Kras

Kaj je to / What it is ?

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Podpiramo pobude revije Kras

Kras

Nismo slučajno sprejeli odločitve, da HIT finančno podpre 7. mednarodni simpozij o sledenju vodâ v Portorožu. V strategiji Hitovega delovanja in pojavljanja na različnih področjih v Sloveniji je tudi jasno zapisano, da bomo podpirali tudi pobude in dejavnosti v zvezi s Krasom v okvirih projekta Podoba Krasa.

Odgovor, zakaj prav Kras, je zelo preprost. Primorcem nam je Kras blizu z vsemi svojimi zanimivostmi in posebnostmi, z vso svojo naravno in kulturno dediščino. Kras je tudi vseslovenski, na kar kaže vrsta pobud več ministrstev in drugih vladnih ustanov v Klubu Kras. Obenem je Kras tudi svetovnega pomena, saj je s svojim unikatnim biotopom, z etnokulturnim izročilom, z univerzalnostjo in s posebnostjo pritegnil zanimanje ustanov Evropske skupnosti... Razumeli smo, da je naše poslanstvo sodelovati tudi v tem projektu.

Je pa še nekaj!

Težko si je zamišljati, da suha, včasih surova in neizprosna pokrajina Kras skriva v sebi vodo, ta tako dragocen vir življenja, in z njo napaja širša območja Slovenije. Tudi HIT s svojo dejavnostjo, žal, ne uživa zadostnih simpatij in podpore javnosti, čeprav napaja pomemben del potreb družbe in države..! Mogoče je prav to še en razlog več za njegovo druženje s Krasom!

Bogdan Soban,
direktor sektorja za trženje/Marketing manager
HIT Nova Gorica

Hoteli Igralnice Turizem

We support the initiatives of the journal Kras

Karst

The decision of HIT to accept the general sponsorship of the 7th International Symposium on Undergroud Water Tracing, Portorož was not taken accidentally. The strategy of HIT's activity and its appearance within different spheres in Slovenia involves a clear massage to support the iniatives and activities dealing with Kras within the project The Image of Kras.

The answer why just Kras, is straight. The inhabitants of littoral region feel Kras and the distinctive character of the Slovene karst environment, including its natural and cultural heritage, as part of themselves. Kras is all-round Slovenian and this is shown by the initiatives of several ministries and other government institutions within the Kras Club. At the same time Kras bears an international importance as its unique biotop, ethno-cultural tradition, ist universal and special properties attracted the interest of the European Community institutions... We understood, that our misson is to contribute to this project also.

Yet, there is still something!

It is hard to imagine that Kras, dry and sometimes even relentless landscape hides in its underground the most precious source of life, drinking water, and feeds by it wider regions of Slovenia. Unfortunately, HIT and its activity also do not enjoy sufficient sympathies and support of public although HIT supplies an important part of public and republic needs..! Maybe this is a reason more for its association with Kras!

K O L O F O N

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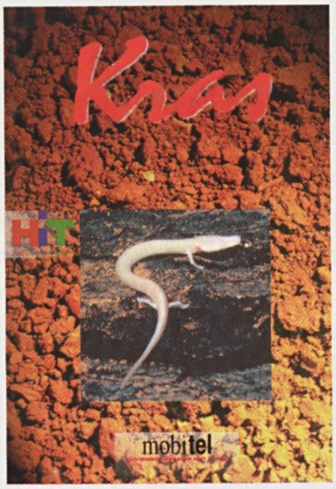

Na naslovnici:
Močeril ali človeška ribica (Proteus anguinus) - biser kraške favne (Foto: C. Mlinar)
Title-photo:
Močeril or Human fish (Proteus anguinus) - the pearl of the karst fauna (Photo: C. Mlinar)

Iz vsebine
Summary

Kras

MAJ / MAY, 1997, št./No: 21

Kras

KRAS JE LAHKO DOTA SLOVENIJE EVROPI IN SVETU

Spoštovani bralci!

Izšlo je že dvajset številk revije Kras. Iz njih lahko zveste veliko o Krasu (in krasu). Od tega, kako in kdaj je nastal apnenec - kraški kamen, do tega, kako so iz njega klesali kolone ali portale in kaj danes klešejo iz njega umetniki; pa od prazgodovinske poselitve Krasa, njegove kulture do modernega gospodarstva na njem. In šemarsikaj... A vsega preprosto ni mogoče našteti!

Nečesa pa je morda manjkalo... Nekaj ste morda pogrešali bralci, ki na Krasu živite. Morda ste še bolj pogrešali tisti, ki niste s Krasa, a vas kras zanima: Zakaj se reče Krasu "Kras" in "kras"? Zakaj je kras nekaj tako posebnega? Zakaj se vsaki podobni pokrajini na svetu reče "kras"? Kako je kras nastal? Zakaj na Krasu ni vode, izpod njegovega roba pa izvirajo prave reke?

Tudi takih vprašanj je mnogo preveč, da bi jih tukaj mogli našteti..!

Da bi bralec dobil odgovore vsaj na nekaj izmed takih vprašanj in da bi obenem lahko dobil zaokrožen pregled nad Krasom, se je uredništvo revije modro odločilo, da posveti vso to številko opisu Krasa. Čeprav tudi v tej izdaji ni mogoče najti vsega, smo se uredništvo in avtorji potrudili, da je opis kar najbolj zaokrožen, kar se da natančen in tudi čim bolj razumljiv.

Že od začetka izhajanja se je za revijo Kras zanimal širok krog bralcev. Ne le tisti s Krasa. S to številko pa se je uredništvo odločilo še za korak dlje... Revijo ponuja tudi tistim bralskim krogom zunaj Slovenije, ki jih Kras zanima ali bi jih utegnil zanimati, a ne razumejo slovensko, pač pa obvladajo angleščino.

Vendar ne gre le za ponudbo revije Kras tistim na tujem, ki jih Kras zanima! Dolžnost Republike Slovenije kot "lastnice" Krasa je namreč svetovni javnosti - tudi širšemu krogu bralcev, ne le ozko usmerjenim strokovnjakom - (ponovno) povedati, da je Kras tisti del Evrope, odkoder izvira ime za tak - kraški - tip pokrajine in za take pojave po vsem svetu, pa tudi, kje je dobila svoje ime veda "krasoslovje".

Tudi Kras, morda predvsem Kras, je dota, ki bi jo mlada država Slovenija lahko prinesla Evropi. Pa ne samo Evropi, ampak vsemu svetu. To najlepše potrjujejo Škocjanske jame, ki so že deset let vpisane v Unescov Seznam svetovne dediščine!

Dr. Andrej Kranjc
dopisni član SAZU

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KRAS MAY BE A DOWRY OF SLOVENIA TO EUROPE AND WORLD

Already 20 issues of the journal called Kras were publiched. They inform us about the Classical Karst and karst in general, from how and when limestone - karst rock - originated to its use for gateways or portals and what challenge this rock present nowadays to artists; from prehistoric settlements on Kras to its culture and modern economy here. And still more... Everything just cannot bi listed!

Maybe, something was missing. Something was maybe missed by the readers who live in Kras. Maybe even more by those who do not live there but are interested in karst. Why Kras has two different ways of being written? Why Kras and kras? Why Kras is so special? Why every similar landscape in the world is called "karst"? How karst originated? Why there is no water at the karst surface yet from its border huge rivers flow?

There are too much of such questions to list them all...!

To give at least some answers to the questions of the readers ant to round out the information about Kras, the editorial board of the journal wisely decided to dedicate a whole number to a description of the Classical Karst. It is true that even in such issue you cannot find everything that is related to karst, however the authors tried that this description is set out in the best possible way, detailed and comprehensible as much as it can be.

Since the beginning of publishing a wide circle of readers was interested in the review Kras. Not only those living there. This issue goes even further... The review is offered to reading audience out of Slovenia, to the people that are interested in Kras or should be interested in it, and as they do not speak Slovene they understand English.

However, this is not just the offer of the Kras journal to foreigners that are interested in Kras. A duty of the Republic of Slovenia who "owns" this beautiful piece of landscape is to tell (again) to the international public - to wider range of readers not only to experts - that Kras is that part of Europe from where the name for such type of landscape and such type of features all over the world derived, and after which also a science - "karstology" - was named.

Kras also, maybe Kras specially, is a dowry that young Republic of Slovenia may offer to Europe. Not to Europe only, but to the whole world. The best example is Škocjanske Jame, the caves that are for ten years already listed in the UNESCO's World Heritage List.

Dr. Andrej Kranjc
associate member of the SAZU

O *imenu* KRAS

Andrej Kranjc

Kras pomeni pokrajino na vodotopnih oziroma vodoprepustnih kamninah, kjer so razvite posebne površinske in podzemeljske oblike (kraški pojavi) in kjer je podzemeljski (kraški) vodni odtok. Sama beseda kras v stroki nima prizvoka sušnosti, kamnitosti, golote ali celo puščave, pač pa je v laičnih krogih ta prizvok še precej močan. Vendar je tudi marsikateri strokovnjak - krasoslovec še danes presenečen ali celo razočaran, ko obišče "klasični" Kras in vidi goste borove gozdove, travnike in pašnike; še posebej, če to ni ob poletni suši, ko je rastlinstvo rjave in rumene barve.

Izsek iz karte W. Laziusa - A. Orteliusa "Goritiae, Karstii, Chazeolae, Carniolae, Histriae at Windorum Marhae Descrip(tio) 1561, 1573", na kateri je med reko "Wypach" (Vipava) in "Tergestinus Sinus" (Tržaški zaliv) zapisano ime "Kras".

A part of W. Lazius - A. Ortelius Map "Goritiae, Kartii, Chazeolae, Carniolae, Histriae et Windorium Marchae Descript(tio) 1561, 1573", where the name "Karst" appear between the "Wypach" (Vipava) river and the "Tergestinus Sinus" (Triest's Bay).

Vendar pa naš Kras ni bil vedno tak, tako gozdnat in zelen, kot je danes. Valvasor piše (1689): "Poleg tega so ponekod velike puščave in marsikje hudo primanjkuje čiste vode... Zemlja je tu vsa izredno kamnita... Ponekod se sicer da videti nekaj milj daleč, a sama sivina, zelenja pa nič, ker je vse s kamenjem pokrito... Marsikje primanjkuje prebivalcem vode, da, čisto brez nje so... Ponekod nimajo prav nič lesa in zelo malo polja. Pomanjkanje lesa in čiste vode pa nadomešča prebivalcem vino. Je najboljše kakovosti, rdeče in belo, vsake vrste... ". Še celo na prvih fotografijah s preloma 19. v 20. stoletje je golo, kamnito površje tam, kjer so danes gosti borovi gozdovi,

Potnikom, ki so potovali čez Vzhodne Alpe iz srednje Evrope proti Trstu, je bila edina mogoča pot čez Kras in edino tod so doživeli pravo "kraško divjino". Takrat je bila Kras gola, pusta in kamnita pokrajina, vroča in suha poleti, pozimi pa je čeznjo brila ledena burja in delala snežne zamete. Potnikom se je to globoko vtisnilo v spomin. Prehoda čez Kras sicer ni mogoče primerjati, na primer, s prelazom čez Saint Bernard, toda tudi za prečkanje Krasa so morali potniki včasih počakati na pravo vreme ter se založiti s hrano in vodo. Lahko si predstavljamo, da se je večina tedanjih potnikov iskreno zahvalila bogu, ko je z roba kraške planote pod seboj zagledala modro morje in Trst.

Z novim vekom, ki je prinesel razcvet potovanj, odkritij in znanosti, je, posebej po zaslugi tiska, tudi Kras postajal vedno bolj znan. Najprej so objavljali opise Krasa in kraških pojavov geografi, kartografi, kozmografi in topografi (Aistingerus), Cluverius, Mercator, Merian, Münster, Ortelius), tedanji učenjaki (Agricola, Baucer, Faber, Kircher) in popotniki (Brown), ki je objavil opis Krasa in njegovih pojavov kot predhodnik modernih znanstvenikov, kot so geografi, geologi in hidrografi.

Geografske, geopolitične in politične razmere od 16. do 19. stoletja so bile vzrok, da je prav Kras postal sinonim za "kraške pojave" in ne kak drug del Evrope ter še posebej dinarskega krasa, kjer so ti pojavi pogosto večji, bolj tipični in bolj slikovito razviti. Med najpomembnejšimi dejstvi je treba opozoriti, da je pripadal večji del Krasa in del Istre s Trstom takrat Habsburžanom (Avstriji); da je postal Trst leta 1719 "svobodna luka"; da sta del Istre in večji del Dalmacije sodili pod Benetke; da so bili notranji deli Balkana v okviru otomanskega imperija, z negotovimi in nevarnimi mejnimi ozemlji; in da najnižji prevali, ki povezujejo Srednjo Evropo in Podonavje z Jadranskim morjem, vodijo čez tedanji kranjski kras.

Tako je slovenska beseda Kras in še posebej nemška oblika (Karst), saj so večino opisov takrat objavljali v nemškem jeziku, tista beseda, ki se pojavlja v opisih tega posebnega tipa pokrajine in počasi postala mednarodni znanstveni termin z variantami v različnih jezikih: Kras, Karst in Carso. Kras (karst) je eden izmed redkih tipov reliefa, ki ima ime po regionalnem, pokrajinskem imenu. Med raziskovalci, ki so morda največ pripomogli k uveljavitvi pojma "kras" v mednarodni terminologiji, je gotovo Jovan Cvijić (žal se je zavzemal za nemško in ne za slovensko obliko imena) s svojim temeljnim delom "Das Karstphänomen" (1893). Mimogrede naj omenim, da so Čehi, Poljaki in Slovaki med svoje strokovno izrazoslovje prevzeli slovensko obliko (kras) in ne nemške oblike; deloma tudi Hrvati, ki pa sedaj izključno uporabljajo svojo besedo "krš".

Že omenjeno Valvasorjevo delo lahko štejemo za prvi "poljudni" opis Krasa kot pokrajine, ne le posameznih kraških pojavov in posebnosti, ki seveda tudi ne manjkajo v njegovi topografiji Kranjske. V 19. stoletju so bili geologi in geografi tisti, ki so največ pripomogli, da je regionalno ime Kras prešlo v geološko in geomorfološko terminologijo, še posebej člani dunaj-

HOW KRAS GOT ITS NAME?

Andrej Kranjc

Karst is a type of terrain with a distinctive and unique assemblage of landforms and hydrology arising from a combination of high rock solubility and well developed secondary porosity, where special superficial and underground features (karst phenomena) developed and where underground (karst) water drainage is in control. Within the profession the word "kras" itself does not imply the meaning of being dry, rocky, bare or even inhospitable, however this meaning is rather strong in laymen circles. Yet, there are experts-karstologists surprised or even disappointed when visiting classical Kras and they find there dense pine forests, meadows and pastures, in particular if the visit does not occur during summer drought when most of vegetation is brown or yellow.

However, our Kras was not always woody and green as it is at the present. Valvasor writes (1689): "Also there are large deserts and on many places a lack of pure water... The Earth is here very stony ... Somewhere one may see for miles, but everything is grey, nothing is green, everything is covered by rocks... On many places the people are lacking water, yes, they are completey without it... Somewhere they do not have any wood and very small fields. The inhabitants, running short of wood and pure water replace it by wine. It is of the best quality, red and white, all sorts..." The first photographs from the turn of the century show bare, rocky surface on the places where there are pine woods now.

For the passengers, who travelled from the Middle Europe over the Eastern Alps towards Triest, the only possible route passed Kras and that 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" (bora) wind and snow-drifts in winter leaving a deep impression on passengers. Kras passes cannot be compared with the Saint-Bernard pass, but also on Kras the passengers had to wait for appropriate weather, had to take water and food, and were happy when the blue sea and Triest emerged in front of their eyes.

Kras and its topographical and hydrological phenomena was becoming largely known specially in New Age when sciences, discoveries and travels began to flourish. After the print discovery Kras became more and more known. The first were geographers, cartographers, cosmographers and topographers (Aistingerus, Cluverius, Mercator, Merian, Münsterus, Ortelius), scientists of the epoch (Agricola, Baucer, Faber, Kircher) and travellers (Brown) who published the descriptions of Kras and its phenomena, forerunners of nowadays sciences as geographers, geologists and hydrographers.?

Geographical, geopolitical and political situation from the 16th to 19th centuries were the reason that just Kras became the synonym for the "karst phenomena" and not some other part of Europe or Balkans where such phenomena are even more important and more typically and spectacularly developed: part of Kras, Istria and Triest were Habsburg (Austrian) domain; Triest got the status of "free port" in 1719; most of Istria and Dalmatia were Venetian territory;

the inner part of Balkans belonged to Otoman Rule, with unsafe and dangerous border regions; the lowest passes from the Middle Europe and Danube regions leading towards the Adriatic crossed Kranjska (Carniola) Kras.

And thus the Slovene (Kras) and in particular German version (Karst) (most of the descriptions were published in German language), entered into common terminology denoting a special type of landscape and gradually appeared in the international scientific terminology with variations due to different languages: Kras, Karst and Carso. Karst as a general term is one of the rare types of relief that is named after a regional name. The man who contributed a lot that the word karst (we are sorry that he used the German version instead of the Slovene one) entered the international terminology was without doubt Jovan Cvijiæ by his fundamental work "Das Karstphänomen" (1893). However, we must stress that Czechs, Polacks and Slovaks adopted in their professional terminology the slovene word kras and not the German version; partly also the Croats used it, but at the present they use exclusively their word "krš".

Valvasor, already mentioned, may be considered as the author of the first "comprehensive" Kras description of a Kras as a region and not only of single karst phenomena and curiosities, which are also not missed in his topography. During the 19th century the geologists and geographers essentially contributed that the regional name Kras entered the general geological, geographical school in particular. 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). A. Schmidl writes (1854) about the characteristic orographic shape "terraced mountains of Kras" including the whole Istria and Dalmatia. J. Lorenz (1858) 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 area (the hinterland of Rijeka) does not differ markedly between them. W. Urbas (1874, 1877) distinguishes within the Carniola karst, the karst of Primorska, Notranjska and Dolenjska.

From where the name "Kras" is derived and what does it mean?

In the ancient Greece and Rome karst phenomena were well known if we consider their mithology and everyday life. Two of such phenomena from the actual Kras were mentioned in the works from B.C. already: the Reka river sinking into Škocjanske jame and Timavo karst springs. Kras and karst curiosities were mentioned in ancient navigation itineraries - periplos (Pseudoskilax's from the middle of the 4th century B.C.). Posidonios of Apameia (135 - 50 B.C.) studied Timavo springs and mentioned Škocjanske jame. Vergilius (70 - 19 B.C.) mentioned this resurgence in his Eneida.

The area that is Kras at the present time, entered the history by the Roman conquest of the region in the 2nd century B.C., by their occupation and later annexation to the Roman Empire under the name of "Regio X - Venetia et Histria". The classical name of the present Kras was "Carusadus, Mons Carusad, Karusad, Carsus" and similar forms, all of them including the pre-indoeuropean stem "ka(r)a/ga(r)a", meaning "stone". The word is still alive in Irish (carraig = rock), in various forms it is known in Dakian, Iranian and Albanian language. Similar origin has morphological feature "karren" or prehistorical pile of stones "cairn" as well as French karst plateaus "causse", rocky plain in the Rhone delta "Crau" and the name of the town Carcassonne (= on the rock). Carniola, Carnia, Karavanke Mts. have probably the same origin. It is sure that in the year 804 the predecessors of the modern Slovenes, Slavic tribes, already settled in Istria. Peaceful and aggressive contacts with old (Romanised) inhabitants were reported and these contacts without doubt contributed to the preservation of the topographic name Kras. The oldest form of the actual Slovene name Kras is "Grast"; it figures on the chart from 1177. This is the early Slovene metathesis "kar-" into "kra-".

In Slovenia "Kras" relatively frequently appears as a toponym or place name, or the names have the same root (two villages named Kras in Beneška Slovenija, Krasinec, Krasna, Krasno, Krašče, Krašči, Krašna vas, Krašnji vrh); the same word may be found in neighbouring countries where there are no Slovenes living now (Kras, Krass, Krasbach, Krastal, Kraswald).

In recent literature the origin of the term "Karst" is often ommitted or misunderstood: In Jennings (1971) it is written that it comes from the "Slovene word krš"; in Faibridge's Enyclopaedia "Kras" is meant to be "the limestone region North and South from the Rijeka port".

In short: the ancient word for "stone" gave the origin to the ancient name for the region (Carusadus, Carsus) and this word changed according to different languages into Kras (Slovene), Karst (German), and Carso (Italian). From this toponym the international term - karst - for such type of landscape is derived and this is the base for other derivations, such as "karst phenomena, karst features" and even relatively new branch of science, karstology.

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Valvasorjevo (1689) besedilo o Krasu:

"Stopimo najprej na K r a s. S tem razumemo ves Kras, ki sega od Lož in Senožeč do Jadranskega morja. Zemlja je tu vsa izredno kamnnita. Dvigajo pa se tod tako številni grički, hribčki in gorice kakor valovi v Beneškem morju, da ni Kras samemu sebi v ničemer tako enak kakor v neenakosti in da se mu ne zdi nič tako ravno kakor naravnost. Ponekod se sicer da videti nekaj milj daleč, a sama sivina, zelenja pa nič, ker je vse s kamenjem pokrito. Kljub temu raste v nekaj krajih med kamni najlepša in najplemenitejša trava, ki rabi živini za pašo; zakaj prebivalci redijo ponekod prav mnogo živine. Tako vzrejajo najboljše konje, ki se imenujejo kraški konji in se izvažajo po vsej Evropi. Rim. ces. veličanstvo ima zato lastno žrebčarno v Lipici na Krasu, sicer na tržaškem ozemlju, a tik ob kranjski meji.

ske geološke in geografske šole. V komentarjih geološke karte Primorske in Istre (1848) govori A. v. Morlot o "kraškem apnencu" (Karstkalk) in o "kraški pokrajini" (Karsland). A. Schmidl (1854) piše, da značilni orografski obliki, kakršno je "terasasto gorovje Krasa", pripadata tudi vsa Istra in Dalmacija. J. Lorenz (1858) v svojih delih ugotavlja, da ni prav imenovati "Kras" le pokrajino med Vrhniko in Trstom, saj tudi "liburnijski kras" (zaledje Reke) ni prav nič drugačen. W. Urbas (1874, 1877) loči v sklopu kranjskega krasa "Primorski, Notranjski in Dolenjski kras".

