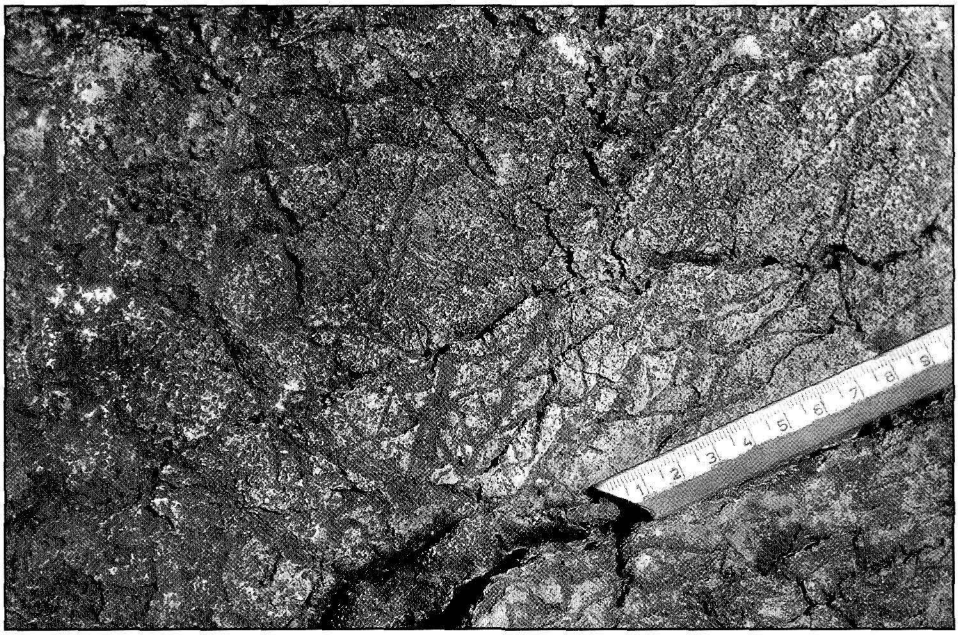

Sl. 24. Lišaji v vhodnem delu Velikega Hublja
Fig. 24. The lichens in the entrance part of Veliki Hubelj

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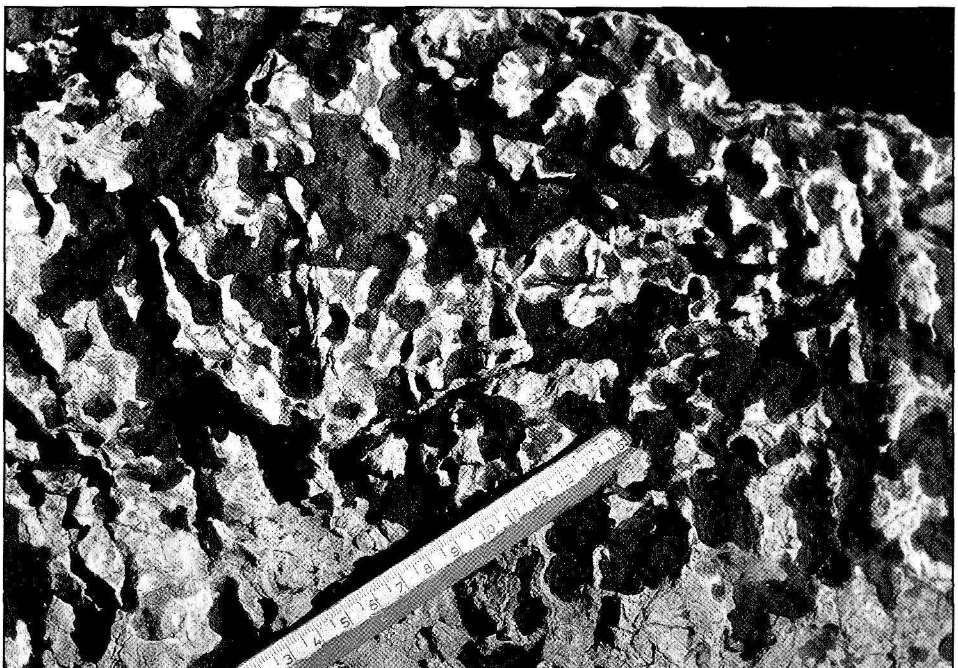

Sl. 25. Vdolbinice pod iztrebki netopirjev
Fig. 25. Solution niche below the guano

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THE FACTORS INFLUENCING ON THE FORMATION OF THE CAVE ROCKY SURFACE

Summary

While studying the cave rocky features a special attention is given to their surface. The surface of the rocky forms may be described as smooth or rough, observed either with the naked eye or magnified. By strong magnification by electron microscopy almost all rocky surfaces are at least partly rough. This is the effect of granular, partly homogeneous composition of carbonate rocks. The rocky surface is washed as the factors, influencing to it, transport the products of the processes or it is weathered. It is such when covered by soft layer of partly dissolved rock.