Od kod torej ime Kras in kaj pomeni?

V stari Grčiji in v Rimu so bili kraški pojavi dobro poznani, tako iz mitologije kot iz vsakdanjega življenja. Dva pojava z današnjega Krasa sta bila omenjana že v delih pred našim štetjem: Reka, ki ponika v Škocjanske jame, in izviri Timave (najstarejša omemba v Pseudoskilaksovem

Valvasor's (1689) text on Karst:

At first let us go on K r a s. I mean the entire Kras, from Lože and Senožeče to the Adriatic Sea. The land is very rocky. But there are so meny hills, butes and small mauntains as there are waves in the Venetian Sea. Karst does not equal anything more that itself, flatness typical of Kras is its unflatness. Somewhere it is possible to see for some miles, but everything is only grey, nothing green, because all the country is covered by stones. Between stones some grass is growing even, the best and the most beautiful grass, which is used by cattle for grazing. Inhabitants have somewhere a lot of cattle. So they are breeding the best horses, called karst horses, which are exported all over the Europe. His Roman Imperial Higness owns the stud at Lipica on Kras, on the Triest territory, but just along the Carniola border.

K a r s t n e r B o d e n (Nakrasso). Wodurch anjetzo der gantze völlige Karst verstanden wird, so von Laytenburg und Senosetsch biß zum Adriatischen Meer geht. Dieser Boden ist durchaus und über die Massen steinigt. Es werffen sich auch soviel kleiner Hügel, Berglein und Bühel schier darinn auf, als wie in einem brausendem Meer Wellen, also daß er ihm selbsten überall an Nichts so gleich, als in der Ungleichheit sieht, und ihm nichts so eben, als die Unebenheit zu seyn scheinet. An theils Orten schauet man zwar etliche Meilenwegs herum, aber nur alles grau und wenig Grün, weil es überall mit Steinen bedeckt. Jedoch wächst einiger Orten gleichwol zwischen den Steinen das schönste und edelste Gras, und dienet dem Vieh zur Weide. Denn die Einwohner halten an theils Orten sehr viel Viehes. So werden daselbst auch die beste Pferde gezogen, welche man die K a r s t - n e r - P f e r d e heisst, und durch gantz Europa verführt. Gestaltsam die Römisch-Keyserliche Majestet deßwegen ihre eigene Stutterey auf dem Karst zu Lippiza, (wie man selbige Gegend nennet) haben, zwar in Triesterischem Gebiet, doch gleich an den Cräinerischen Grentzen.

periplu iz sredine 4. stoletja pred našim štetjem). Pozidonij iz Apameje (135-50 pr. n. št.) je preučeval izvire Timave v zvezi s plimovanjem, Vergil (70-19 pr. n. št.) pa omenja te izvire v Eneidi.

Pokrajina, ki jo danes imenujemo Kras, je vstopila v zgodovino z rimskim napadom na to ozemlje v letih 178 in 177 pr. n. št. in z njeno vključitvijo v rimski imperij kot "Regio X - Venetia et Histria", to je kot del prave Italije. Klasično ime te pokrajine je bilo "Carusadus, Mons Carusad, Karusad, Carsus", vsekakor predindoevropskega izvora iz korena "Ka(r)a/ga(r)a", kar pomeni kamen. V tem pomenu je beseda še živa v irščini (carraig = skala), v raznih oblikah je znana iz dakijskega, iranskega in albanskega jezika. Podobnega izvora je tudi termin za drobno kraško obliko "karren" ali za prazgodovinske kamnite gomile "cairn", kot tudi za francoske kraške planote "causse", kamnito dolino v delti Rona "Crau" in za mesto Carcassonne) ("na skali"). Kranjska, Karnija, Koroška (Karintija), Karavanke in druga taka imena so morda podobnega izvora. Zagotovo vemo, da so bila slovanska plemena, predniki današnjih Slovencev, leta 804 že naseljena v Istri. Viri poročajo tako o miroljubnih kot tudi o sovražnih odnosih z romaniziranimi staroselci, kar je gotovo pripomoglo h ohranitvi in h kontinuiteti topografskega imena Kras. Najstarejši zapis slovenskega imena za Kras je v dokumentu iz leta 1177 kot "Grast", kar je rezultat rane slovenske likvidne metateze "kar" v "kra".

V Sloveniji se "kras" pogosto pojavlja kot topografsko ali krajevno ime oziroma so pogosta imena s tem korenom (dve vasi Kras v Beneški Sloveniji, Krasinec, Krasna, Krasno, Krašče, Krašči, Krašna vas, Krašnji vrh). Taka imena so tudi v sosednjih pokrajinah, kjer Slovencev danes ni več (Kras, Krass, Krasbach, Krastal, Kraswald).

V sodobni literaturi izvor termina kras pogosto ni omenjan ali pa je napačno razlagan: Jennings (1971) piše, da izhaja iz "slovenske besede krš", medtem ko v Fairbridgovi geomorfološki enciklopediji "Kras" pomneni "apnenčevo pokrajino nad pristaniščem Reko".

Če na kratko strnem: iz stare besede za "kamen" je nastalo antično ime za pokrajino (Carusadus, Carsus), ki se je, glede na jezik, spremenilo v Kras (slovenski), Karst (nemški) in Carso (italijanski). Iz tega imena je nastal mednarodni termin za tako pokrajino - kras (karst), iz česar izvirajo izrazi, kot je, na primer, kraški pojavi, in tudi relativno mlada znanstvena veda "krasoslovje".

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KAMNINE na Krasu

Bojan Otoničar

Na Krasu so izrazite kraške oblike, ki so ponesle njegovo slavo širom po svetu, razvite na apnencih in dolomitih. Ti so nastali iz krednih in terciarnih karbonatnih usedlin v plitvih, toplih obkontinentalnih morjih. Kljub navidezni monotonosti kamnin nam nekoliko natančnejši pogled razkrije številne različke. Te so znali s pridom izkoristiti Kraševci kot arhitektonske - gradbene tipe, točno določena kamninska osnova pa je nudila tudi podlago, kjer uspeva vinska trta, ki daje teran.

Kredne kamnine, ki grade Kras, so opisane v starostnem zaporedju, od najstarejših do najmlajših. Po litoloških podobnostih so uvrščene v večje skupine - formacije, ki se delijo na člene. Opisi kamnin ter poimenovanje formacij, členov in horizontov so v glavnem povzeti po rezultatih najnovejših raziskav (Jurkovšek et al., 1996, in Šlibar, 1995). Imena geoloških enot so v glavnem povzeta po krajih na Krasu, kjer so določeni tipi kamnin najznačilnejši - Brje, Povir, Repen, Komen, Sežana, Lipica in Tomaj.

Brska formacija (K_1)

Najstarejše kamnine na Krasu so zrnati bituminozni dolomiti in sivi apnenci s tanjšimi paketi dolomita ter apnenčeve in dolomitne breče. Te kamnine pripadajo brski formaciji in so razvite na severozahodnem delu Krasa med divaškim prelomom in slovensko-italijansko mejo. Starost formacije je še najbolje določena v vrhnjem delu, kjer nam kažejo paleoorbitoline aptijsko stopnjo.

Med delci, ki sestavljajo kamnine (alokemi), so pogosti peleti (okameneli iztrebki rakcev, črvov, ...) in bioklasti (fosilni organizmi in njihovi delci), med katerimi prevladujejo bentoške enocelične luknjičarke (foraminifere), mikroskopski rakci oklepniki (ostrakodi), skeletne in neskeletne alge, polži ter drobci debelolupinastih školjk. Morje, v katerem so se usedali apnenci, je bilo v glavnem zatišno, celo lagunsko. Obdobja, ko je bilo morje bolj razburkano, so bila le občasna. Predvsem na koncu usedanja te formacije so bili posamezni deli platforme izpostavljeni kopnim pogojem, kar kažejo intraformacijske breče ter manjši žepi in lezike boksitne gline.

Povirska formacija ($K_{1,2}$)

Nad kopno fazo, ki predstavlja zgornjo mejo brske formacije, so se usedali temnosivi apnenci in dolomiti povirske formacije. Sedimente te formacije lahko razdelimo na dva ločena dela, med katerima je horizont s hondrodontami. Te kamnine najdemo v dva do tri kilometre širokem vzporednem pasu ob meji z Italijo ter na območju med Sežano in Divačo. Najprej so se usedali sedimenti, iz katerih so nastali temnosivi apnenci, med katerimi so posamezni lečasti vložki bituminoznega dolomita ter dolomitnih in apnenčevih breč. Med aptijem in albijem (geološki obdobji zgornjega dela spodnje krede) je (v kopnih pogojih) nastala emerzijska breča z glineno osnovo. Starostno pripada zgornjekredni del povirske formacije cenomaniju.

Zgornjekredni apnenec s preseki rudistov (Foto: B. Otoničar).
Upper Cretaceous limestone with rudists (Photo: B. Otoničar).

ROCKS IN KARST

Bojan Otoničar

Kras displays distinctive karst landforms in limestone and dolomite. These rocks are characteristic Cretaceous and Tertiary carbonate deposits of shallow, warm-water carbonate shelf environments. In spite of apparent monotony there is a great deal of variation in consolidated limestone. Variety of forms was successfully used by people living in Kras as building and decorative stones; precisely determined rocks offer the basement to thrive the vine that gives teran.

The principal Cretaceous rocks that build Kras are divided by time sequence from the oldest to the youngest. In terms of lithology they are classified to formations and members. The description of rocks and nomenclature of formations, members and beds are mostly taken from the results of current researches (Jurkovšek et al., in the press; Šribar 1995). The names of geological units are mostly taken from the local names in Kras where the types of rocks are the most characteristic - Brje, Povir, Repen, Komen, Sežana, Lipica and Tomaj.

The Brje formation (K_1)

The oldest rocks in Kras are coarse-grained bituminous dolomites and grey limestones interbedded by thin packages of dolomite and lime and dolomitic breccias. These rocks belong to Brje formation and developed in the north-western part of Kras between Divača fault and Slovene-Italian border. The age of formation is the best defined in its upper part where paleoorbitolinae indicate the Aptian stage.

Among grains (allochems) composing the rock, the pellets (lithified faecal excrements of shrimps and worms) and bioclastics (skeletal grains) are frequent, among the latter benthonic unicellular species as foraminifera, a group of small arthropods as ostracoda, skeletal and non-skeletal algae, molluscs and particles of shells prevail. The sea where the described limestones deposited was mostly calm, of lagoon type even. Only occasionaly the periods of agitated sea occurred. Towards the end of this formation sedimentation single parts of the platform were subaerially exposed evidenced by intraformational breccias and smaller chokes and bedding-planes of bauxitic clays.

The Povirje formation ($K_{1,2}$)

Above subaerial exposure phase which is the top border of the Brje formation dark grey limestones and dolomites of Povirje formation deposited. The sediments of this formation may be divided into two distinctive parts interbedded by hondrodonts. These rocks are displayed in two to three kilometers wide belt parallel to the border with Italy and in the area between Sežana and Divača. At first the sediments out of which dark grey limestones developed were deposited; among them there are lense-shaped inliers of bituminous dolomite and dolomitic and limestone breccias. Between the Aptian and Albian (these are two geological stages of the upper part of the Lower Cretaceous) the emmersion breccia with clay matrix developed. The Upper Cretaceous part of the Povir formation is dated at the Cenomanian.

Among allochems the bioclastics prevail, the most frequent being benthos foraminifera and ostracodes, followed by pellets. During their genesis all these particles were "dipped" in carbonate mud; where the water energy was slightly higher the mud was washed out. On some places of this formation also oolitic limestones (ooids - a spherical or subspherical rock coated grains which has grown by calcareous accretion around a nucleus) are found.

1. The Hondrodonta beds

The rocks of lower part of the Povir formation are underlain by narrow, up to 9 m thick bed of shelly limestones and dolomites consisting mostly of hondrodonta shells (these are flattened, tall shells of tongue-shaped form) Between single layers of hondrodonta lumachelle (in lumachelle more than 50% of the rock consists of shells) up to half meter thick layers of rudist limestone and dolomite occur. The rudist is cornute in shape, having a bivalce calcareous shell which is secreted by a bivalve mantle laterally about the animal; it is attached by lower valve to a basement while upper one forms a cover; they lived on vast meadows and on reefs of warm sea. The hondrodonta beds belong to the Upper Cenomanian.

Riba Ancylostylos gibbus iz komenskih apnencev, dolga približno 30 cm.
Fish Ancylostylos gibbu gro the Komen limestone, which is approximately 30 cm long.

Med alokemi prevladujejo bioklasti, med katerimi so najpogostejše bentoške foraminifere ter ostrakodi. Od ostalih delcev pa je največ peletov. Vsi ti delci so bili v času nastajanja "potopljeni" v karbonatno blato, ki je bilo tam, kjer je bila energija vode nekoliko višja, izprano. Ponekod se v tej formaciji pojavljajo tudi oolitni apnenci (ooidi - sferični, do 2 milimetra veliki oviti delci, ki so nastali v veliki meri s kemičnim izločanjem karbonata okrog jeder).

1. Hondrodontni horizont

Kamninam spodnjega dela povirske formacije sledi ozek, do devet metrov debel pas apnencev in dolomitov, ki jih sestavljajo pretežno lupine hondrodontnih školjk (to so sploščene, visoke školjke - ostrige, jezičaste oblike, z močnimi rebrci; po obliki so še najbolj podobne današnjim leščurjem). Med posameznimi plastmi hondrodontnih lumakel (v lumakelah več kot 50 % kamnine sestavljajo školjke) se pojavljajo do pol metra debele plasti rudistnega apnenca in dolomita. Rudisti so ukrivljenemu rogu podobne školjke, ki so bile s spodnjo lupino prirasle na podlago, zgornja pa je tvorila pokrovček, in so živeli v obsežnih tratah in grebenih toplih morij. Starostno se plasti hondrodontnega horizonta uvršča v zgornji cenomanij.

2. Nadhondrodontni apnenec

Mlajši so apnenci in ponekod tudi dolomiti, ki so podobni tistim pod plastmi s hondrodontami, le da so svetlejši in debeleje plastoviti. Med alokemi je spet največ bioklastov in peletov, pogosti pa so tudi odlomki kamnin - intraklasti... Tudi tu med organizmi prevladujejo bentoške foraminifere, predvsem miliolide, pogosti pa so tudi intenzivno endolitizirani (z organizmi navrtani) delci rudistov. Med sedimentnimi teksturami so najpomembnejše izsušitvene razpoke, ki kažejo, da je bil sediment občasno izpostavljen izsuševanju na kopnem.

Usedline, iz katerih so nastale sedimentne kamnine povirske formacije, so nastale v zelo plitvem zatišnem morju, kjer so se izmenjavali podplimski (področje, ki je stalno pod morsko gladino) do nadplimski (področje, ki je poplavljeno le ob izjemno visokih plimah) pogoji sedimentacije. Predvsem v spodnjem delu je šlo za lagunsko in priobalno zatišno plitvomorsko okolje, ki pa je postajalo proti zgornjemu delu formacije vedno bolj razgibano.

Repenska formacija ($K_2^{1,2}$)

Nad povirsko formacijo ležijo v normalnem položaju pelagični mikritni apnenci in repenski bioklastični apnenci repenske formacije, ki jih sestavljajo trije deli: 1. kalcisferski apnenci (kalcisfere so odprtomorski kroglasti mikrofosili), 2. bioklastični repenski in koprivski apnenci, in 3. temen bituminozni, tudi laminiran, apnenec, poznan kot komenski skrilavec. Na slovenskem delu Krasa lahko te kamnine sledimo v pasu od Škrbine čez Komen do Kobjeglave. Najdemo jih še severno od Velikega Dola in severno od Koprive ter med Vrhovljami, Sežano in Divačo. Starostno so te kamnine uvrstili med zgornji cenomanij in srednji turonij.

1. Kalcisferski apnenec

Glavni alokemi v kalcisferskih mikritnih (mikrit je strnjeno karbonatno blato) apnencih so kalcisfere, planktonski iglokožci in foraminifere ter iglice morskih kumar. Na posameznih območjih je te apnence nadomestil grobozrnat poznodiagenetski dolomit.

2. Bioklastični repenski in koprivski apnenci

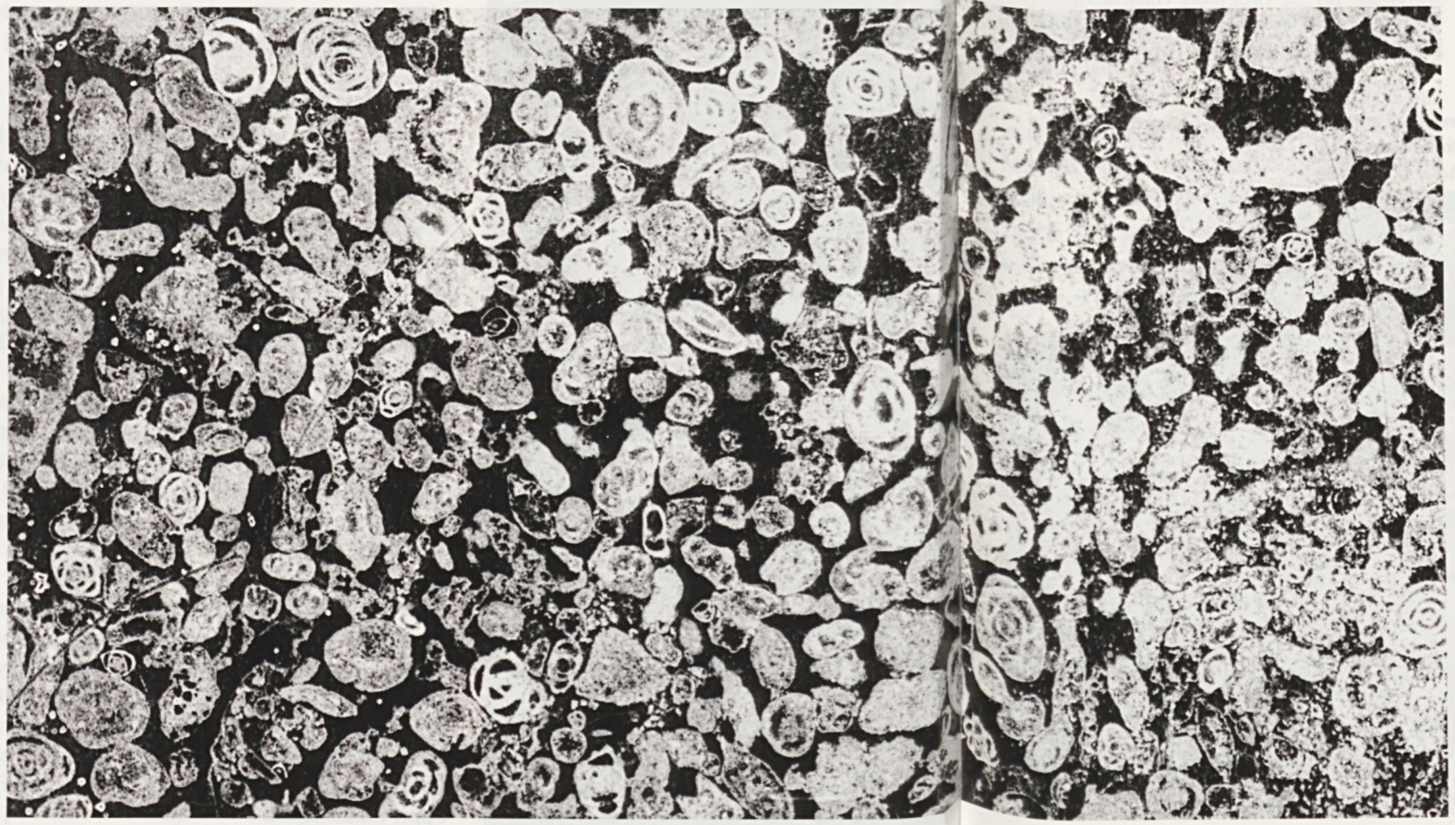
Med temi pelagičnimi apnenci se na več območjih in časovno ne povsem istočasno pojavljajo od enega metra do tridesetih metrov debele leče bioklastičnih apnencev. Med temi kamninami se pojavljata dva značilna različka, ki sta pomembna za kamnarstvo. To sta repenski in koprivski apnenec. V repenskem apnencu so drobci rudistov izredno številni in dajejo ponekod kamnini videz "rožastega" apnenca - tip "fiorito". Koprivski apnenec se od repenskega loči po tem, da je temnejši in da so rudistni ostanki bolj zdrobljeni in zaobljeni. Pogosto so med njimi tudi fosilni ostanki drugih školjk in polžev. Kjer se je mikritno blato ohranilo, lahko vidimo, da je podobne sestave kot opisani kalcisferski apnenec.

3. Komenski apnenec

V širši okolici Komna ležijo na spodnji povirski formaciji temni ploščati apnenci, ki so poznani kot komenski skrilavci. V njih se menjavajo debele in tanke plasti črnega, pogosto laminiranega apnenca, med katerimi se mestoma pojavljajo pole in leče roženca (kremenova kamnina). V bituminoznih apnencih lahko opazujemo tudi številne manjše zdrse, ki so pomembni za ugotavljanje okolja nastanka teh kamnin. Tudi tu se pojavljajo odprtomorske foraminifere in kalcisfere. V skrilavih polah so našli številne dobro ohranjene fosilne ribe.

Biomikritni (kalcisferski) odprtomorski apnenci in bituminozni laminiti - komenski skrilavci kažejo, da je prišlo na meji med cenomanijem in turinijem do dviga morske gladine ne samo na območju Krasa in jadransko-dinarske karbonatne

Foraminiferni miliolidni apnenec - negativ zbrusek (Foto: M. Knez).
Foraminiferal miliolidal limestone (Photo: M. Knez).



2. The above hondrodonta limestone

There are limestones and somewhere dolomites similar to those underlain to the beds with hondrodonta, yet they are younger, lighter and thick-bedded. Again among allochems the bioclastics and pellets prevail, frequent are also fragments of rocks - intraclastics. Here also the benthos foraminifera prevail among the organisms, in particular milliolids, however frequent are also fragments of rudists that are intensively endolithised (rock bored by organisms). Regarding the sedimentary structure the dissication cracks are the most common indicating that the sediment was occasionally exposed to dessication on land.

The sedimentary rocks of the Povir formation are due to very shallow, calm sea environment where subtidal (the area permanently below the sea level) and supratidal (the area flooded during extremely high tides only) sedimentation conditions alternated. In particular in its lower part there was lagoon and leeward shallow marine environment which got more and more agitated towards the upper part of the formation.

The Repen formation ($K_2^{1,2}$)

Above the Povir formation are located in normal position pelagic micritic limestones and Repen bioclastic limestones of the Repen formation composed by three parts: 1. calcisphereous limestones (calcispheres are open sea spherical microfossils), 2. bioclastics Repen and Kopriva limestones and 3. dark, bituminous laminated limestone known also as Komen shale. In the Slovene part of Kras these rocks are displayed in a belt from Škrbina over Komen to Kobjeglava. They may be found north of Veliki Dol and north of Kopriva and between Vrhovlje, Sežana and Divača. According to sequence in time these rocks belong to the Upper Cenomanian and to the Middle Turonian.

1. The Calcisphereous limestone

The main allochems in calcisphereous micritic (micrite is lithified carbonate mud) limestones are calcispheres, planktonic echinoderma and foraminifera and spicules of sea cucumbers. On some areas these limestones are replaced by coarse-grained late diagenetic dolomite.

2. Repen and Kopriva bioclastic limestones

On several areas and not wholly contemporaneously between these pelagic limestones appear lenses of bioclastic limestones, from 1 to 30 m in thickness. Among these rocks two distinctive varieties occur very important for stonecutting: these are Repen and Kopriva limestones. In the Repen limestone the rudist fragments are very numerous giving the appearance that rock is rose-like - type "fiorito". The Kopriva limestone differs from the Repen one in that that it is darker, rudist fragments are more crushed and rounded. Frequently there are among them fossil remains of other shells and snails. Where the micritic mud is preserved one may see that it has a similar composition as above described calcisphereous limestone.

3. The Komen limestone

In wider vicinity of Komen the Lower Povir formation is underlain to dark, flat (tabular) limestones known as Komen shales. Thick and thin layers of black, usually laminated limestone alternate in them; they often contain the interbeds or lenses of chert (quartz rock). In bituminous limestones one may see numerous smaller interbedded slides which are important to determine the environment of the origin of these rocks. Here too the open sea foraminifera and calcispheres occur. In shale strata numerous, well preserved fossil fishes were found also.

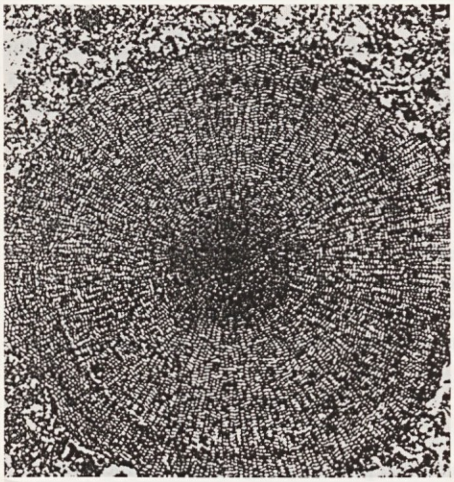
Biomicritic (calcisphereous) open sea limestones and bituminous laminithes - Komen shales indicate that since the turn of Cenomanian to Turonian a widespread marine transgression occurred, which at its maximum extent produced the greatest proportion of sea relative to land on the Earth's surface since Palaeozoic time also in the area of Kras and Adriatic-Dinaric carbonate platform.

In respect to organism associations in biomicritic limestones one may conclude that they were deposited in relatively shallow parts of open sea, howeveer deep enough that on carbonate platform the shallow sea benthos organisms did not flourish any more; eventually, these organisms play the main role at growth of carbonate platforms.

As I have mentioned the origin of black bituminous Komen limestones may be associated with the uplift of sea level. They were probably deposited in slightly deeper parts of carbonate platform in the initial phases of its emmersion and when oxygen was lacking.

Skeletal limestones consisting mostly of rudist fragments, should slide into deeper sea from the areas which were at this time tectonically uplifted (Savudrija and Kvarner blocks and probably some areas on the Italian side of Kras).

In the Upper Turonian a relatively fast sea regression occurred thus some deposits were above the sea level occasionaly indicated by distinctive dessication pores. Such rocks may be seen north of Kobjeglava, near Skopo, Kopriva and Pliskovica, close to Sežana and towards Divača and above the Raša valley.



Foraminifera keramosphaerina tergestina (premer 0,7 cm).
Foraminifera Keramosphaerina tergestina (diameter 0,7 cm).

platforme ampak na območju vseh svetovnih oceanov.

Tako po združbah organizmov v biomikritnih apnencih sklepamo, da naj bi se odložili v razmeroma plitvih delih odprtega morja, vendar dovolj globoko, da na karbonatni platformi niso več mogli uspevati plitvomorski bentoški organizmi, ki igrajo sicer glavno vlogo pri rasti karbonatnih platform.

Kot je že omenjeno, lahko tudi nastanek črnih bituminoznih komenskih apnencev povezujemo z dvigom morske gladine. Verjetno so nastali v nekoliko globljih predelih karbonatne platforme, v začetnih fazah njenega poplavljanja, in v pomanjkanju kisika.

Skeletni apnenci, sestavljeni v glavnem iz fragmentov rudistov, naj bi se v globlje morje splazili z območij, ki so bila v tistem času že nekoliko tektonsko dvignjena (savudrijsko-kvarnerski blok ter verjetno tudi nekatera območja na italijanskem delu Krasa).

V zgornjem turoniju je sledila nagla relativna poplitvitev morja, tako da so bili sedimenti občasno celo nad morsko gladino, kar dokazujejo izrazite izsušitvene pore. Te kamnine lahko opazujemo severno od Kobjeglave, v okolici Skopega, Koprive in Pliskovice, v okolici Sežane in proti Divači ter nad dolino Raše.

Sežanska formacija (K_2 $^{2\text{-}5}$)

Neposredno na repenski formaciji leži sivi mikritni apnenec z izsušitvenimi porami, v katerem se ponekod pojavlja nekaj metrov debel horizont z do tri centimetre velikimi onkoidi. Onkoidi so sferični delci, nastali s pomočjo mikroorganizmov. Nad temi plastmi so se v mirnem zatišnem morju in v lagunah usedali olivno sivi gosti apnenci sežanske formacije, z občasnimi medplimskimi in celo emerzijskimi značilnostmi, kot so tanke leče breč in majhni črni prodniki. V strnjenem karbonatnem blatu najdemo številne mikrofosile (foraminifere, zelene skeletne alge, ostrakode, drobce rudistov in iglokožcev, posebno zanimiv pa je mikrofosil *Aeolisaccus kotori*, ki ga raziskovalcem še ni uspelo uvrstiti v nobeno znano fosilno skupino in ponekod predstavlja edino alokemično komponento). Izmed ostalih delcev so najpogostejši peleti.

Občasno so se v te sedimente naplavljali tudi mikroorganizmi globljega morja. V različnih nivojih se med temi apnenci pojavljajo lokalne leče poleglih rudistov in njihovega drobirja.

Okolje, v katerem so se usedali opisani karbonati, kaže prehod od spodnjih plitvih podplimskih, medplimskih in celo nadplimskih pogojev proti zgornjim podplimskim pogojem.

Lipiška formacija (K_2 ^{5,6})

Apnenci naslednje, lipiške formacije, ki so se usedali v normalnem zaporedju glede na prejšnjo formacijo, ležijo na ozemlju med Dutovljami, Tomajem, Avbrom in Štorjami ter med Lipico in Divačo. Starostno je začetek usedanja teh apnencev uvrščen v zgornji del spodnjega kampanija, konec pa je na različnih področjih časovno nekoliko različen. Med njimi je najznačilnejši kamninski tip svetel debeloplastoviti do masivni lipiški apnenec, bogat z rudisti in predvsem z njihovim drobirjem. Odlagal se je v nemirnem morju v nekoliko globljem podplimskem okolju, kamor se je drobir nanašal iz bližnjih rudistnih trat. Zaradi debelin ter ugodne strukture je kamen pomemben za kamnoseštvo in ga izkoriščajo v lipiškem kamnolomu.

V nekoliko bolj zatišnih delih so se odlagali mikritni apnenci, v katerih prevladujejo med fosili foraminifere, prisotni pa so še ostrakodi in neskeletne zelene alge. Da je šlo zares za neprezračena okolja, kažejo temna barva apnencev, ki je posledica organske snovi, in pa drobne piritne kocke. Ti apnenci so ponekod deloma poznodiagenetsko dolomitizirani. Tu so zanimive plasti temnega apnenca z belimi pikami, ki predstavljajo foraminifere - keramosferine (*Keramospherina tergestina*, ki je dobila vrstno ime po Trstu). Ta apnenec je bil občasno izpostavljen medplimskim pogojem, o čemer pričajo izsušitvene razpoke.

1. Tomajski apnenec

V okolici Dutovelj, Tomaja, Dobravelj in Kazelj ter tudi v dolini Raše se znotraj lipiške formacije pojavljajo tankoplastoviti, ploščati in laminirani temni bituminozni apnenci, ki so litološko podobni komenskim apnencem. Tomajski apnenec

Paleokraška površina loči apnence lipiške formacije (spodaj) od apnencev liburnijske formacije.
Paleokarstic surface seporates limestones of the Lipica formation (below) from the limestones of the Liburnia formation (Foto/Photo: B. Otoničar).

predstavlja lokalni razvoj znotraj lipiške formacije in se pojavlja v obliki vložkov ter paketov, ki se bočno izklinjajo.

Med alokemi prevladujejo predvsem bioklasti, ki ležijo v mikritni osnovi. Med njimi prevladujejo predvsem odprtomorski mikrofosili, drobci iglokožcev ter ostrakodi in neskeletne alge. V kamnini je opazen tudi framboidalni pirit (pirit v obliki drobnih kroglic), ki kaže na redukcijske pogoje (območja, kjer primanjkuje kisika). O takih pogojih pričajo tudi karbonizirani ostanki rastlin, rib in amonitov (izumrla skupina mehkužcev). Tomajski apnenec vsebuje tudi gomolje in tanjše plošče roženca.

Konec odlaganja sedimentov lipiške formacije je povzročila kopna faza, ki je bila verjetno tektonske narave. V kopnih pogojih je prišlo do zakrasevanja (paleokras) in predvsem na obrobju Matarskega podolja do nastajanja boksita. Paleokraški pojavi so ponekod označeni z izrazitim paleokraškim površinskim reliefom. Zanj so značilne breče z boksitno-glinastim vezivom. Ponekod se pojavlja tudi podpovršinski paleokras, ki je izražen z zapolnjenimi manjšimi jamami. Zapolnitve so lahko boksitno glinene, ponekod pa verjetno debelozrnati kalcit predstavlja prekristaljene sige. Najmlajše ohranjene kamnine pod paleokraško površino so na različnih območjih Krasa in Matarskega podolja različne starosti.

Ta prekinitev sedimentacije je trajala na različnih območjih Krasa in Matarskega podolja različno dolgo in je pustila tudi različne sledi. V glavnem se je začela sedimentacija naslednjih plitvovodnih apnencev liburnijske formacije že v kredi, ponekod pa se je začela šele v paleocenu.

Poudariti moramo, da je prišlo v zgornjem maastrichtiju do hitrega znižanja morske gladine v vseh svetovnih morjih. To znižanje gladine naj bi bilo okrog 100 metrov, zaradi česar je območje Krasa postalo kopno (čeprav je bilo ponekod kopno, zaradi tektonskih vplivov, že prej). To je imelo različen vpliv na različne dele opisanega območja; odvisno od tega, ali so se sedimenti liburnijske formacije že odložili čez paleokras nad lipiško formacijo ali ne.

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The Sežana formation (K_2^{2-5})

Directly on the Repen formation lies grey micritic limestone with dessication pores; on some places horizons with up to three cm large oncoides, several metres in thickness, occur. Oncoides are spherical particles formed by assistance of microorganisms. In calm sea and lagoons above these layers the beds of olive grey dense limestones of the Sežana formation were deposited with occasional intratidal and even emersion properties as are, for example thin lenses of breccias and small black pebbles. In lithified carbonate mud one may find numerous microfossils (foraminifera, green skeleton algae, ostracoda, fragments of rudists and echinoderma; the most attractive is microfossil *Aeolisaccus kotori* which is not yet ranged in any known fossil group though it somewhere represents the only allochem component). From other particles the pellets are the most frequent. Occasionally the microorganisms of a deep sea were deposited into these sediments. At differing levels among these limestones local lenses of rudists and their fragments occur.

· The environment in which the described carbonates were deposited indicates the transition from lower subtidal, intratidal and even supratidal conditions towards upper subtidal conditions.

The Lipica formation ($K_2^{4,5}$)

The limestones of the following formation, called Lipica formation deposited in normal succession in respect to previous formation; they lie in the area between Dutovlje, Tomaj, Avber and Štorje and between Lipica and Divača. In time sequence the deposition of these limestones belong to upper part of the Lower Campanian, its upper boundary varies according to different regions.

The most typical of them is light thick-bedded to massive Lipica limestone, rich in rudists, in particular in their fragments. It was deposited in agitated sea in rather deeper subtidal environment where the broken pieces were carried from near rudist meadows. Due to thickness and favourable structure the rock is important for stonecutting and is exploited in the Lipica quarries.

In lee-ward parts the micritic limestones deposited; in them the fossils of foraminifera but also ostracoda and non-skeletal green algae prevail. That the environment was oxygen-poor is evidenced by dark colour of limestones, due to organic matters and tiny pyrite cubes. Somewhere these limestones have been dolomitised by a late diagenesis. Very interesting are layers of dark limestone with white dots that represent foraminifera - Keramospherinae (*Keramosphaerina tergestina* got its species name by Triest). This limestone was occasionally exposed to intratidal conditions, the dessication cracks providing evidence.

1. The limestone of Tomaj

In vicinity of Dutovlje, Tomaj, Dobravlje and Kazlje and in the Raša valley there are inside the Lipica formation thin-bedded, platy and laminated dark bituminous limestones, in lithology similar to Komen limestones. The Tomaj limestone is local development within the Lipica formation and occurs in form of inliers and packages disappearing laterally.

Among allochems the bioclasts prevail lying in micritic matrix. Among them there is the most of open sea microfossils, fragments of echinoderma and ostracoda and non-skeletal algae. In the rock a framboidale pyrite was noted (this is pyrite in a form of tiny globules) indicating the reduction conditions (the area where oxygen is lacking). Such conditions are also indicated by carbonised plant, fishes and ammonites (extinct group of Mollusca) remains. The Tomaj limestone contains bands or thin layers of chert nodules.

The subaerial exposure phase, probably tectonically controlled, caused the end of Lipica formation sedimentation. Karstification (paleokarst) took place under terrestrial conditions and in particular at the border of Materija lowland the bauxites developed. Somewhere the paleokarst features are distinctly displayed on paleokarstic surface topography. Breccias with bauxite-clay cement are typical of this relief. Somewhere the subsurface paleokarst appears in a form of filled up smaller caves. The fills are either bauxite clay or, elsewhere coarse grained calcite exhibits recrystallized flowstone. The youngest preserved rocks below the paleokarst surface are of different age in different places of Kras and Materija lowland. The interruption in sedimentation generated in each different area of Kras and Materija lowland different traces and lasted for variously long time. In general the sedimentation of shallow water limestones of Liburnian formation started in the Cretaceous, however elsewhere in the Palaeocene only. It should be emphasized, however, that in the top of the Maastrichtian a widespread marine regression occurred which diminished the proportion of sea relative to land on all the global oceans. The fall of the sea level should be for about 100 m, and thus the area of Kras became land (although, some areas had been affected by tectonic forces earlier and were already land). These changes differently affected different parts of the described area, depending whether the sediments of the Liburnain formation had already been deposited over paleokarst above Lipica formation or not.

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TERCIAR

Liburnijska formacija

Martin Knez

Pretežno karbonatne sedimente, ki nastopajo v jugozahodni Sloveniji in Istri med rudistnimi apnenci in apnenci z alveolinami ter numuliti, je imenoval G. Stache leta 1872 liburnijska stopnja ali protocen. To skladovnico kamnin je podrobno preiskoval med leti 1859 in 1889 ter jo takrat razdelil na tri dele: na spodnje foraminiferne (imperforatne) apnence, na kozinske plasti z vložki glavnega haracejskega apnenca in na zgornji imperforatni (miliolidni) apnenec.

Stachejeva razdelitev naj bi imela prvotno le facialni značaj, kar pomeni, da so bile v posamezne odseke združene tiste plasti apnenca, ki se je odlagal v približno enakih sedimentacijskih pogojih. Pozneje so liburnijsko stopnjo ovrednotili kot formacijo (R. Pavlovec & M. Pleničar. 1979). Liburnijska formacija (slika 1) naj bi bila kronolitološki pojem. To pomeni, da vključujemo v liburnijsko formacijo litološko in facialno plasti iz istega razvojnega cikla (od maastrichtija, ki je vrhnji del zgornje krede, do thanetija, ki je zgornji del spodnjega paleogena).

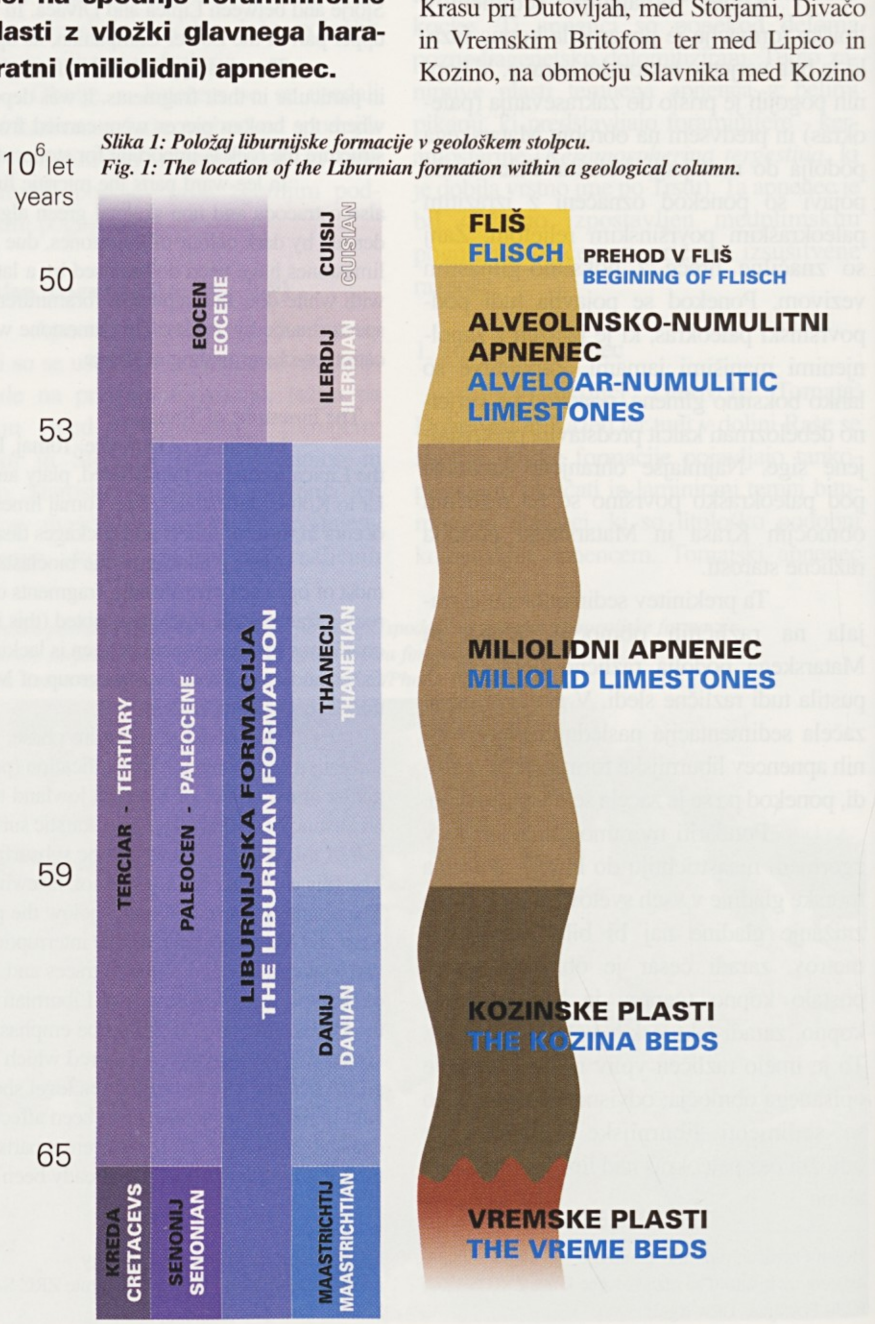
Plasti liburnijske formacije so različni avtorji uvrščali v kredo, v terciar ali spodnji del v kredo in zgornjega v terciar. Danes imenujemo spodnji del liburnijske formacije vremske plasti, ki so zgornjemaastrichtijske starosti, srednji del so danijske kozinske plasti, vrhnji del pa so miliolidni apnenci thanetijske starosti (R. Pavlovec & K. Drobne, 1991).

Meje treh delov liburnijske formacije so zaradi vertikalnega in horizontalnega prepletanja favne nestalne. To pomeni, da so istočasno na raznih krajih nastajali različni faciesi (videzi nasploh) ali da ponekod nekaterih delov liburnijske formacije sploh ni. V Istri in Dalmaciji ni vremskih plasti. Favna kozinske plasti pa se v Istri nekoliko razlikuje od značilnih oblik v južni Sloveniji.

Nastanek liburnijske formacije sovpada z laramijsko tektonsko fazo. S tem si lahko razložimo heterogenost ali neenotnost in hitro spreminjanje sedimentacijskih pogojev.