Granular and heterogeneous composition of the carbonate rocks is controlled by different formation of their surface. The same factor acting upon various rocks or various factors acting upon the same rock may cause, that its surface is more smooth or more rough. The connection of the processes velocity and the velocity of the products transport with the

smoothness of the surface (Trudgill 1979, 33) may hardly be generalised. Yet the properties of particular effects to various rocks may be distinguished.

Frequently the rocky features do not appear on remarkably unhomogeneous rock. The properties of the rock thus predominate over the efficiency of the factors and the rock surface is mostly controlled by its lithology and joint frequency. The exception is the mechanical rock polish by the water flow transporting a load. The lithology dictates the surface of the fragments, on displaced limestone blocks only the tectonic sliding planes may be seen.

On relatively homogeneous rock the characteristic smoothness of rock surface occurs. Its surface is controlled by various factors, shaping it and causing the transport controlled processes.

The water flow with load mechanic action included into eddies, shapes the rock in the characteristic way. The rock surface is frequently polished, abrased or bruised. By great magnification even on smooth surfaces having rather flat basic plane small abrasions and craters are clearly seen.

The surface of the along-sediment rocky features is smooth too. Corrosion, acting equally over the entire surface polishes it, if, of course, the lithology permits. But studying such smooth surface by great magnification of electron microsope we may infer that it is rough in details. This is the result of weathering of better soluble rock particles.

Quick water streams without load transport due to eddy diffusion cause more quick dissolution of the rock and transport of the solution. Less soluble particles may be torn from the surface and they are transported unsolved. The surface of small scallops and ceiling pockets on the homogeneus rock is thus smooth either with a naked eye of by great magnification. Slower water flow on equal rock leaves rough surface.

Similar effect to the rock may be left by great quantity of condense humidity. Smaller quantity of such moisture makes the rock's surface rough. By great magnifications of the electron microscope the surface is in all cases thinnly rough. For both factors, i.e. fine-grained sediments moisture level and corrosion due to condense humidity is characteristical mostly less efficient dissolution and slower transport of the solution.

Bigger quantity of trickling water, in particular if it trickles over the ceiling, polishes the homogeneous rock. It does not have any bigger effect to unhomogeneous or fissured rock.

Unique is biogenic surface weathering. The lichens cause the porous and scaly surface when penetrating among the crystals.

Weathered surface results by rock dissolution due to condensed humidity or the fine-grained sediment moisture level.

The rocky surface is concordant to the rocky relief, it means to the processes in control or else, it is the result of its later, less effective transformation. Old rocky features which had been incised by a quick water flow and had smooth surface may, due to changed hydrologic conditions, be encircled by the fine-grained sediment or transformed by the condense corrosion and bio-corrosion. Their surface is then rough.

The rocky surface tells us which factors and processes the last influenced on the rock formation. It completes the knowledge offered by the cave rocky relief and thus may be an important trace for the karst caverns genesis.

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Sl. 14: Perinivalni grušč ponika v sredino vrtače Renčelica pri Sežani (jesen 1987). Foto F. Šušteršič
Fig. 14 Perinival material sinking into the center of the doline Renčelica near Sežana (autumn 1987). Photo F. Šušteršič

Sl. 2: Sedanje stanje Cvijićeve "vrtače" (Sl. 1). Foto F. Šušteršič
Fig. 2: Present state of the Cvijić's "doline" section (Fig. 1). Photo F. Šušteršič

Sl. 13: Prehod "sklede" vrtače v osrednji jašek. (kamnolom Verd, pomlad 1974). Foto F. Šušteršič
Fig. 13 Transition of the "bowl" into the central shaft (Verd quarry, spring 1974). Photo F. Šušteršič

Sl. 12: Središčni prerez ene izmed vrtač v čelu kamnoloma Verd (jesen 1972). Foto F Šušteršič
Fig. 12 Central section of a doline at Verd quarry (autumn 1972). Photo F. Šušteršič