Klasična nahajališča liburnijske formacije so v jugozahodni Sloveniji na južnem krilu vipavske flišne kadunje, na Krasu pri Dutovljah, med Štorjami, Divačo in Vremskim Britofom ter med Lipico in Kozino, na območju Slavnika med Kozino

Slika 1: Položaj liburnijske formacije v geološkem stolpcu.
Fig. 1: The location of the Liburnian formation within a geological column.



Slika 2: V vremskih plasteh je eden izmed lepših fosilov Rhapydionina liburnica s pahljačasto oblikovano hišico.
Fig. 2: In the Vreme beds one of the nicests fossils Rhapydionina liburnica with fan-shaped test is found.

in Podgorjem ter na severovzhodnem krilu brkinske flišne kadunje.

Vremske plasti

Glede starosti vremskih plasti je bilo zelo veliko različnih mnenj. A. Stache jih je uvrstil v protocen, R. Schubert v danij (kreda), S. Vardabasso v eocen (paleocen) in C. D'Ambrosi v zgornjo kredo. M. Pleničar in B. Martinis imenujeta vremske plasti "apnenci z giroplevrami" in jim pripisujeta danijsko (kredno) starost. R. Pavlovec (1963) je vremskim plastem dal ime in jih uvrstil v spodnji del liburnijske formacije v danij (paleocen). Po G. Bignotu so vremske plasti senonijske starosti. Za danijsko starost se je opredelila tudi K. Drobne. R. Pavlovec in M. Pleničar trdita, da je meja med kredo in terciarjem nad vremskimi plastmi, M. Hözl in R. Pavlovec zagovarjata maastrichijsko starost plasti z giroplevrami. Podobno se opredeljujeta tudi R. Pavlovec in M. Pleničar. Ista avtorja sta prišla do sklepa, da so vremske plasti zgornjemaastrichtijske, kar še velja.

Vremske plasti sestavljajo predvsem temni drobnoplastnati, ponekod močno bituminozni apnenci, redkeje laporni apnenci in premogovi skrilavci ter vložki premoga. Med omenjenimi plastmi so najverjetneje tudi singenetske breče. V nekaterih horizontih so številne "hamidne školjke" (M. Pleničar, 1961) iz rodov *Gyropleura* in *Apricardia*, foraminifere (luknjičarke, ki imajo enocelično telo, obdano z enokamričnim ali večkamričnim skeletom) *Rhapydionina liburnica* (slika 2), *Montcharmontia appenninica* in miliolide.

Fosilni ostanki kažejo, da se je večji del vremskih plasti sedimentiral v plitvem morju, blizu obale in deloma v plitvih lagunah, ki so bile najverjetneje občasno omejene z rudistnimi biohermami (podvodni grebeni, ki niso bili zgrajeni iz koral, temveč so iz lupin školjk).

THE TERTIARY

The Liburnian formation

Martin Knez

Mostly carbonate sediments that occur in southwestern Slovenia and Istria between the rudist limestones and limestones with alveolines and nummulites, were named in 1872 by G. Stache Liburnain formation or Protocene. From 1859 to 1889 he studied in detail this rocks packed together and he subdivided them into three parts: lower foraminifera (imperforat) limestones, Kozina beds interbedded by principal haracea limestone and upper imperforat (milliolid) limestone.

At first Stache's division had a facies character only, that means, that only those layers of limestone that had approximately similar sedimentation conditions belonged to a single division. Only later the Liburnian stage was evaluated as a formation (Pavlovec & Plenièar 1979). The Liburnian formation (Fig. 1) should be applied in chronolithological term. It means that the Liburnian formation includes lithological properties and sedimentary facies (the sum total of features such as sedimentary structures) of all the similar layers within the same development cycle (from the Maastrichtian which is the top of the Upper Cretaceous to the Thanetian which is the upper part of the lower Palaeogene).

The layers of the Liburnian formation were determined variously by different authors, either to the Cretaceous and Tertiary, or its lower part to the Cretaceous and its upper part to the Tertiary. Today the lower part of the Liburnian formation is named Vreme beds ranged to the upper Maastrichtian, the central part are Danian Kozina beds and the upper part are milliolid limestones of the Thanetian age (Pavlovec & Drobne 1991).

The boundary of the three parts of the Liburnian formation is unstable due to vertical and horizontal fauna preplet moves. It means that contemporaneously at various places different facies occurred and that somewhere the Liburnian formation is missed. In Istria and Dalmatia there are no Vreme beds. The fauna of the Kozina beds slightly differs in Istria from the typical forms in southern Slovenia.

The Liburnian formation development corresponds to Laramide orogeny. This fact explains the heterogeneity and rapid changes in sedimentary environment.

Classical finding spots of the Liburnian formation are in southwestern Slovenia at the left limb of the Vipava flysch basin, in Kras near Dutovlje, between Štorje, Divača and Vremski Britof and between Lipica and Kozina, further on in the area of Slavnik between Kozina and Podgorje and at the northeastern limb of Brkini flysch basin.

The Vreme beds

A lot of differing opinions in respect to the age of Vreme beds existed. G. Stache ranged them to the "Protocene", R. Schubert to the Danian (the Cretaceous), S. Vardabasso to the Eocene (Palaeocene) and C. d'Ambrosi to the Upper Cretaceous. M. Plenièar and B. Martinis named Vreme beds "the limestones with Gyropleura" and range them to the Danian (the Cretaceous). R. Pavlovec (1963) who gave the name to these beds ranged them to the lower part of the Liburnian formation in the Danian (the Palaeocene). According to G. Bignot Vreme beds are of the Senonian age. Also K. Drobne opted for the Danian age. As R. Pavlovec and M. Pleničar stated that the boundary between the Cretaceous and the Tertiary lies above the Vreme beds, M. Hötzl and R. Pavlovec argued for the Maastrichtian age of the beds with Gyropleura. Similar are the conclusions of R. Pavlovec and M. Pleničar. The same authors came to the conclusion that Vreme beds are upper Maastrichtian and this holds true for now.

The Vreme beds consist mostly of dark thin-bedded, somewhere very bituminous limestones, rarely marl limestones and coal shales with coal inliers. Among the mentioned beds there are the most probably singenetic breccias also. In some horizons "hamide shells" (Pleničar 1961) of *Gyropleura* and *Apricardia genus*, foraminiferas (a unicellular animal of various forms ranging from a single, non-chambered flask-shaped animal to the complex chambered form) *Rhapydionina liburnica* (Fig. 2), *Montcharmontia appenninica* and Milliolids are common.

The fossil remains indicate that major part of the Vreme beds was deposited in shallow sea, close to the coast and partly in shallow lagoons which were the most probably occasionally dammed by rudist bioherms (a large reef knoll mostly build of shell debris and not corals).

Slika 3: V spodnjem delu kozinske plasti najdemo navadno le oogonije haracej.
Fig. 3: In the lower part of the Kozina beds usually only the oogonia of Haracea may be found.

Slika 4: Ponekod so v kozinskih plasteh s čistim kalcitom zapolnjeni polži zelo pogosti.
Fig. 4: At some places within the Kozina beds the snails filled with pure calcite are very common.

Slika 5: Fosilna združba v miliolidnih apnencih je izredno bogata.
Fig. 5: Fossil association within the milliolid limestones is very diversified.

Kozinske plasti

G. Stache je v skladovnici plasti, ki jo danes imenujemo liburnijska formacija, prvotno poznal samo njen srednji del, čeprav je ločil še spodnje in zgornjeforaminiferne apnence. Kozinske plasti je razdelil na stomatopsidne apnence (ime so dobili po polžih, ki so pogosti v teh plasteh) v nižjih in haracejske apnence (ime so dobili po ponekod izredno številnih algah v njih) v višjih nivojih. Pozneje (1889) je srednji del poimenoval po vasi Kozina kozinske plasti. Do danes se ime kozinske plasti ni več spreminjalo. M. Hamrla meni, da ne bi bilo primerno obdržati tega imena le za spodnji paleocenski del liburnijske formacije, temveč da bi ga razširili na vse bituminozne apnenčeve plasti s premogom, favno polžev (kozinij in stomatopsisov), haracej in drugih. Posebej značilen za kozinske plasti je (najverjetneje) fosilni ostanek *Microcodium elegans*, katerega poreklo še ni dokončno razjasnjeno.

M. Pleničar (1961) je spodnji terciar označil kot "zgornji del kozinske plasti" oziroma "glavni haracejski apnenec". Stachejev spodnji del kozinske plasti je M. Pleničar uvrstil v 17. (sladkovodni) in 18. (morski) horizont.

Nekateri avtorji, ko sta, na primer, G. Bignot in L. Grambast, ločijo v kozinskih plasteh dva stratigrafsko ločena nivoja s haracejami. V spodnjem delu so apnenci z oogoniji haracej (*Porochara stacheana*), v zgornjem apnenci z oogoniji haracej in z drugimi deli steljk (*Lagynophora liburnica*). Oboje navadno spremljajo polži, drobne foraminifere (*Discorbidae*) in *Microcodium elegans*.

Čeprav najdemo v spodnjem nivoju kozinskih plasti skoraj vedno samo oogonije (slika 3) iz rodu *Porochara*, jih v vznožju Slavnika dobimo skupaj z rodom *Lagynophora*.

Spodnji del kozinskih apnencev definirata J. Pavšič in M. Pleničar kot brečaste apnence z rodovoma *Microcodium* in *Discorbis*, s polži (slika 4) iz rodov *Stomatopsis* in *Cosinia*, z ostrakodi in s koralami. Mlajši del kozinske plasti pa obsega bituminozne apnence z miliolidami in haracejami.

Medtem, ko je G. Stache haracejske apnence uvrščal v paleocen, so jih italijanski raziskovalci šteli v eocen. Na podlagi haracej so nekateri predvidevali, da spadajo kozinske plasti v najstarejši paleocen ali v najmlajšo kredo. Danes uvrščamo kozinske apnence v danij.

Miliolidni apnenci

Miliolidni apnenci se po izredno bogati fosilni združbi miliolid (najpogostejše in najbolj razširjene luknjičarke v Zemljini zgodovini), koral, alg in drugih fosilov že makroskopsko ločijo od temnih apnencev, ki pripadajo kozinskim plastem (slika 5). Prav tako so miliolidni apnenci že na zunaj različni od alveolinsko-numulitnega apnenca, ki je nekoliko svetlejši in navadno bolj zrnat. V miliolidnih apnencih jugozahodne Slovenije so najpogostejši rodovi miliolid: *Idalina*, *Lacazina*, *Fabularia* in *Periloculina*. Posebno za oko lepo obliko imajo miliolide iz rodov: *Quinqueloculina*, *Triloculina* in *Coscinolina*. V te apnencih so še pogoste različne apnenčeve alge in navadno številni primerki iz družine *Textulariidae* (luknjičarke z eno kamrico ali z več kamricami v enem zavoju). Za dokaz thanetijske starosti poleg omenjenih fosilov raziskovalci omenjajo tudi dejstvo, da v teh plasteh ni numulitov, ki se pojavljajo šele v ilerdiju.

The Kozina beds

Probably G. Stache was acquainted within the layers known today as the Liburnian formation, only by its central part, although he distinguished the lower and upper foraminiferal limestones. He divided the Kozina beds to ?stomatopside limestones (the name is derived from snails very common in these beds) in lower levels and Haracea limestones (extremely numerous in algae) in higher levels. Later (1889) he named the central part after the Kozina village. Till now the name of the Kozina beds did not change. M. Hamrla thinks that it would be appropriate to maintain this name not only for the lower Paleocene part of the Liburnian formation but also for all the bituminous limestones containing coal, snails (Kozinij and stomatopsis), Haracea and others. In particular typical of the Kozina beds is (the most probably) fossil remain of Microcodium elegans; its origin is not yet definitely explained.

M. Pleničar (1961) denoted the lower Tertiary as "the upper part of Kozina beds" or "the main Haracea limestone". Stache's lower part of the Kozina beds M. Pleničar ranged to the 17th (fresh-water) and the 18th (sea-water) horizon.

Some authors, as for example G. Bognot and L. Grambast distinguish in the Kozina beds two stratigraphically different levels with Haracea. In lower part there are the limestones with oogonia of Haracea (*Porochara stacheana*) and in upper part limestones with oogonia of Haracea and other parts of steljk (*Lagynophora liburnica*). Common are snails, tiny foraminiferas (*Discorbidae*) and *Microcodium elegans*.

Although in the lower level of the Kozina beds the oogonia (Fig. 3) of the *Porochara* genus are almost always the only ones they are at the foot of Slavnik together with *Lagynophora* genus.

The lower part of the Kozina limestones is defined by J. Pavšić and M. Pleničar as breccia limestone consisting of *Microcodium* and *Discorbis genera*, of snails (Fig. 4) of *Stomatopsis* and *Cosinia* genera, Ostracods and corals. Younger part of the Kozina beds includes bituminous limestones with Milliolida and Haracea.

On one hand G. Stache ranges the Haracea limestones into the Palaeocene while the Italian researches to the Eocene. Based on Haracea some have presumed that the Kozina beds belong to the oldest Palaeocene or to the youngest Cretaceous. Today the Kozina limestones are ranged to the Danian.

Milliolid limestones

The milliolid limestones macroscopically differ from dark limestones that belong to the Kozina beds (Fig. 5). by extremely rich fossil association of milliolids (the most common and widespread animals in the Earth's history), corals, algae and other fossils. Also the milliolid limestones differ with unaided eye from the alveolar-nummulite limestones which is slightly lighter and usually granular. Within the milliolid limestones of the southwestern Slovenia the most common genera of milliolides are: *Idalina*, *Lacazina*, *Fabularia* and *Periloculina*. For appearance's sake very nice form is displayed by the milliolids of the genus: *Quinqueloculina*, *Triloculina* and *Coscinolina*. In these limestones various calcareous algae are common and also numerous specimens of the Textulariidae family (one or more-chambered form in one test?). The evidence for the Thanetian age is besides the mentioned fossils also the fact that there are no nummulites in these layers as they occur in the Ilerdian only.

Alveolar-nummulitic limestone

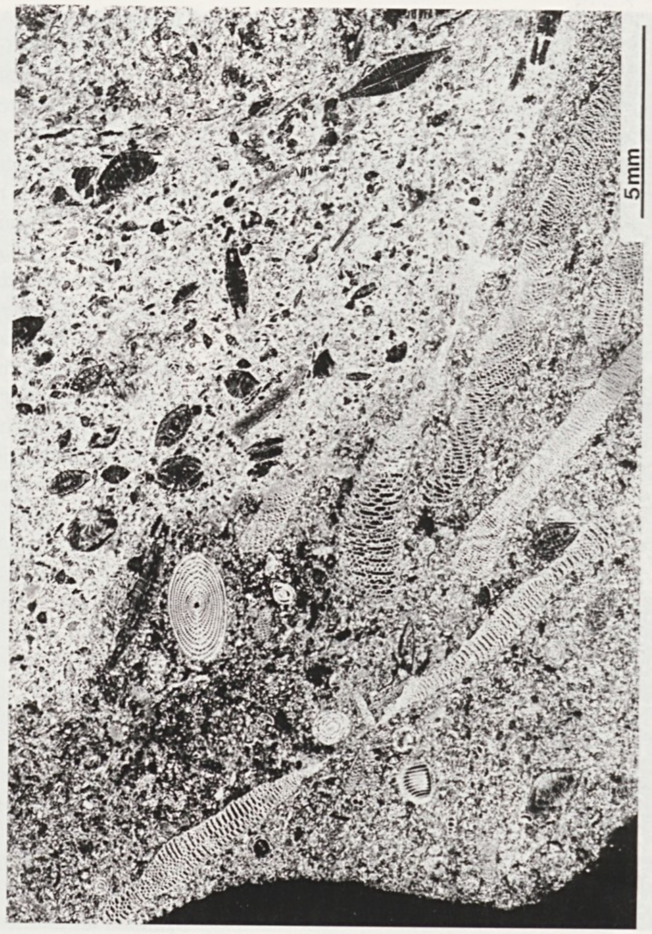
Within the samples of alveolar-nummulitic limestones overlain to the milliolid limestone there occur numerous nummulites, discociclina and operculina. All these fossils are discshaped and the largest attain even 20 cm in diameter. Further on there are numerous fragments of sea urchins, tiny milliolids and alveolars, naturally, that are ranged among milliolids (Figs. 6 and 7). The species *Operculina exiliformis Pavlovec* is typical of the Ilerdian limestones of the southwestern Slovenia.

In alveolar-nummulitic limestones the nummulites are frequently the most common fossil remains. However, usually nummulites, operculina and asilina are mixed and almost always all the three genera are present. Somewhere nummulites prevail, elsewhere operculina and thus some samples may be named nummulitic and other operculina limestones. Usually there are less of asilina.

Paleogeographic and paleoecological properties of the Liburnian formation and alveolar-nummulitic limestones

The layers of the Liburnian formation were deposited from the Maastrichtian until the Thanetian. M. Pleničar, A. Polšak and D. Šikić write in the commentary to the geological map that the region of the northern Littoral was involved in the Laramide folding at the end of the Cretaceous. The troughs so produced were invaded by sea in the Danian and in the Palaeocene. At the transition from the Cretaceous to the Tertiary the sea bottom uplifted and subsided several times.

Slika 6: Ponekod so alveoline tako pogoste, da bi alveolinsko-numulitne apnence lahko imenovali le alveolinske.
Fig. 6: Somewhere the alveolinas are so frequent that alveolar-nummulitic limestone could be named alveolar limestone.



Slika 7: Poleg numulitov in alveolin se tu in tam pojavljajo tudi diskasto oblikovani orbitoliti.
Fig. 7: Besides nummulites and alveolinas here and there disc-shaped orbitolites occur.

Slika 8: Fliš je klastična kamnina, sestavljena iz drobnih delcev kamnine ter ponekod tudi bolj ali manj pogostih hišic umrlih organizmov.
Fig. 8: Flysch is a clastic rock consisting of small rock particles and somewhere of more or less common shells of extinct organisms.

Alveolinsko-numulitni apnenci

V vzorcih alveolinsko-numulitnega apnenca, ki leži na miliolidnem apnencu, nastopajo številni numuliti, diskocikline in operkuline. Ti fosili so luknjičarke diskaste oblike, med katerimi največji dosežejo kakšnih 20 centimetrov premera. Nadalje so pogosti tudi odlomki morskih ježkov, navadno drobne milionide ter, seveda, alveoline, ki jih uvrščamo med miliolide (sliki 6 in 7). Vrsta *Operculina exiliformis Pavlovec* je značilna za ilerdijske apnence jugozahodne Slovenije.

A alveolinsko-numulitnem apnencu so numuliti zelo pogosto najštevilčnejši fosilni ostanki. Navadno pa so numuliti, operkuline in asiline pomešane in skoraj vedno so zastopani vsi trije rodovi. Ponekod prevladujejo numuliti, drugod operkuline, tako da bi nekatere vzorce lahko imenovali numuliti, druge pa operkulinski apnenec. Asilin je v vzorcih navadno manj.

Paleogeografske in paleoekološke značilnosti liburnijske formacije in alveolinsko-numulitnih apnencev

Plasti liburnijske formacije so nastajale od maastrichtija do thanetija. M. Pleničar, A. Polšak in D. Šikić v tolmaču geološke karte pišejo, da je prostor Slovenskega Primorja ob koncu krede zajelo laramijsko gubanje. V nastale sinklinale je v daniju in paleocenu vdrlo morje. Po D. Šikiću in M. Pleničarju so v tem delu pri koncu krede znaki splošnega dviganja ozemlja. Na prehodu krede v terciar pa se je morsko dno večkrat dvigalo in spuščalo.

Po sedimentaciji plasti z rudisti je sledila regresija, zaradi katere so v Sloveniji začele nastajati vremske plasti. V zgornjem senoniju so se nekateri deli Tržaško-Komenske planote dvignili iz morja. V senoniju in paleocenu so se pogosto menjavali morski, brakični in sladkovodni pogoji sedimentacije.

Sedimenti liburnijske formacije naj bi se po predstavah G. Stacheja usedali v bližini zelo razčlenjene obale. Morje naj bi bilo deloma brakično, med lagunami pa naj bi bili estuariji in ločena obalna jezera. Z upoštevanjem pojavljanja koskinolin in miliolid se nekateri avtorji bolj navdušujejo za epikontinentalni kot za 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 krajevnmimi kopninami. V morskih lagunah in deloma v sladkovodnih jezerih so se plasti liburnijske formacije usedale brez večjih vmesnih tektonskih premikov. Na koncu krede je prišlo sicer do dviganja, ki pa je imelo značaj epirogenetskih in ne orogenetskih procesov.

Pri določanju domnevno sladkovodnih plasti liburnijske formacije se je G. Stache opiral na polže, plasti premoga in haraceje. Za povže je R. Pavlovec izrazil dvom, da bi bili sladkovodni. M. Hamrla je prišel do sklepa, da so premogi nastajali tudi v limnično-brakičnem okolju. Nekateri mislijo, da so bili površinski in podzemni kraški pojavi v času odlaganja liburnijske formacije že dobro razviti in da zato ne moremo pričakovati številnih tekočih vodá, ki bi polnile obalna jezera.

Po tako imenovanih Nortonovih conah *Rhapydionina liburnica,* ki se v kamninah na krasu pojavlja v več horizontih in je najvažnejši fosil maastrichtijskih vremskih plasti, kaže, da je bila globina morja približno 9 metrov in temperatura morja od 21 do 30 stopinj C.

Vremske plasti so se najverjetneje odlagale na mirnem in plitvem ter zatišnem delu morskih plitvin, najpogosteje v bližini obal, z nizkim energijskim indeksom (1-2). Takšno okolje naj bi bilo enotno na širšem prostoru slovenskega dela Zunanjih Dinaridov.

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.

Karbonatna sedimentacija, katere rezultat je nastanek apnencev, se je po odložitvi alveolinsko-numulitnega apnenca v cuisiju, pred približno 50 milijoni leti, končala. Začelo se je odlaganje fliša in flišu podobnih sedimentov (slika 8). To so kamnine, v katerih se ciklično izmenjujejo laporji in peščenjaki; torej klastični sedimenti, ki so posledica orogenetskih procesov. Po odložitvi flišnih sedimentov se je morje iz jugozahodne Slovenije dokončno umaknilo in pokrajina je bila od tedaj vedno podobna današnjemu Krasu.

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After the rudist layers sedimentation the regression followed resulting in Slovenia by the Vreme beds. In the Upper Senonian some parts of the Trieste-Komen plateau uplifted from the sea. In the Senonian and Palaeocene sea-water, brackish and fresh-water conditions of sedimentation frequently alternated.

According to G. Stache the sediments of the Liburnian formation were deposited close to a very dissected coast. The sea is supposed to be partly brackish, among the lagoons should be estuaries and single basins. Considering the occurrence of Coscinolina and milliodia some authors prefer the epicontinental origin of the Liburnian beds from the continetal one.?

Breccias and bauxites of the Liburnian formation found on several places all over the Littorla indicate the sea regression resulting in shallow water with interlying land. In marine lagoons and partly in fresh-water lakes the layers of the Liburnian formation deposited without major tectonic displacements. At the end of the Cretaceous an uplift appeared having, however, the character of epirogenetic and not orogenetic process.

Determining the supposingly fresh-water beds of the Liburnian formation G. Stache based upon snails, coal layers and Haracea. R. Pavlovec, however, doubted that the snails could be fresh-water. M. Hamrla concluded that coals were deposited in limni-brackish environment. Some authors think that the superficial and underground karst features were well developed in the time of the Liburnian sedimentation and that one cannot expect flowing waters to fill the coastal basins.

According to so-called Norton's zones *Rhapydionina liburnica*, that occurs in several horizons of the karst rocks and is zone fossil of the Maastrichtian Vreme beds, indicates that the sea was about 9 m deep and the water temperature ranged from 21 to 31 **o** C.

The most probably the Vreme beds deposited in calm, shallow part of the sea shoals, near to the coast with low energy index (1 - 2). Such environment is supposed to exist in wider areas of the Slovene part of the Outer Dinarids.

According to modern researches the layers of the Liburnian formation are neither entirely sea nor fresh-water. Above the Vreme beds there are limestones with numerous Haracea. These limestones indicate the vicinity of fresh-water and brackish environment.

The sedimentation of the carbonates resulting in the development of limestones ended after the deposition of alveolar-nummulitic limestones in the Cusian, some 50 millions of years ago. The sedimentation of flysch and flysch similar deposits began (Fig. 8); these are rocks where marls and sandstones alternate cyclically, hence, clastic sediments due to orogenetic processes. After the flysch sediments were deposited sea has withdrawn from the southwestern Slovenia and the landscape since then resembles the present-day Kras.

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TEKTONSKA ZGRADBA MATIČNEGA Krasa

Stanka Šebela

V smislu geotektonske razdelitve Slovenije pripada matični Kras (slika 1) **jadransko-dinarski tektonski plošči in sicer območju Zunanjih Dinaridov. Kras je del manjše tektonske enote z imenom tržaško-komenski antiklinala. Ta je zgrajena iz več manjših antiklinal, to je nagibov skladov usedlin v zemeljski skorji, ki so se dvignili, in sinklinal, to je nagibov skladov takih usedlin, ki so se pogreznili. Imajo dinarsko smer gub. Gube tonejo proti severozahodu.**

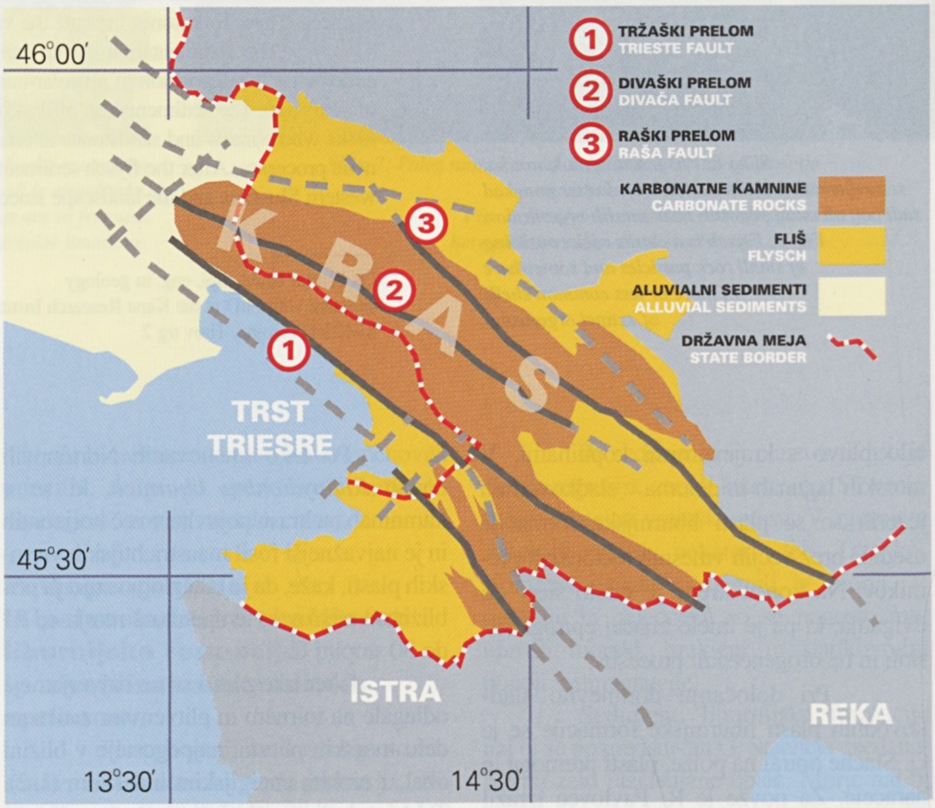
Zaradi gibanja jadransko-dinarske plošče (premikati se je začela v spodnji kredi, to je pred 135 do 97 milijoni leti) proti severu, kjer je trčila v evrazijsko ploščo, je prišlo do nastanka Vzhodnih Alp ter narivanja Severnih Apneniških Alp z juga proti severu. Zaradi rotacije ali sukanja jadransko-dinarske plošče v nasprotni smeri gibanja urinega kazalca, pri čemer je prav tako treščila v evrazijsko ploščo, je prišlo do dviga in nastanka Zahodnih Alp.

Pred 50 milijoni let sta evrazijska plošča in jadransko-dinarska plošča trčili. Pri stiku obeh plošč se je spodnji, prožnejši del litosfere ali kamnitega plašča Zemlje upognil in se začel pogrezati globoko v njeno notranjost, zgornji, krhki deli pa so se začeli luskati in narivati drug čez drugega. V terciarju (pred 65 milijoni let do 1,8 milijona let) in v kvartarju (pred 1,8 milijona let) se je tako podrinilo več kot 200 kilometrov celinske litosfere.

Ta proces nastajanja in dviganja gorskih verig se imenuje orogeneza in se je iz paleocena (pred 65 do 55 milijoni let) in eocena (pred 55 do 37 milijoni let) nadaljeval v miocenu (pred 22 do 5 milijoni let), policenu (pred 5 milijoni let do 1,8 milijona let) in kvartarju ter poteka še danes.

Konec krede je Slovensko Primorje zajelo laramijsko gubanje. Po obdobju regresije, to je umika morja, v paleocenu se je v eocenu začela trangresija, to je ponovno dvigovanje morske gladine, in odlaganje fliša. Konec eocena se je pričelo ilirsko dviganje in splošni umik morja.

Po odložitvi eocenskega fliša, to je v pirenejski fazi, so bile kamnine nagubane v smeri severozahod-jugovzhod. Pozneje so se gube deformirale z narivnimi, normalnimi in longitudinalnimi prelomi.



Slika 1: Strukturna skica Krasa
Fig.1: Structural sketch of Kras

O močnih tektonskih premikanjih lahko sklepamo na podlagi kamnin iz tega obdobja. Taka kamnina je fliš, ki nastaja v globljem morju. Ozemlje na severu Slovenije se je dvignilo nad morsko gladino prej, kot se je dvignilo njeno ozemlje na jugu. Fliš, ki je nastajal pri orogenetskih procesih na severu, je starejši od fliša na jugu.

Zaradi pritiskanja jadransko-dinarske plošče proti severu je nastalo regionalno napetostno polje z največjim vodoravnim pritiskom približno v smeri

Slika 2: Matični Kras med Divačo in Sežano (Foto: S. Šebela).
Fig.2: Classical Karst between Sežana and Divača (Photo: S. Šebela)

sever-jug in z natezno napetostjo v smeri vzhod-zahod.

Vodoravni strižni prelomi in prelomni sistemi so ena izmed skupin geoloških struktur, ki je nastala zaradi regionalnega napetostnega polja. Poleg tega so kot posledica tega regionalnega napetostnega stanja nastale tudi velike gube. Tako ločimo vsaj dve fazi tektonskega razvoja. V prvi fazi so nastale večje gube s spremljajočim sistemom razpok, v drugi fazi pa so nastopili vodoravni premiki vzdolž večjih prelomov, kot sta na Krasu raški prelom in divaški prelom, zaradi katerih so nastale sekundarne ali drugotne gube s smerjo severovzhod-jugozagod ter sistemi razpok.

V delu tržaško-komenske antiklinale sta najbolj izrazita dinarska preloma (severozahod-jugovzhod) ob Raši (raški prelom) ter med Divačo in Sežano (divaški prelom) (slika 2).

Ob raškem prelomu so apnenci tektonsko zdrobljeni v široki coni. Prelom ima kompleksno zgradbo. Na terenu se kaže kot globoka soteska reke Raše. Prelom ima delno narivni in delno vodoravni značaj. Od glavnega preloma se cepi več stranskih prelomov, ki se zopet združijo pa ponovno cepijo. Generalna smer vodoravnega gibanja kaže značilnost desnega zamika.

Raški prelom je imel, podobno kot ostali veliki longitudinalni prelomi v Zunanjih Dinaridih, v prvi fazi reverzen ali

TECTONIC STRUCTURE OF CLASSICAL KARST

Stanka Šebela

Referring to geotectonical classification of Slovenia, Classical Karst belongs (Fig. 1) to Adriatic-Dinaric tectonic plate, to the region of Outer Dinarids. Kras belongs to smaller tectonic unit called Triest-Komen anticline. It consists of several smaller anticlines and synclines with Dinaric trending folds striking towards NW.

Due to the Adriatic-Dinaric plate movements (displacement started in the Lower Cretaceous, it means 135 to 97 million years ago) towards north where it collided with the Euroasian plate the Eastern Alps came into existence and the Northern Limestone Alps were overthrusted from the south to the north. Due to rotation of Adriatic-Dinaric plate in anti-clockwise direction it also collided with the Euroasian plate and caused the uplifting and thus giving rise to the Western Alps.

50 million years ago the Euroasian and Adriatic-Dinaric plates collided. At the contact of both plates the lower, more flexible part of litosphere bended and drowned deep into the Earth interior while the upper, rigid parts in imbricate structure were thrusted one over the other. In the Tertiary (from 65 to 1.8 million years ago) and in the Quaternary (1.8 million years ago) more than 200 km of continental litosphere was drowned.

This process of origin and uplifting of mountain chains is called orogenesis and it continued from the Paleocene (65 to 55 million years ago) and Eocene (55 to 37 million years ago) to the Miocene (22 to 5 million years ago) and the Pliocene (5 to 1,8 million years ago) to the Quaternary and is still active at the present time.

In the Late Cretaceous the Slovene Littoral was influenced by a Laramide folding. After the regression (sea retreat) in the Palaeocene, the transgression (repeated sea level rise) and deposition of flysch started. At the end of the Eocene the Illyrian uplift and general sea regression followed.

nasproten značaj. Naslednja faza razvoja so bili procesi relaksacije, ko je prelom postal gravitacijski. Tretjo fazo predstavljajo vodoravna gibanja. Zaradi njih prihaja končno do rotacije ali vrtenja in premeščanja posameznih tektonskih blokov.

Divaški prelom pa poteka po smeri kamnin in pada strmo proti severovzhodu. Ob obeh straneh ga spremlja milonitna cona (kot moka zdrobljena kamnina) v apnencih in dolomitih. Divaški prelom ima v zahodnem delu narivni značaj, v vzhodnem delu pa ima gravitacijski značaj.

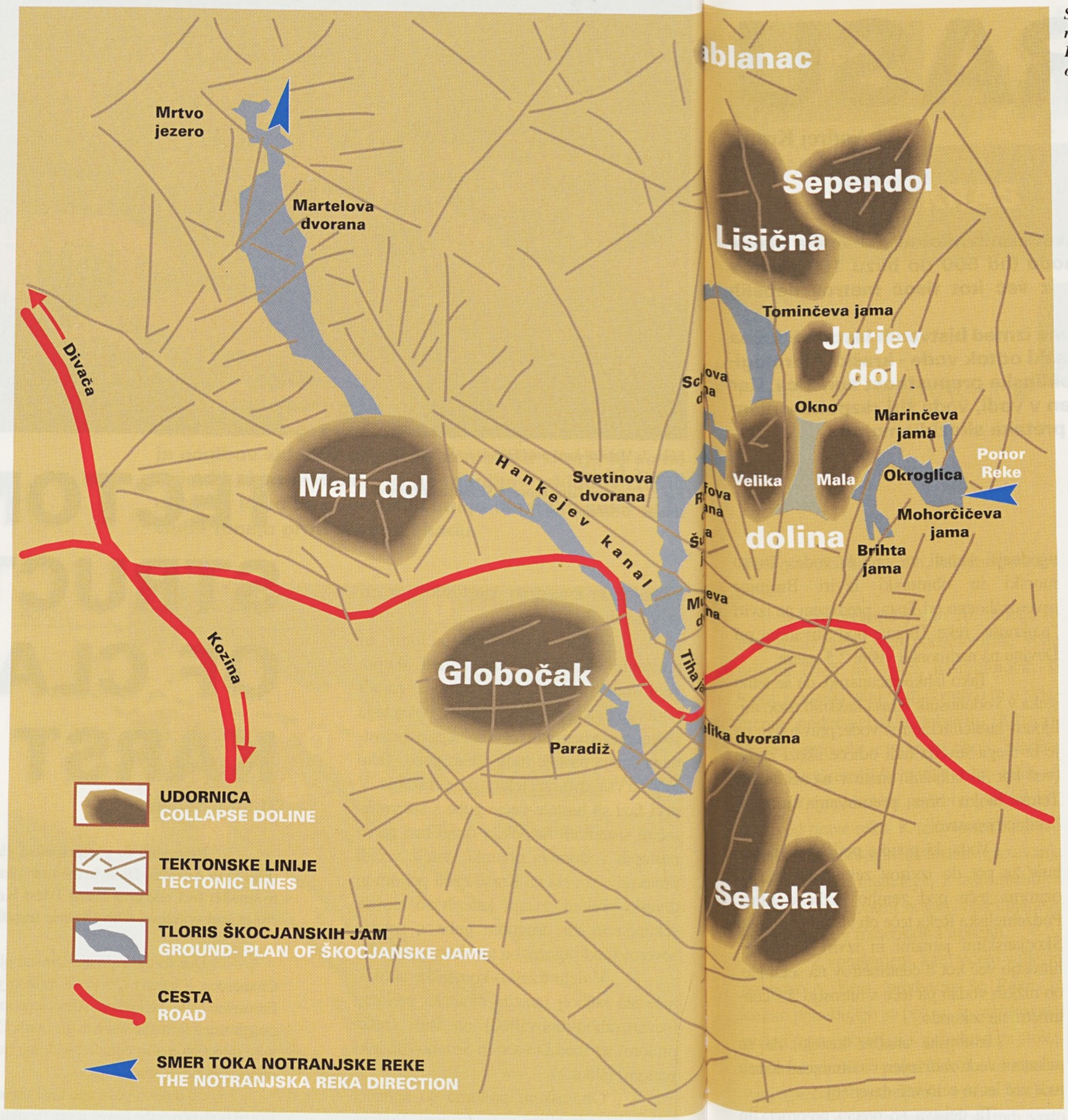
Geološka zgradba nad Škocjanskimi jamami, določena z letalskimi posnetki

Na površju nad Škocjanskimi jamami so karbonatne kamnine prelomljene v smereh severozahod-jugovzhod in severseverovzhod-jugjugozahod. Prelomi imajo zelo strme in valovite drsne ploskve pretežno zmičnega značaja. V geološkem smislu je to ozemlje močno tektonsko pretrto.

Za geologa, ki raziskuje teren, je pomembno čim več osnovnih informacij. Ena izmed metod, ki jih je mogoče opraviti še pred terenskim geološkim kartiranjem, je opazovanje letalskih posnetkov. Letalsko snemanje Slovenije opravlja Geodetski zavod Republike Slovenije. Večina uporabnikov uporablja posnetke v merilu 1:30.000. Z zrcalnim stereoskopom pregledujemo hkrati dva letalska posnetka istega terena. Na ta način dobimo njegovo reliefno podobo. S tem lahko ločimo morfološke stopnje terena, ki jih določa geološka struktura. Predhodna analiza terena s pomočjo letalskih posnetkov olajša geološko kartiranje na terenu, ker smo na določene izrazite morfološke stopnje bolj pozorni.

Izrazite tektonske linije, določene z interpretacijo ali razlago letalskih posnetkov, ki potekajo čez udornice, kot so, na primer, Mala in Velika dolina, Sapendol, Sekelak (slika 3), imajo generalno smer sever-jug, oziroma severseverovzhod-jugjugozahod. Drugo izrazito smer predstavljajo tektonske deformacije v dinarski smeri severozahod-jugovzhod, ki je izrazita v severnem in južnem deli terena.

Največ tektonskih deformacij (16%) je v smeri 285-300 kotnih stopinj. Na drugem mestu (11%) so tektonske deformacije v smeri 300-315 kotnih stopinj. Če združimo prvo in drugo skupino v enotno smer v razponu 285-315 kotnih stopinj, odpade na to smer 27 odstotkov vseh meritev, ki predstavljajo dinarsko usmerjene (severozahodne-jugovzhodne) deformacije.



Slika 3: Interpretacija tektonskih con površja nad Škocjanskimi jamami s pomočjo letalskih posnetkov
Fig.3: Aerophoto interpretation of tectonic zones of the surface above Škocjanske jame

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When in the Pyrennean phase the Eocene flysch was deposited the rocks were folded in NW-SE direction. Later the folds were deformed by thrust, normal or longitudinal faults.

Severe tectonic displacements are evidenced in the rocks of this period. Such rock is flysch which originated in a deep sea. The area to the north of Slovenia uplifted above the sea level earlier than the one to the south. Consequently, flysch due to orogenetic processes in the north is older than flysch in the south.

Due to pressure of the Adriatic-Dinaric plate towards north a regional tension field with the highest pressure state in the axis north-south and tension strain east-west occurred.

Horizontal strike-slip faults and fault systems make part of geological structure groups due to regional tension field. As a result of this regional tension field large folds have arisen. Thus at least two phases of tectonic development may be distinguished. Larger folds with associated system of fissures are due to the first phase and horizontal displacements along important faults, in Kras these are Raša and Divača faults, where secondary folds trending NE-SW and fissure systems developed, are due to the second phase.

In a part of Triest-Komen anticline the Dinaric faults (NE-SW) along Raša (Raša fault) and between Divača and Sežana (Divača fault) are the most prominent (Fig. 2).

Along Raša fault the limestones are tectonically crushed within a wide zone. The composition of the fault is complex. In the field it is denoted as a deep canyon of the Raša river. The character of fault is partly thrusted and partly horizontal. From the main fault several lateral faults fork and join again and fork again. General trending of horizontal movement indicates the properties of the right wrench-fault.

Similar as other large longitudinal faults in Outer Dinarids also the Raša fault had in its first phase reverse character. The following development phase were processes of relaxation when the fault became gravitational. The third phase is presented by horizontal movements due to final rotation and displacement of single tectonic blocks.

The Divaèa fault follows the rock trending and strikes steeply towards NE. On both sides it is accompanied by millonite zone (rock crushed into flour) in limestones and dolomites. The Divača fault is displays thrusting in the western part and is gravitational in the eastern part.

Aerophoto interpretation of geologic structure above Škocjanske jame

On the surface above Škocjanske jame the carbonate rocks are broken and trending NW-SE and NNE-SSW. Sliding planes are very steep and ondulated of mostly wrench-fault character. In geological sense this area is strongly tectonically crushed.

A geologist, mapping the terrain needs a lot of basic informations. One of the methods which may help before geologic field mapping is stereoscopic observing of aerophoto images. The filming in Slovenia is done by Geological Survey of Slovenia. Most of users use the images on the scale 1:30.000. By the device called mirror stereoscope, two aerophoto images of the same terrain may be observed simultaneously. Thus one gets the relief presentation of the terrain. The morphological stages controlled by geological structure may be discerned. By previous aerophoto interpretation of the terrain geological mapping in the field is easier due to special attention given to morphological steps seen on the images already.

Prominent tectonic lines determined by aerophoto interpretation run over the collapse dolines, as for example Mala and Velika Dolina, Sapendol, Sekelak (Fig. 3) and have a general trending N-S, or NNE-SSW. The second general trending are tectonic deformations in the Dinaric trending NW-SE which is very prominent in the northern and southern part of the area.

The most of tectonic deformations (16%) are found in the direction 285-300^0. The second place (11%) take the deformations in the direction 300-315^0. If we join the first and the second group into uniform direction ranging from 285^0 to 315^0, 27% of all the measurements correspond to this direction and represent the Dinaric (NW-SE) trending deformations.

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Voda na KRASU

Andrej Kranjc

Kras je kakšnih 500 kvadratnih kilometrov velika planota, nagnjena proti severozahodu (od 500 do blizu 100 metrov nadmorske višine), zgrajena iz več kot tisoč metrov debelih skladov apnenca.

Kot je že zapisano, je ena izmed bistvenih lastnosti krasa tudi podzemeljski oziroma kraški odtok vode - kraška hidrologija. Prvotni vzrok zanj je razpoklinska prepustnost apnenca. Ker je apnenec tudi relativno topen v vodi, voda širi razpoke v njem in se še lažje oziroma hitreje pretaka skozi kamnino.

Ob predpostavki, da je na Krasu kakšnih 1200 milimetrov padavin letno, pomeni, da pade nanj okrog 600 milijonov kubičnih metrov vode letno. Vsa ta voda, razen tiste, ki izhlapi, in tiste, ki jo porabijo rastline (to imenujemo s tujko evapotranspiracija), ponikne v kraško notranjost. Tudi če bi za evapotranspiracijo predpostavili 50 % na površju zadržane vode, ostane še vedno velika količina vode - 300 milijonov kubičnih metrov (Za lažjo predstavo naj povem, da je skupna prostornina zadrževalnikov Klivnik in Molja na pritokih Reke 4 milijone kubičnih metrov vode!).

Na Krasu ni niti enega površinskega toka, zato vsa ta voda, ki ponika vanj, od določene globine navzdol (ta je odvisna od letnega časa oziroma od splošnega stanja vode) zapolnjuje vse votline, kanale in razpoke v apnencu. Taki kamninski masi ali gmoti, v kateri se zadržujejo velike količine vode, pravimo kraški vodonosnik. Voda se seveda ne more le nabirati v vodonosniku, saj bi bil hitro poln, ampak na robovih in najnižjih mestih odteka iz njega v obliki kraških izvirov.

Od razpokanosti in zakraselosti ter razvitosti podzemeljskih kanalov je odvisno, kako hitro se voda v vodonosniku "zamenja", koliko časa potrebuje padavinska voda od takrat, ko je padla na zemljo, do takrat, ko priteče skozi izvir spet na površje. Danes vemo, da so v razvitih vodonosnikih vodilni kanali, po katerih voda zelo hitro teče, v stranskih sistemih in špranjah pa se lahko zadržuje tudi stoletja.

Seveda pa se v Krasu ne zbira le površinska voda. Do roba Krasa pritekajo tudi površinski tokovi iz sosedstva, nato pa skozi požiralnike ali ponorne jame ponikajo v kraško notranjost. Pri tem ne gre le za manjše tokove, ampak gre tudi za razmeroma velike reke. Najbolj znana je gotovo Reka, ki zbira svoje vode iz precejšnjega dela kraškega pogorja Snežnika, s flišnih (vododržnih) Brkinov in z dela Košanske doline. Nekaj kilometrov po prestopu na apnence teče po soteski, dokler v Škocjanskih jamah končno ne izgine pod zemljo. Njen povprečni pretok je 8 kubičnih metrov na sekundo, največji pretok pa preseže 300 kubičnih metrov na sekundo!

S flišnega površja zatekajo v Kras še vode z manjšega dela Pivške kotline (Sajevški potok), iz Košanske doline, Senožeški potok in Raša z vipavskega fliša. V Kras odteka tudi del voda reke Vipave (do 1 kubični meter na sekundo) skozi požiralnike v strugi pod Mirnom. Čeprav je Kras višji od Furlanske nižine in se kot planota dviga nad njo, se vseeno dogaja, da se občasno talna voda iz soške prodne naplavine pretaka v vodonosnik Krasa.

Podzemeljska voda v Krasu, med ponori in izviri, je človeku dostopna v nekaterih globljih jamah, kot sta Kačna jama in Labodnica.

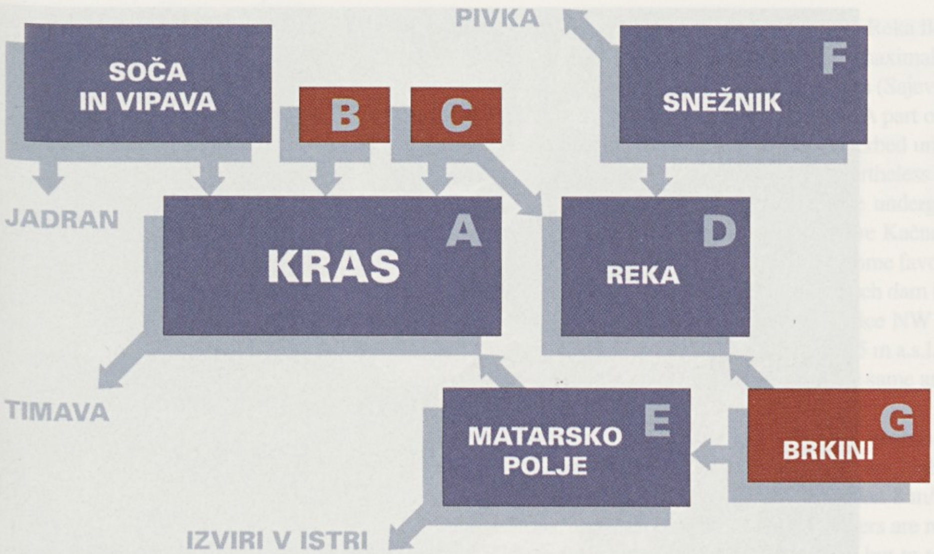
Iztok izpod Krasa je osredotočen na nekaj najugodnejših mest, kjer so se razvili zelo pomembni kraški izviri; bodisi na mestih, kjer je nepropustna flišna pregrada najnižja, bodisi na mestih, kjer so najugodnejši kanali za pretok vode. To so morski in obmorski izviri Brojnice severozahodno od Trsta, predvsem pa izviri "najkrajše" reke Timave pod Štivanom pri Devinu na nadmorski višini 2,5 metra.

Tako lahko računamo, da se letno steka v vodonosnik Krasa kakšnih tisoč milijonov kubičnih metrov vode, prav toliko pa je iz njega seveda tudi odteče skozi izvire (več kot 30 kubičnih metrov na sekundo). Temu lahko brez pretiravanja rečemo "vodno bogastvo".

Voda, ki ponika pod Kras, potrebuje za pot do izvirov zelo različen čas, oziroma teče pod zemljo različno hitro. Podzemeljska Reka teče ob visoki vodi med Škocjanskimi jamami in izviri Timave s hitrostjo več kot 8 centimetrov na sekundo, ob nizkih vodah pa teče s hitrostjo 2,5 centimetra na sekundo.

Izotopske analize kažejo, da se nekatera voda zadržujen v notranjosti Krasa tudi več let in celo več desetletij.

Ta dejstva so precej preprosta in lahko razumljiva. Da pa so jih ljudje spoznali oziroma prišli do teh spoznanj, je trajalo stoletja. Že antični avtorji so domnevali, da so Reka in izviri Timave v tesni povezavi. Prvi naj bi to zapisal Pozejdon Apamejski: "Reka Timav priteka z gora, pada v brezna in potem, kot teče pod zemljo približno 130 stadijev (starogrška dolžinska mera 1 stadium je okrog 200 metrov - op. ur.), izvira ob morju". Oče Imperato je leta



Shematični prikaz hidrografskih enot Primorskega krasa - modri paralelogram predstavlja kraški vodonosnik, rdeči paralelogram predstavlja porečje na neprepustnem svetu, puščice kažejo splošno smer vodnega odtoka, B označuje porečje Raše in C označuje porečje Sajevškega potoka.

Draft review of hydrographic units of Littoral Karst - the blue parallelogram indicates karst aquifer, the red one the water basin on impermeable landscape, the arrows indicate general direction of water flow, B is the Raša river basin, C is the Sajevški potok river basin.

1599 poskušal to potrditi, žal neuspešno, s plovci.

Na prelomu 19. in 20. stoletja so intenzivno raziskovali podzemeljske vode pristaši dveh na videz nasprotujočih si teorij: o kraški talni vodi (Grund) in o sklenjenih podzemeljskih tokovih (Katzer). Danes vemo, da je v krasu oboje, gladina (stalne) podzemeljske vode (stalno zalita ali freatična cona) in hitri podzemeljski tokovi, ponekod prave reke. K tem spoznanjem so bistveno pripomogla natančna opazovanja in preučevanja majhnega, z inštrumenti in merilnimi napravami bogato opremljenega vodonosnika v francoskih Pirenejih.

Z vprašanjem, kam tečejo vode, ki ponikajo v Kras, predvsem še Reka, in koliko potrebujejo za pot, so se raziskovalci pričeli resno ukvarjati v začetku tega stoletja. Za raziskave so poleg hidroloških opazovanj (pretoki, spremljanje vodne gladine, opazovanje padavin) uporabljali tudi vrsto sledilnih metod: s pomočjo jegulj, soli in barvil. V najnovejšem času je bil velik poudarek na izotopskih analizah (zvrsti istega elementa, katerih atomi se razlikujejo po masi jeder). Tudi slovenski raziskovalci so opravili več sledenj (Reke, Raše, Vipave) in s tem bistveno pripomogli k poznavanju hidrologije Krasa, s tem pa tudi k poznavanju kraških vodonosnikov nasploh.

WATER IN KRAS

Andrej Kranjc

Kras, about 500 km2 large plateau, inclined towards NW (from 550 to about 100 m a.s.l.), consists of more than 1000 thick layers of limestone.

As it was said, one of the basic properties of karst is subterranean, karst water drainage - karst hydrology. The main reason lies in permeability of a rock to transmit water. Permeability may be primary, due to the effects of interlinked porosity or open tectonic fractures, or secondary, due to the dissolutional enlargement of fissures developing cavernous or conduit permeability.

Supposing that in Kras the average annual precipitation amounts to about 1200 mm it means that about 600 millions of m^3 of water fall on it. All this water, with exception of amount that evaporates and the amount used by plants (this is called evapotranspiration) sinks into karst interior. Even if we take for evapotranspiration 50% of water a huge amount still remains - 300 millions of m^3 (for better understanding let me tell that the total volume of the water reservoirs Klivnik and Molja placed on the tributaries of Reka, contain 4 millions of m^3 of water).

There is not any superficial stream in Kras and thus all this water disappearing into it, fills from a certain depth (it depends on season and general water table) all the cavities, channels and fissures within the limestone. The rock mass where this huge amount of water is stored, is called karst aquifer. Obviously the water does not only accumulate in the aquifer, it would be sooner or later filled up, but it outlfows on the borders and at the lowest places through the karst springs. The degree of fissures and karstification in general development controls the time required by water to "exchange" within the aquifer, it means, how long the rainwater needs since it touches the ground to reappear in the karst spring. Today we know that within the aquifers there are main conduits through which water flows very fast while it may be for centuries retained in lateral systems and fissures.

Of course, most groundwater is of meteoric origin but also superficial streams reach the karst border from the impermeable landscape and disappear through swallow-holes and influent caves into a karst interior. These are not only small streams but relatively large rivers also. The most famous is without doubt Reka where the waters from major part of Snežnik karst massif and flysch (water impermeable) Brkini and a part of Košana Valley are gathered.

Tako velike količine vode, kot so v podzemlju Krasa, so za človeka zelo pomembne. Zato ni čudno, če jo že od nekdaj izkoriščа. V antiki so izviri Timave sloveli kot najprimernejši za oskrbo ladij z vodo. Danes so izviri Brojnice in Timave zajeti za tržaški vodovod, pod Brestovico (Klariči) pa je črpališče Kraškega vodovoda Sežana. Vodo črpajo iz stalno zalite (freatične) cone z morske ravni. Nihanja v količini in kakovosti so v freatični coni manjša; voda je bolje zaščitena pred neposrednim onesnaženjem. Če pa bi vendarle onesnažili to vodo, ki je v največjih globinah Krasa in ki nima neposrednega stika s površjem, bi lahko govorili o katastrofi.

Izviri, ki jih izkorišča Trst, so tesneje povezani s hitrejšimi podzemeljskimi tokovi in z Reko, zato se njihove lastnosti, tudi onesnaženost, spreminjajo glede na stanje Reke. To je bil tudi vzrok za številne italijanske pritožbe, ko je bila zaradi ilirskobistriške industrije Reka močno onesnažena. Zato je precej predlogov za projekte, tudi medregijske, ki vključujejo zaščito in sanacijo oziroma ozdravitev vsega Krasa.

Voda izpod Krasa je vedno bolj cenjena in potrebna, zato postaja vse bolj pereče vprašanje o njenem varovanju in ohranjanju. Hujše onesnaženje Reke se hitro zazna v izvirih Timave. Kaj se zgodi z onesnaženo vodo, ki vteka v globlje dele vodonosnika Krasa in ne priteče neposredno ter hitro v kraške izvire, moremo zaenkrat le ugibati. Postavlja se vrsta vprašanj. Ali se snovi, ki vodo onesnažujejo, z leti usedajo, reagirajo druga z drugo ali z drugimi snovmi in se spreminjajo, ali ostajajo nespremenjene v vodi? Kaj bo, če se bo koncentracija onesnaženja v freatični coni močneje povečala? Kaj najbolj onesnažuje vodo v globoki coni kraškega vodonosnika - ali industrijske odplake, kemikalije v kmetijstvu, komunalne in gospodinjske odplake ali promet?

Kar nekaj raziskav je usmerjenih v ta vprašanja; nekaj je tudi že znanih odgovorov. Pogosto pa se ob eni rešitvi pojavi več novih vprašanj.

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Some kilometers after reaching the limestones, the Reka flows in a canyon until it finally disappears into Škocjanske jame. The average discharge is 8 m^3/s, its maximal discharge surpasses 300 m^3/s. From the flysch surface also the waters from smaller part of Pivka basin (Sajevški Potok), from Košana Valley and Senožeški Potok and Raša from the Vipava flysch drain into Kras. A part of waters of the Vipava river (up to 1 m^3/s) flow into Kras as well through the swallow-holes in the riverbed under Miren. Although Kras is higher than the nearby Friuli Plain and rises above it as a plateau, it nevertheless happens that seasonally the groundwater from Soèa gravel alluvium drains through Kras aquifer. The underground water in Kras, between a swallow-hole and spring, is accessible in some deep caves only, as are Kačna Jama and Labodnica (Grotta di Trebiciano).

Outflow from Kras is concentrated on some favourable spots only where very important karst springs occur, either on places where the impermeable flysch dam is the lowest or there where the most favourable conduits for water exist. These are sea-springs Brojnice NW of Triest and specially the springs of the "shortest" River Timavo below Štivan at Devin (Duino) at 2.5 m a.s.l. Thus one may reckon that annually about 1000 millions of m^3 of water flow into Kras aquifer and the same amount outflows through the karst springs (more than 30 m^3/s). This may well be called "water wealth".

The water sinking below Kras, requires various amount of time to reach the springs; it flows underground with various velocities. When the waters are high the underground Reka flows between Škocjanske jame and Timavo springs with velocity of more than 8 m/s, when the waters are low the velocity decreases to 2,5 cm/s. Isotopic analyses indicate that some waters are retained inside karst for more years, decades even.

These facts are rather simple and clear but to take them in required centuries. The antique authors already supposed that Reka and Timavo springs were closely connected. The first to write it down is supposed to be Poseidonius from Apameia: "A river, the Timavus, runs out of the mountains, fall down into a chasm, and then, after running underground about a hundred and thirty stadia, makes its exit near the sea". Father F. Imperato in 1559 tried to confirm it, unfortunately without success, usig the floats.

At the turn of the century to the 20th century the underground waters were intensively studied by adherents of two, apparently contradictory theories: the first argued that ground water in karst terrain is regionally interconnected and ultimately controlled by sea level (Grund) and the second interpreted karst as consisiting of shallow and deep types, imagining water circulation to occur in essentially independent river metworks (Katzer). Today we know that both exist within karst, the water level of (permanent) underground water (water-filled or phreatic zone) and fast underground flows, true rivers somewhere. An important contribution to this knowledge was given by detailed studies and observations of small aquifer in French Pyrenees, well equipped by the instruments and measurement devices.

By the beginning of this century the researchers seriously approached to the questions where flows the water disappearing in Kras, Reka in particular and how long does it take to reappear in the spring. For their researches they used not only hydrological observations (discharge, observations of water level, measurements of rainfall) but also a series of tracing methods, by eels, salts and dyes. However, in the last time, great stress is laid upon the isotopic analyses (varieties of an element, identical in properties but differing in atomic weight). Slovene researchers also carried out several tracing tests (Reka, Raša, Vipava) and thus essentially contributed to understand the Kras hydrology and karst aquifers in general.

These large amount of water, found in the Kras underground, is very important for man and no wonder if it is exploited since ever. In antiquity the Timavo springs were renowned for being the most suitable for ships water-supply. Today the springs of Brojnica and Timavo are captured for Trieste water supply, below Brestovica (Klariči) there is a pumping station of Sežana water supply, named Kraški vodovod. The water is dipped out of permanently water-filled (phreatic) zone at the sea level. Fluctuations of yield and quality are smaller within a phreatic zone, the water is better protected against direct pollution. But, if the water in the deepest parts of Kras without direct contact with surface is once polluted, one could speak about a catastrophe.

The springs exploited by Triest are more tightly connected with fast underground streams and with the Reka, this is why their properties as well as pollution change concordantly to Reka conditions. Here lies the reason for numerous Italian complaints, when the Reka was very polluted due to Ilirska Bistrica industry. There are many proposals of projects, interregional also, including the protection and sanitation of the entire Kras.

The water from Kras is more and more valued and needed and thus the question of its protection and safeguarding is more and more urgent. Each pollution of Reka is felt at the Timavo springs. But what would happen to polluted water that drains into deeper parts of the Kras aquifer and does not reach the karst springs directly, we can only guess. A lot of questions arise: Do the substances that pollute water sediment during the years, maybe they react with each other or other substances and change, or do they remain unchanged in the water? What will happen if the concentration of pollution in the phreatic zone increases? Which pollutants are the most dangerous to water in deep phreatic zone of Kras - industrial wastes, chemicals used in agriculture, communal or household waste waters, traffic?

Several researches are directed to solve these questions, some answers are known, but frequently one solution opens a lot of new questions.

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MORFOLOGIJA Krasa

Andrej Mihevc

Obenem z uveljavljanjem besede "kras" kot mednarodnega znanstvenega termina so se uveljavili tudi izrazi "dolina", "polje" in drugi z dinarskega krasa. Svet s posebnimi reliefnimi, vodnimi in podzemnimi pojavi, ki so nastali v dolgih geoloških dobah na vodotopnih kamninah, predvsem na apnencu in dolomitu, danes imenujemo k r a s. V Republiki Sloveniji je vsega skupaj 8.780 kvadratnih kilometrov ali 43 odstotkov celotne površine kraške.

Topnost karbonatnih kamnin, njihova prepustnost, tanek in nesklenjen pokrov prsti in velike količine vode so glavni dejavniki zakrasevanja. Zelo pomemben je tudi način odtekanja vode. Če voda hitro odteče, ne utegne porabiti vse svoje korozijske ali razjedalne moči. Močnejše raztapljanje kamnin je tam, kjer voda prenika skozi prst in se iz nje počasi izceja. Intenzivnost ali izdatnost korozije je odvisna tudi od lastnosti kraške kamnine, zlasti od njene plastovitosti in tektonske pretrtosti. Vsi ti dejavniki na svojstven način usmerjajo in kontrolirajo korozijsko delovanje vode, katerega končni učinek je tudi oblikovanje kraškega površja.

Raztapljanje kraških kamnin je najmočnejše na površju oziroma nekaj metrov pod njim, vendar ohranja voda svojo korozijsko sposobnost še dolgo časa. Na goli površini apnenca nastajajo drobne korozijske razjede različnih velikosti, zaradi katerih je takó razjedeno površje skale neravno in hrapavo. Pomemben dejavnik pri njihovem nastanku je sama kamnina: plastovitost, tektonska prepokanost ter fizikalne in kemične lastnosti kamnine. Nekatere izmed korozijskih oblik so tako pravilne in pogoste, da so dobile posebna imena, in ker vemo, v kakšnih okoliščinah so nastale, nam lahko pomagajo pri spoznavanju sprememb na krasu.

Udornica Risnik pri Divači je nastala s počasnim udiranjem stropa nad večjimi votlinami, ki jih je oblikovala podzemna Reka. Risnik je globok 80 metrov in ima prostornino okrog 1,4 milijona m^3
Collapse doline Risnik near Divača developed by slow roof subsidence above larger spaces that had been formed by the underground Reka river. Risnik is 80 m deep, its volume is 1,4 mill. of m^3.

Značilne in pogoste oblike na krasu so škavnice. To so okrogle, podolgovate ali nepravilne vdolbine v skali z izrazitim ravnim dnom ter pogosto z nekoliko izpodjedenimi stenami. Velike so od nekaj centimetrov do enega metra. Nastajajo na mestih, kjer se zaradi majhnega strmca zadržuje voda dlje časa. Tam nastanejo majhne vdolbinice, v katerih stoji voda, ki ima dovolj časa za raztapljanje apnenca. Ker je raztapljanje najmočnejše na stiku površine vode s skalo, se škavnice bočno širijo ter manj poglabljajo. Raztapljanje apnenca pospešujejo še biološki procesi, predvsem razgrajevanje organskih snovi, pri čemer nastajajo organske kisline. Voda iz škavnic odteka - to so odprte škavnice, ali pa izhlapeva. Ko voda izhlapi, se raztopljeni kalcit iz raztopine obori, izloči, veter pa kalcitove kristale odpihne... Pogosto so pastirji na krasu škavnice umetno zajezovali, da so tako dobili vodo za napajanje živine.

Nekoliko so škavnicam podobne korozijske stopničke. To so oblike z jasno izraženim strmim polkrožnim obodom in z ravnim dnom, ki pa je na eni strani navzdol odprto; ponavadi v naslednjo stopničko. Ponavadi so od 10 do 30 centimetrov velike.

Značilna oblika razjed so drobni vzporedni ali večji, žlebovom podobni žlebiči. Oblikuje jih padavinska voda, ki odteka po razgaljenem kamnitem površju v smeri največjega strmca. Na grebenih na najvišjih delih skale nastajajo mikrožlebiči. Široki so od enega do treh centimetrov. Navzdol se znižujejo in izgubijo, ponavadi v plosko, nerazčlenjeno površje. Tod je korozija ploskovna, saj se voda razliva, njen spodni sloj, ki je v stiku s kamnino, se zasiti in ne razjeda več. Ker mešanja med sloji vode ni, se korozijski proces ustavi oziroma

Mikrožlebiči in škavnice so značilna korozijska oblika na izpostavljenih skalnih površinah Krasa.
Micro-lapis and kamenitzas are typical solution forms on exposed rocky surfaces of Karst.

napada le izbočene dele površja ter tako izravnava in ohranja nerazčlenjeno površje.

Večji so žlebiči, ki se prično pod cono ploskovnega zniževanja površja ter potekajo v smeri največjega strmca. Poglabljanje žlebičev se začne zaradi združevanja ploskovno tekoče vode v stržen njenega toka. Tam je hitrost njenega toka največja, zato prihaja do vodnih turbulenc ali vrtinčenj in do mešanja slojev, da korozija sega do dna sloja tekoče vode ter začne poglabljati žlebič. Na goli skali imajo ti žlebiči ostre robove ter ozko dno. Če so se oblikovali pod pokrovom prsti, ki je bila pozneje odstranjena, so v prerezu bolj zaobljeni. Kanali se navzdol povečujejo. Široki so od treh do tridesetih centimetrov, dolgi pa so tudi po več metrov. Lahko so ravni, če je pobočje strmo, ali pa meandrirajo ali vijugajo, če je naklon manjši. Lahko se tako poglobijo, da prerežejo ves sklad kamnine in nastanejo škraplje.

Solzajni žlebiči nastanejo na mestih, kjer priteka na površino apnenca že združeni manjši vodni tok, na primer iz škavnice, z višjega sklada, iz razpoke ali iz drevesnega debla. Navzdol se zmanjšujejo.

Večja oblika, škraplje, nastanejo zaradi hitrejšega raztapljanja apnenca vzdolž razpok ali drugih ploskev manjše odpornosti v kamnini. Če so nastale pod prstjo, so zaobljene. Dolge so lahko tudi po več metrov, pogosto so mrežasto razporejene razpoke. Če razčlenjujejo skalo v kaos manjših kamnov, rečemo temu tudi griža.

Korozijske oblike nastanejo lahko tudi na površini skale, ki je pokrita s prstjo. Te oblike se od razjed, oblikovanih na površju, ločijo po manjši hrapavosti. Površina skale je zato gladka, skala pa oblikovana v nenavadne oblike, vdolbke in luknje. Na Krasu, kjer je tudi zaradi človekove dejavnosti erozija odnesla prst, lahko po oblikah na skalah opazujemo, do katere višine je nekoč segal prsteni pokrov.

KARST MORPHOLOGY

Andrej Mihevc

When the word "kras" entered the international scientific terminology also other words as "dolina", "polje" etc. deriving from Dinaric karst were implemented. A landscape with special topographical, hydrological and subterranean properties that had been developing over long span of geological history on soluble rocks, mainly on limestone and dolomite, is now called k a r s t. In Republic Slovenia it covers 8.780 km² or 43% of the total surface.

The solubility of carbonate rocks, their permeability, thin and interrupted soil cover and large quantity of water are effective agents of karstification. The mode of water drainage is also very important. When water drainage is fast is does not use all of its corrosional capacity. The dissolution is higher there where the water drains through soil and infiltrates slowly. The corrosion intensity depends on properties of karst rock in particular how it is bedded and how much the area was affected by tectonic forces. All these factors direct and control the corrosion activity of water and their final effect is also the morphology of karst surface.

The rate of karst rock solution is the most intensive on the surface or some meters below it; however, water solvent capacity persists longer. Bare limestone surface is etched by thin corrosional notches of various sizes and thus the rock surface is uneven and rough. An important role at their origin is played by the rock itself: bedding, tectonics and physical and chemical properties of the rock. Some of these dissolutional features are very regular and frequent, they got special names and, as we know by which conditions they are controlled they may help us to study the changes on karst.

Typical and frequent features on karst are solution pans or kamenitzas. These are relatively shallow sub-circular generally flat bottomed basins, formed by dissolution upon an exposed limestone surface; walls are steepened by undercutting and may display a basal corrosion notch. Dimensions range from a few centimeters to one meter across. They develop where a pool may form due to gently inclined surface. Where the water stands and has enough time to dissolve the limestone small pans occur. The dissolution is the strongest at the contact of water level and the rock this is why kamenitzas mostly widen laterally and less in depth. The limestone dissolution is accelerated by biological proceses that degrade organic substances and organic acids occur. Overflow channels are common - these are open kamanitzas; out of closed types water evaporates only. When the water evaporates from the kamenitza the dissolved calcite precipitates and calcite crystalls are blown off by the wind... Shepherds frequently artificially dammed up the pans to get water for their cattle.

Slightly similar are corrosional steps. These features have clearly expressed steep half-rounded rim and flat bottom opened on one side downwards, usually into another step. They are from 10 to 30 cm in size.

Typical and frequent features are thin parallel rillenkarren. Rillenkarren must be the product of direct rainfall because there is no other feasible source of water. On the crest, on the highest part of a rock micro-lapis occur, ranging from 1 to 3 cm in width. They head at the crest of a bare slope and diminish in depth down slope until they are replaced by a planar solution surface. This is sheet erosion, the water spreads over, the lower layer at the contact with a rock is saturated and does not dissolve any more. As there is no mixing of water layers, the dissolution process stops or at least it attacks convex parts of the surface and levels and preserves the undissected surface.

Larger are runnels that start below the zone of sheetflow lowering of the surface in the direction of the steepest gradient. The etching starts due to joining of spread water into path of maximm velocity. Due to higher velocity the turbulence occurs, the layers mix and water deepens the channel. On a bare rock these channels are sharp edged and narrow bottomed. When they developed below a soil cover that was later removed, they appear more rounded when seenin cross-section. The channels enlarge downwards, ranging from 3 to 30 cm across and they may be several metres long. On steeper slopes the channels are parallel; on gentle slopes there may be dendritic confluence or centripetal orientation into a karren shaft or grike.

For larger features a German term "Karren" is widely used to describe dissolution pit, groove and channel forms due to accelerated dissolution of limestone along fissures or other spots of modest resistivity within a rock. If they developed below the soil they are rounded. They may have several metres in length, frequently they are distributed along dendritic pattern of fissures. When bare limestone surface is scored and fretted by karren it is termed limestone pavement.

The dissolution features occur also on the rock surface covered by soil. They differ from the features developed on the bare surface because they are less rough. The surface of the rock is smooth and the rock itself shaped in curious forms, notches and holes. In Kras where a lot of soil was eroded due to human impact one may assess, in respect to features on the rock, to which height the soil cover reached in former times.

Zaradi različne stopnje razpokanosti in prepustnosti apnenca padavinska voda ponika in odteka v podzemlje. To povzroča nastajanje kraških kotanj različnih velikosti. Najpogostejše kraške kotanje so vrtače. To so lijakaste ali skledaste kotanje, povečini do 10 metrov globoke in s premerom do 50 metrov. Nastale so tam, kjer je mogoče navpično prenikanje v globino in raztapljanje kamnine najmočnejše.

Vrtače so povsod po krasu; največ jih je na kraških uravnavah, na pobočjih pa le malo in na bolj strmih pobočjih celo nič. Vrtače naj bi nastale na mestih, kjer je spiranje v podzemlje in s tem tudi raztapljanje najmočnejše. Proti temu pa govori dejstvo, da se le v vrtačah lahko ohrani kraška rdeča prst. Torej spiranje v kras tod ni tako močno, pač pa je močno raztapljanje.

Vrtače so zelo pomembna reliefna oblika našega Krasa. Zaradi prsti v njihovem dnu ter zaradi nekaj boljše zaščitenosti pred burjo so v njih njive in njivice, odvisno od velikosti vrtače. S pobočij in dna takšnih vrtač so nekdaj pazljivo odstranili kamenje, dno pa izravnali. Del kamenja so zakopali pod prst v dno vrtače, ostalega pa zložili v suhe zidove okrog dna. Suhi zid je imel dvojno nalogo: vanj so na najmanjši možni prostor spravili kamenje, zid pa je tudi varoval skromno obdelano površino na dnu vrtače. Vrtače so dobile svoja imena; po reliefnih značilnostih, po lastnikih ali po vaseh, katerim so pripadale. Zlasti večje vrtače - doli so imeli takšna imena. Ker pa so pripadale različnim lastnikom, jih pogosto prepredajo še kamniti zidovi, ki so hkrati tudi meje posesti.

Dna vrtač so pogosto uporabljali za vodne zbiralnike - kale. Domiselni Kraševci so tod uporabili spoznanje, da postane ilovica v dnu vrtač nepropustna, če je dobro pregnetena in se s tem porušita njena poroznost in prepustnost. Iz dna vrtač so tako najprej odstranili vrhnjo prst, potem pa so po ilovici gonili živino in tako naredili njihovo dno dovolj nepropustno, da se je v njih obdržala voda daleč v suho poletje.

Vrtač na krasu še ni nihče preštel. Njihova gostota je različna od kraja do kraja, odvisna pa je tudi od njihove velikosti. Ponekod je vse površje vrtačasto, drugod pa so vrtače posejane le na redko. Njihova gostota je torej različna, prav pogosto pa je večja kot 50 vrtač na kvadratni kilometer površine.

Najbolj pogosta reliefna oblika na Krasu so vrtače. Le v njih se je ohranila prst.
Dolines are the most common morphological features in Kras. Only at the bottom some soil is preserved.

Veliko večje kot običajne vrtače so udorne vrtače, udornice ali koliševke. Ime nakazuje, da so nastale z rušenjem stropov nad večjimi podzemnimi votlinami. Običajno imajo strma pobočja, pa tudi navpične skalne stene so pogoste. Udornice ne nastanejo nenadoma z udorom, ampak nastajajo z dolgotrajnim krušenjem stropa in sten nad dvoranami in tokovi podzemnih rek. Za njihov nastanek je potrebnih več pogojev. Prvi je primerno prepokana kamnina, ki se prične krušiti, ko doseže dvorana ali rov dovolj velik razpon. Drugi pogoj pa je nedvomno podzemna reka, ki raztaplja odpadlo kamenje in ga kot raztopino odnaša proč. Pomembno je prav to, saj bi se sicer podzemna dvorana kaj hitro zapolnila s podornim skalovjem, ki zavzema večjo prostornino kot kompaktni strop jame... Udornice so torej nastale, in še tudi nastajajo, počasi s krušenjem in podiranjem pobočij, podzemne reke pa grušč v globini raztapljajo veliko hitreje kakor kompaktni apnenec ter tako ustvarjajo reliefno depresijo.

Večje udornice na Krasu so globoke od 50 do 200 metrov ter široke do nekaj sto metrov, njihova prostornina pa dosega do več milijonov kubičnih metrov. Največ udornic je blizu ponorov Reke pri Škocjanskih jamah ter med Lipico in Sežano. Najbolj znane udornice so doli Globočak in Sekelak, Sapendol in Dol Lisična. Njihov nastanek povezujemo z bližino ponorov Reke v Škocjanske jame. Pri Divači so veliki doli Risnik, Radvanj ter Bukovnik. Pod dolom Bukovnik potekajo tudi spodnji rovi Kačne jame, prav pod njimi pa se eden izmed rovov konča v velikem podoru. Reka je tod 200 metrov pod dnom same udornice.

Z Reko povezujemo tudi nastanek večjih dolov na Sežanskem krasu. Pri Orleku je veliki dol Draga, pri Sežani pa so dol Leskovec, Huslov dol in Kolovreči dol, ki je že napol zasut z odpadki iz sežanskih kamnoseških podjetij. Manj jasno je, kako so nastali veliki stari dol Šator pri Štorjah, Petnjak ali drugi doli na Krasu pri Kazljah, Dutovljah in drugod, ki jih težje povezujemo s podzemnim tokom Reke. Očitno pa lahko oblikujejo take velike dole tudi manjše podzemne reke, če je kamnina primerno pretrta in če je dovolj časa na voljo... Poleg velikih udornic pa je nastalo na tak način tudi veliko vrtač, le da pogosto ne moremo zanesljivo ugotoviti njihovega nastanka.

Značilna večja oblika kraškega površja so ravniki. Pravzaprav je ves Kras tak ravnik, ki ga razčlenjujejo trije nizi nekaj višjega sveta. Ti nizi so Gabrk severno od Divače, Taborski hrib, ki se od Divače čez Sežano, Repen in Veliki Vrh nadaljuje do Mavhinjskega hriba in Grmade nad izviri Timave. Tretji niz hribov poteka pod samim robom Krasa, od Bazovice do Devina. Med temi nizi gričev in hribov sta obsežna ravnika.

Nekdaj so razlagali, da so Kras oblikovale večje površinske reke, ki da so pozneje poniknile. Ostanki teh rek naj bi bili dve širokim dolinam podobni podolji. Prvo se od Vremske doline čez Divačo med Gabrkom in Taborskimi griči nadaljuje proti severozahodu, drugo pa poteka južneje, od Lokve čez Lipiški kras proti Nabrežini. Danes menimo, da je ti podolji oblikovala talna kraška voda. Zaradi višjega nepropustnega obrobja so reke, ki so ponikale v gornjem, jugozahodnem delu Krasa, tekle plitvo pod površjem, kamor so segale še občasne poplave. Zaradi te vode plitvo pod površjem je bilo vertikalno spiranje majhno; na površju je bilo obilo prsti, ki je še pospeševala raztapljanje apnenca. Poplavna voda pa je uravnavala površje ter oblikovala v grobem sedanji relief. Pozneje, ko se je gladina kraške vode spustila za več sto metrov, je deževnica izprala prst v podzemlje in v izvire, površje pa je voda razčlenila v številne zaprte kotanje, med katerimi so najštevilnejše vrtače.

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As limestone is fissured and permeable the meteoric water sinks and drains into underground. On the surface it is displayed in a shape of different karst depressions of various size. The most frequent karst depressions are dolines. They yield a spectrum of features from saucer shaped hollows to funnel pits; they are mostly up to 10 m in depth and up to 50 m in diameter. The majority have a predominantly solutional origin.

The dolines are found all over our karst, mostly on karst plains, there are few on slopes and if slopes are steep there are no dolines. The dolines developed there where the drainage into the underground exists and the solution is the strongest. However, the fact that karst terra rossa is preserved only in the dolines speaks against this hypothesis. The outwash is overwhelmed by the solution.

Dolines are very common morphological feature in our karst. There is soil in their bottom and they are better protected against bora this is why they are cultivated. From the slopes and the bottom of these dolines the stones had been carefully removed and the bottom flattened. Dry wall played double role: the packed rocks consumed as little place as possible and they protected modest field in the bottom of a doline. Dolines got their names, either by topographic properties or by names of owners or villages to which they belonged. In particular larger dolines or ouvalas have such names and as they belonged to various owners they are often divided by walls which are at the same time the borders of a property.

The bottoms of dolines were frequently used for water reservoirs - sinkhole ponds. Clever farmers used the knowledge that loam becomes impermeable if it is well compacted so that hole holds water. Thus they first of all removed the upper layer of soil from the bottom of a chosen doline and later made the cattle to pace up and down the loam; thus loam became impermeable in such a degree that water was kept in it long into dry summer.

Till now nobody counted dolines on karst. Their density varies from place to place, it depends on their size also. Somewhere all the surface is dotted by dolines elsewhere they occur sparsely. The density is varying, but frequently it is well over 50 dolines per square kilometer.

Much larger than solution dolines are collape dolines. The name indicates that they are due to collapse of the span of a cave roof. Usually they are steep-sided, and vertical rocky walls are common. They are not due to sudden collapse but to long lasting solution either from above or from below that widens and progressively weakens the span of a cave roof or by breaking of roofs and walls above chambers and river channels. Several conditions must be fulfilled for their origin. The first is appropriate rock which became unstable when the span of a chamber or passage is large enough. The second condition is underground stream that dissolves the crushed rocks and transports it away. The water flow is extremely important otherwise the underground chamber should be quickly filled up by breakdown rocks that have larger volume than the compact roof of the cave... Collapse dolines originated and are still developing by slow solution and breaking, the underground streams dissolve the rubble much quicker than the solid limestone and thus a relief depression is formed.

Larger collapse dolines in Kras are from 50 to 200 m across and over 100 m in depth, their volume reaches several millions of m^3. Most of collapse dolines are found near the Reka swallow-holes at Škocjanske jame and between Lipica and Sežana. The most famous collapse dolines are Globočak and Sekelak, Sapendol and Lisièna. Their origin may be connected by the vicinity of the Reka swallow-holes into Škocjanske jame. Near Divača are huge collapse dolines Risnik, Radvanj and Bukovnik. Lower passages of Kačna jama underlay the collapse doline Bukovnik and just at this spot one of the passages ends in a huge breakdown. The Reka flows here 200 m lower than is the bottom of a collapse doline.

The origin of major collapse dolines in the Sežana karst should be connected with the Reka. Near Orlek is a large collapse doline Draga and near Sežana dolina Leskovec, Huslov dol and Kolovreèi dol, the latter half buried by rests of Sežana stonecutting industry. Less clear is the origin of old, large collapse dolines Šator near Štorje, Petnjak and other collapse dolines near Kazlje, Dutovlje and elsewhere in Kras that cannot possibly be connected by the underground Reka flow. Obviously such huge collapse doline may be due to smaller water streams if the rock is crushed and enough time available. Not only collapse dolines but also a number of solution dolines developed by such a way, however their origin cannot be ascertained.

Another typical feature of karst surface are karst plains; in fact, the whole Kras is such a plain, dissected by three series of slightly elevated landscape. These series are Gabrk north of Divača, Taborski hribi, passing from Divača over Sežana, Repen and Veliki Vrh to Mavhinjski hrib, and Grmada above Timavo springs. The third series of ridges passes the border of Kras, from Bazovica to Devin. Among these series of hills and ridges extensive karst plains are located.

In the past an explanation was that Kras had been formed by superficial rivers that have disappeared later into the underground. The first one should flow from Vremska dolina over Divača between Gabrk and Taborski griči northwestwards; the second one should pass more to the south, from Lokve over Lipica karst towards Nabrežina. Today we think that these lowered surfaces were formed by underground karst water. Due to higher impermeable border the rivers disappearing in upper, southwestern part of Kras had been flowing close below the surface and seasonal floods only reached the surface. Due to the water close below the surface the vertical percolation had been unsignificant and a lot of soil remained on surface accelerating the limestone dissolution. The flood water levelled the surface and roughly shaped the actual relief. Later, when the karst water dropped for several hundred meters the rainwater outwashed the soil into the underground and springs; the surface was dissected into numerous closed basins, dolines mostly.

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SPELEOLOŠKE ZNAČILNOSTI matičnega Krasa

Andrej Mihevc
Tadej Slabe

Jame na krasu so opisovali številni naravoslovci. Med prvimi opisi je Valvasor. Opisoval jih je tudi popotnik in naravoslovec Fortis. V prejšnjem stoletju se je pričelo tudi že prvo znanstveno raziskovanje jam. Prvi raziskovalci so bili hidrotehniki, ki so hoteli izboljšati preskrbo Trsta z vodo. V ta namen so organizirali tudi raziskave jame Labodnice, ki je tako postala najgloblja jama sveta in je to prvenstvo držala do konca 19. stoletja. Raziskave so usmerili tudi v Škocjanske jame in v Kačno jamo.

Raziskovanje največjih jam na Krasu je, seveda, spremljalo tudi raziskovanje številnih drugih jam. Pomemben motiv za to je bil tudi jamski turizem. Prva turistična jama je bila Vilenica, ki je bila z urejenim obiskom že leta 1633 med najstarejšimi turističnimi jamami na svetu. Rezultati razioskovanja jam na Krasu so bili prikazani v številnih člankih in monografijah. Sistematično so obdelani v monografijah "Il Timavo" in "Duemila Grotte", v Speleološki karti Slovenije in v knjigi Kras. Poleg tega so bile posamezne jame ali posamezna območja podrobneje obdelana v posebnih študijah.

Jame na Krasu lahko glede na razvoj vodonosnika razdelimo na stare jame, v katerih so sledi vodnih tokov in so plitvo pod površjem, na jame, skozi katere se še danes pretakajo vodni tokovi, in na brezna, skozi katera razpršeno prenika voda s kraškega površja do podzemeljske vode, katere gladina je lahko tudi več kot 300 metrov pod površjem.

Stare jame s sledmi različnih vodnih tokov, poplavnih obdobij, z različnimi naplavinami in sigami, so ostanki nekdanjih, najbolj izrazitih obdobij oblikovanja podzemlja kraškega vodonosnika. Zemeljska dela pri gradnji avtocest odkrivajo verjetno najstarejše jame, ki so tik pod površjem. Zato imajo tanke strope ali so že celo brez njih. Večina je zapolnjena z drobnozrnato naplavino, s sigo ali z mlajšim gruščem. Sprva so jih oblikovali počasni tokovi v stalno zaliti coni, nekatere pa so pozneje preoblikovali hitrejši tokovi, ki so le občasno zalili rove. O tem priča prod v njih. Končno so bile, že po suhih obdobjih razvoja, ko se je v njih kopičila siga, zapolnjene s poplavno drobnozrnato naplavino.

Pri študiju jamskega skalnega reliefa lahko v prečnem prerezu vodonosnika razberemo različna obdobja razvoja in raznovrstne dejavnike oblikovanja votlin. V starih jamah se prepletajo sledi počasnejših vodnih tokov, ki so rove oblikovali v zaliti coni, in hitrejših vodnih tokov, ki so značilni za jame v piezometričnem nivoju ("gladina kraške talne vode") podzemeljske vode, ali pa se s prosto gladino pretakajo po večjih podzemeljskih prostorih. Poplavne zapolnitve votlin z drobnozrnato naplavino so pogosto povzročale, da se je voda občasno pretakala po naplavini in preoblikovala jamske strope.

Apnenci kraškega vodonosnika so bili, ko so bili še obdani s flišem, zaprti in podzemeljska voda je bila zajezena. To je ohranjalo površinske tokove. Ti naj bi zapustili sledi na kraškem površju v suhih dolinah in naplavinah, so ugotavljali krasoslovci. Sledimo lahko počasnemu in pogosto skokovitemu zakrasevanju vodonosnika s postopnim nižanjem gladine podzemske vode, ki je vezana predvsem na navpično tektonsko členjenje kraških predelov in na višino nižajočega se obrobnega flišnega jezu. Občasna manjša nihanja gladine podzemeljske vode pa so zlasti posledica spremenljivih klimatskih razmer. Ponekod so flišne zaplate ostale dlje časa. Z njimi se je stekala voda v kraško podzemlje. O tem pričajo tudi krhki flišni prodniki v jamah sredi Krasa, torej daleč od današnjega flišnega roba. Voda s kraškega površja skozi brezna in špranje razpršeno prenika v podzemlje in deloma preoblikuje stare votline.

Poleg podatkov speleoloških raziskav so osnovni podatki o jamah zbrani v Katastru jam, ki ga vodita Jamarska zveza Slovenije in Inštitut za raziskovanje krasa. Podatki v njem so zbrani v obliki zapisnikov o posamezni jami, načrtov in fotografij. Kataster je zbirka podatkov o jamah, vendar se stanje v njem stalno spreminja. Vzrok so odkritja novih jam ali odkritja novih delov v že starih jamah.

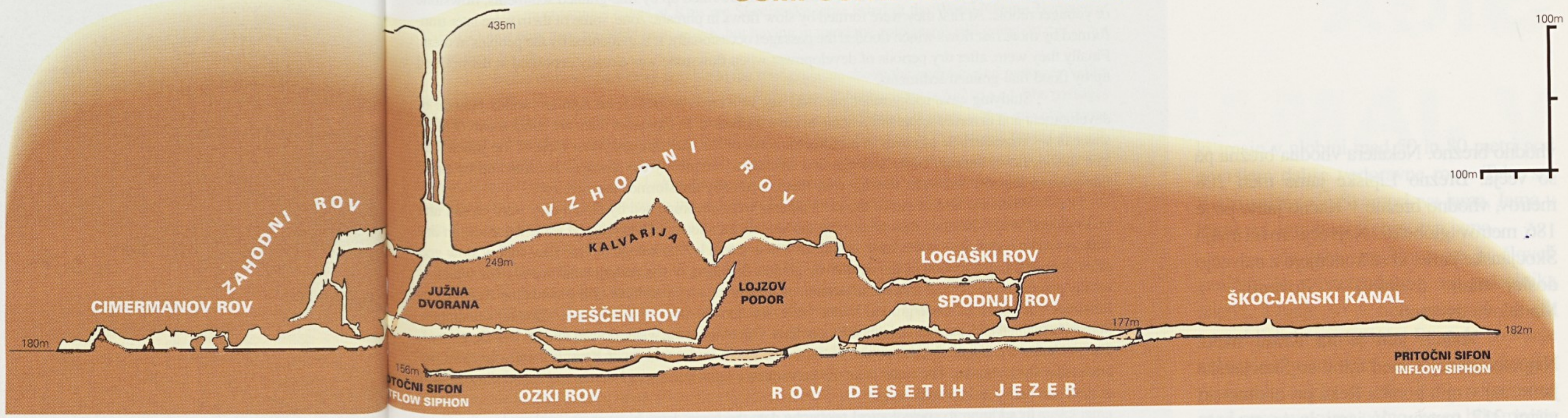
Na slovenskem delu Krasa je znanih in registriranih 522 kraških jam. Običajno jih delimo na brezna in jame. Taka delitev pa ni natančno opredeljena. Jame so bolj vodoravne in so daljše kot globlje, brezna pa so globlja kot daljša.

Vhodi v jame leže med višinami 660 in 35 metrov nad morjem. Najdaljša jama na Krasu je Kačna jama z dolžino 9612 metrov, sledijo ji: Škocjanske jame z dolžino 5088 metrov, Lipiška jama s 1194 metri, Vilenica z 803 metri, Divaška jama s 772 metri in Škamprlova jama s dolžino 565 metrov. Najgloblja je Kačna jama z globino 279 metrov in na italijanski strani Krasa Labodnica z globino 319 metrov.

Običajno so jame plitvejše. Povprečna globina jam na Krasu je 31 metrov, povprečna dolžina pa je 85 metrov. Skupni seštevek vseh jamskih rovov na Krasu je 42 kilometrov. So pa te številke začasne, saj se jame še raziskuje.

Najpogostejše jame so torej kratke in plitve ter jih predstavlja le navpično

KAČNA JAMA - SESTAVLJENI PREREZ
COMPOSITE CROSS-SECTION



SPELEOLOGICAL PROPERTIES OF CLASSICAL KARST

Andrej Mihevc
Tadej Slabe

Numerous natural scientists have described the caves in karst. The first to approach to this particular matter was Valvasor but also traveller and Earth scientist Fortis. In the past century the first scientific cave researches started. Among first were hydrotechnicians who tried to improve the water supply of Triest. Within these endeavours they organised the exploration of the Labodnica (Grotta di Trebiciano); thus the cave became the deepest cave in the world and kept its primacy by the end of the 19th century.

The researches were directed towards Škocjanske jame and Kačna jama also. Obviously the explorations of larger caves were accompanied by discoveries of smaller ones. An important motive for exploration was cave tourism also. The first show cave was Vilenica, which was displayed for public visit in 1633 already and thus is one of the oldest show caves in the world. The results of Kras investigations have been presented in numerus articles and monographs. They are systematically treated in the monographs "Il Timavo" and "Duemila Grotte", in the Speleological Map of Slovenia and in the book Kras. In addition single caves or areas are treated in detail in special studies.

The caves in Kras may be divided in respect to the aquifer development to: - old caves, where there are traces of water flow close below the surface, - active caves and, - shafts, through which diffuse recharge from the surface infiltrates down to the underground water; ground water table may be even more than 300 m below the surface.

Old caves with traces of various water flows, flood periods, different deposits and flowstones are the remains of former, the most distinctive periods of karst underground development. The earthworks during the con vhodno brezno. Nekatera vhodna brezna pa so večja. Brezno Lipiške jame meri 208 metrov, vhodno brezno v Kačno jamo pa je 186 metrov globoko. Največje rove imajo Škocjanske jame, ki se končujejo z največjo doslej znano dvorano v Sloveniji - z Martelovo dvorano.

Vodnih jam je na Krasu malo. Najpomembnejše med njimi so Škocjanske jame, saj v njih ponika Reka pri nadmorski višini 317 metrov. V jami jo je mogoče spremljati še kakšnih 4000 metrov daleč v podzemlje do sifona na višini 214 metrov nad morjem... Mejame so ponor majhnega potoka z Brkinov, ki ponika v bližini Škocjanskih jam. Podzemski tok Reke lahko v podzemlju dosežemo še v Kačni jami pri Divači na nadmorski višini okrog 180 metrov ter v Labodnici na italijanski strani. Gladino kraške vode, to je gladino stalno zalite kraške cone, je mogoče doseči še v jamah Drča in Dolenjca.

Večina jam je brez vodnih tokov. Med njimi prevladujejo tipi jame z brezni in z vodoravnimi odseki, sledijo enostavna brezna ter poševna in stopnjasta brezna. Jame so razporejene povsod po Krasu, večje zgostitve pa so zlasti med Lipico, Orlekom in Sežano ter v okolici Divače, kjer so tudi največje med njimi.

Najbolj znane jame na Krasu so Škocjanske jame, ki so tudi v Unescovem seznamu Svetovne naravne dediščine. Dolge so 5088 metrov, vendar zaradi še potekajočih raziskovanj in novih odkritij v zadnjem času to še ni njihova dokončna dolžina.

V vzhodnem delu sta zaradi rušenja stropa nad podzemeljskimi rovi nastali Velika in Mala dolina. Jama je ponor Reke, ki ponika v podzemlje na nadmorski višini 317 metrov. Sledijo do 80 metrov visoki ter do 40 metrov široki rovi. Mestoma se rovi razširijo v dvorane. Največja je Martelova dvorana, ki je dolga 308 metrov, do 146 metrov visoka in 123 metrov široka ter zavzema prostornino 2,100.000 kubičnih metrov. V zgornjem delu jame so oblikovani ovalni rovi, v katere je potem poglobljen podzemni kanjon, ki se imenuje po velikem raziskovalcu iz prejšnjega stoletja Hankejev kanal. Vzdolž toka Reke se dno jame spusti do sifona v Martelovi dvorani na nadmorski višini 214 metrov. Navzdol je mogoče slediti Reki še kakšnih 200 metrov do nadmorske višine okrog 210 metrov, kjer je naslednji, še neraziskani sifon.

Okrog 1500 metrov severno se lahko doseže podzemni tok Reke ponovno na nadmorski višini 182 metrov v Kačni jami. To je najdaljša (8612 metrov dolga ter 280 metrov globoka) jama na Krasu, obenem pa tudi hidrološko med najpomembnejšimi, saj po njenih spodnjih rovih teče Reka. Ob normalni vodi je mogoče slediti toku Reke v jami kakšnih tisoč metrov. Voda priteka v jamo skozi sifon na nadmorski višini 182 metrov ter zapusti jamo skozi sifon na nadmorski višini 156 metrov. Reka ob normalnem vodostaju teče po enem rovu, ob višjem vodostaju pa se razteka po več rovih. Tako lahko poplavne vode raznesejo onesnaženje tudi v višji in širši del krasa. Sledovi kažejo, da lahko Reka naraste v jami za kakšnih 90 metrov ter poplavi okrog 6 kilometrov rovov.

Med Sežano in Lipico je nekaj zelo globokih jam. Lipiško brezno in Lipiška jama sta globoki več kot 200 metrov. Poleg tega je v tem predelu več jam,

struction of motorway discover probably the oldest caves existing close to the surface. This is why they have thin roof or they are even without it, most of them are filled up by fine-grained sediments, flowstone or younger rubble. At first they were formed by slow flows in phreatic zone, some of them were later tranformed by more fast flows which flooded the passages occasionally. It is evidenced by the pebbles in them. Finally they were, after dry periods of development when flowstone was already deposited in them, filled up by flood fine-grained sediments.

Studying cave rocky relief one may see in a cross section of an aquifer various periods of development and diverse factors influencing to cave formation. In old caves there are either traces of slow water flows characteristic of caves in piezometric level of the underground water table or the water with free surface flows through larger underground chambers. Frequently the passages are filled up by flood fine-grained deposits and water flowing over them seasonally transformed the cave roof.

When the limestones of the karst aquifer were encompassed by flysch they were closed and underground water dammed thus preserving the superficial streams. These should leave the traces in dry valleys and in sediments on the karst surface as it was stated by karstologists. One may follow slow and often intensive karstification of the aquifer by gradual lowering of the underground water table which is mostly associated to vertical tectonic dissection of karst areas and to altitude of the bordering flysch dam. Seasonal variations in underground water table are mostly due to changeable climatic conditions. Somewhere the flysch patches remained longer time. Out of them the water flowed into karst underground. The evidence are fragile flysch pebbles found in the caves in the middle of Kras, it means far from the presentday flysch border. The water from the karst surface infiltrates through shafts and fissures into underground and partly reshape old caves.

In addition to speleological researche data the basic data on caves are gathered in the Cave Register managed by the Association of the Speleological Societies of Slovenia and Karst Research Institute. The data are collected in a form of protocoles about a single cave, surveys and photographs. The Cave Register is a collection of cave data yet its state is permanently changing. The reason lies in discoveries of new caves or new parts of the known caves.

In the Slovene part of Kras there are known and registered 522 karst caves. Usually they are divided to horizontal caves and shafts, however such division is not precisely determined. In general caves are more horizontal and longer in respect to depth, while shafts are more deep than they are long.

The entrances into caves are located at the altitudes between 660 m and 35 m a.s.l. The longest cave of Kras is Kačna jama, 9612 m in length, followed by Škocjanske jame, 5088 m, Lipiška jama, 1194 m, Vilenica, 803 m, Divaška jama, 772 m, and Škamprlova jama, 565 in length. The deepest cave is again Kačna jama, 279 m in depth and on the Italian side of Kras Labodnica, 319 m in depth.

However, most of the caves are less deep, the average depth is 31 m in Kras, and the avergae length is 85 m. Sum total of all the cave passages is 42 km. These numbers are temporary as the explorations are still going on.

A typical cave is short with vertical entrance pit. However, some shafts are deeper, for example Lipiško brezno is 208 m deep, the entrance shaft into Kačna jama is 186 in depth. The largest passages are in Škocjanske jame ending with the largest underground chamber in Slovenia called Martelova dvorana.

There are only few water caves in Kras. The most important is Škocjanske jame where the Reka river sinks at the alttude 317 m and may be followed in the cave for about 4000 m up to the final siphon at 214 m. The cave Mejame is a swallow-hole of a small stream flowing from Brkini and disappearing not far from Škocjanske jame. The underground flow of the Reka river may be reached in the underground in Kačna jama near Divača only at 180 m a.s.l. and in Labodnica, the latter being in Italy already. The karst water table, it means the phreatic zone of Kras may be reached in the caves Drča and Dolenjca.

Most of caves are without water flows. Prevailing type is cave with avens and horizontal sections, followed by simple shafts, inclined shafts or shafts with ledges. The caves are located all over the

Kras, their density is higher in the area between Lipica, Orlek and Sežana and near Divača where the largest among them are to be found.

The most famous caves of Kras are Škocjanske jame listed in the World Natural Heritage at UNESCO. For now they are 5088 m in length, but having in mind the eplorations still going on this is not yet the final length.

In the entrance part there are due to the roof collapse above the underground passages Velika and Mala dolina. The cave is a swallow-hole of the Reka river that disappears at 317 m a.s.l. The passages up to 80 m in height and up to 40 m in width follow. On some places the passages widen into chambers. The largest is Martelova dvorana, 308 m in length, up to 146 in height and 123 m in width, having the volume of about 2.100.000 m^3. In upper part of the cave the oval passages developed and the underground canyon is incised into them, called after the explorer of the past century Anton Hanke. Along the Reka flow the bottom of the cave lowers to the siphon in Martelova dvorana at 214 m a.s.l. Downstream the river may be followed for another 200 m up to 210 m a.s.l. where is the next, not yet explored siphon.

About 1500 m northwards the Reka underground flow may be reached again in Kačna jama at 182 m a.s.l. This is the longest (8612 m in length and 280 m in depth) cave in Kras and at the same time hydrologically the most important being a conduit for the Reka river in its lower passages. During medium waters one may follow the Reka flow in the length of about 1000 m. The water enters the passage by a siphon at 182 m a.s.l. and leaves the cave through another siphon at 156 m a.s.l. During normal water level the river flows through one passage while at high waters it floods several levels. Thus the flood waters may spread the pollution into higher lying and wider areas of karst. The traces provide evidence of the Reka increase in the cave for about 90 m thus flooding about 6 km of passages.

Between Sežana and Lipica there are some very deep caves. Lipiško brezno and Lipiška jama are both more than 200 m in depth. In addition there are in this area several caves with horizontal passages at 50 to 80 m below the surface. Such caves are: Križmančičeva and Škamprlova jama, Jama v Partu pri ogradi and Čebulčeva jama.

Man was interested in caves since prehistory, since Palaeolithic. People lived in caves or used them as shelters. Later they visited them as underground admirers. The caves were very important during the First World War when many of them were changed to refuge.

In caves the traces of human activity may be preserved for a long time. The second half of this century provided another special use - pollution. Pollution seeps into underground through soil and fissures or directly by sinking streams. The most harmful, however very frequent, is dumping the shafts. The thrown objects and substances degrade caves even if they are not toxic by themselves. Usually it is a direct input of matters into karst and no, either partial degradation occurs at the surface or in the soil. To find out, control and sanitate such point pollution is extremely difficult.

Important cave pollution by illegal dumping through the entrance pits was noticed at 48 caves. Disposal of industrial wastes was registered in 3 caves. In the same caves the wastes of slaughterhouses and households were thrown. The number of caves into which people throw from time to time the household wastes or even dead cattle is very high. A speciality of cave pollution is old, useless ammunition left there by both world wars. Without doubt the traces of this kind of activity will remain for the benefit of future generations.

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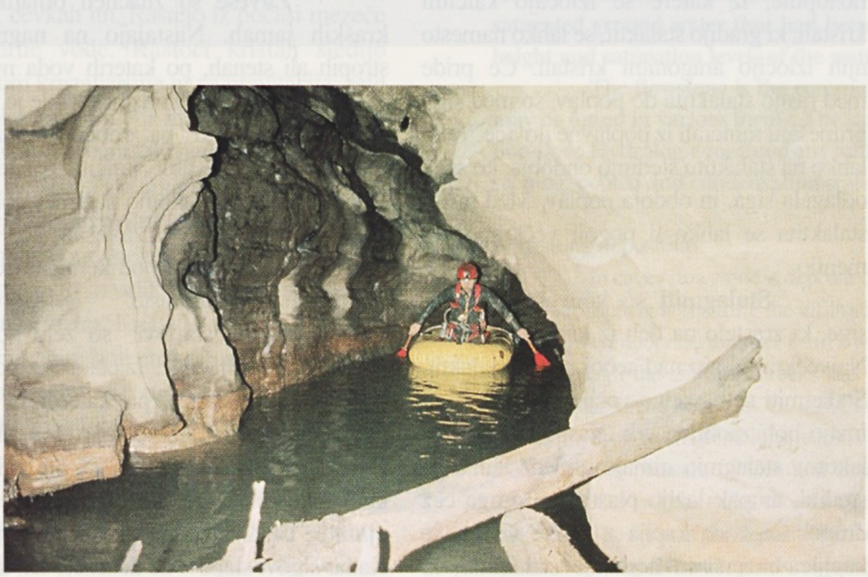

ki imajo v globini med 50 in 80 metri pod površjem daljše vodoravne rove. Take so: Križmaničeva in Škamprlova jama, Jama v Partu pri ogradi ter Čebulčeva jama.

Za jame na Krasu se je človek zanimal že v prazgodovini, od paleolitika naprej. Ljudje so v njih prebivali ali jih uporabljali kot zatočišča. Pozneje so vanje zahajali predvsem kot občudovalci podzemlja. Zelo so bile jame pomembne med prvo svetovno vojno, ko so bile mnoge preurejene v zavetišča.

V jamah se sledovi človekove dejavnosti ohranijo zelo dolgo. Druga polovica tega stoletja bo jamam dodala še eno posebno rabo, to je onesnaženje. Prenaša se v podzemlje s spiranjem in prenikanjem skozi prst, preperino ali neposredno z vodo ponikalnic. Najbolj škodljivo, a žal zelo pogosto, je odmetavanje škodljivih snovi v brezna. Odvrženi predmeti in snovi jame uničujejo, četudi sami po sebi niso strupeni. Ker pa je to neposredno vnašanje snovi v kras, ne prihaja do vsaj delnega razgrajevanja na površju ali v prsti. Oteżkočeno je tudi ugotavljanje, kontroliranje in odstranjevanje, ozdravljanje takih onesnaževalnih točk.

Pomembnejše onesnaženje jam z odlaganjem odpadkov skozi vhodna brezna so ugotovili v 48 jamah. Odlaganje industrijskih odpadkov so zabeležili v treh jamah. Vanje so odlagali klavniške in komunalne odpadke. Število jam, v katere ljudje občasno odmetujejo gospodinjske odpadke ter celo poginulo živino, je veliko. Posebnost onesnaževanja v jamah predstavljata tudi stara in neuporabna municija ter razstrelivo iz obeh velikih vojn. Sledovi teh početij se bodo nedvomno ohranili še v naslednja stoletja.

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SIGA V JAMAH NA Krasu

Nadja Zupan Hajna

Siga je usedlina, ki se izloči iz prenasičene mineralne raztopine. Po Slovenski kraški terminologiji je to odkladnina kalcijevega karbonata iz zasičene jamske vode, ki se zrači. Oblika sige je odvisna od načina dotoka vode.

Siga je najpogostejša oblika nastopanja kalcita. V kraških jamah je siga v različnih oblikah. Njena oblika je odvisna od načina pretakanja raztopine, ki vpliva na njeno odlaganje. Različne oblike sige nastajajo iz kapljajoče, tekoče, mezeče, ujete in kondenzne vode.

Izločanje sige

Siga se izloča v jamah iz raztopin, prenasičenih s kalcijevim karbonatom. Deževnica se v atmosferi in pri prenikanju skozi tla obogati s CO_2. Ti dve komponenti skupaj tvorita šibko ogljikovo kislino ($H_2O+CO_2 = H_2CO_3$). Ta kislina pri prenikanju skozi karbonatne kamnine te raztaplja, pri čemer nastajajo kalcijevi in hidrogenkarbonatni ioni ($CaCO_3 + H_2CO_3 = Ca^{2+} (HCO_3)^-$). V trenutku, ko raztopina, bogata s kalcijevimi hidrogenkarbonatnimi ioni, doseže jamski prostor, se ravnotežje v raztopini poruši. Zaradi spremembe parcialnega tlaka CO_2 in temperature se začne izločati kalcijev karbonat ($Ca^{2+} + (HCO_3)^- = CO_2 + CaCO_3 + H_2O$).

Kakšna oblika sige se bo izločila, je odvisno od načina dotoka vode, kakšna bo siga po mineralni sestavi, pa je odvisno od vsebnosti ostalih ionov v raztopini.

Sigo lahko sestavljajo zelo drobni, srednji in veliki kristali kalcita. Veliki kristali v sigi največkrat zrastejo iz zelo čistih raztopin in iz počasi mezeče vode ali pri prekristalitvi sige. Do prekristalitve drobnozrnate sige pride, ker vse snovi težijo k čim popolnejši in obstojnejši obliki, veliki kristali so pa precej bolj stabilni kot majhni.

Najpogostejše oblike sige

Oblike sige so odvisne od količine in načina dotoka raztopin. Na prvem mestu je primer kapljajoče vode, iz katere rastejo stalaktiti in stalagmiti v vzdolžni smeri kapljajočega curka. Iz vode, ki teče po stenah ali tleh, se izloča siga v plasteh. Koralne oblike sige se izločajo iz mezeče ali pljuskajoče vode, helektiti rastejo iz kapilarne vode, ki mezi skozi tanke kanale. Na ujeti vodi v bazenih in lužah rastejo tanke plavajoče skorje sige. Iz kondenzne vode se izločajo sigove obrobe, ostale oblike sige pa so rezultat različnih hidroloških mehanizmov.

Stalaktiti so najbolj znana oblika sige, pritrjeni na strop. So najrazličnejših velikosti in debelin, od drobnih do debelih in masivnih ter nekaj metrov dolgih. Vsak tipični stalaktit ima v sredini votel kanal, okrog katerega si radialno sledijo tanke plasti sige. Del stalaktitov pa takega kanala nima, ker so se oblikovali z nalaganjem posameznih plasti sige. Stalaktiti so ponavadi iz čistega kalcita, včasih pa vsebujejo zaradi različnih pogojev pri svoji rasti tudi druge minerale. Kadar se spremeni sestava raztopine, iz katere se izločajo kalcitni kristali, ki gradijo stalaktit, se lahko namesto njih izločijo aragonitni kristali. Če pride med rastjo stalaktita do poplav, so med sigo primešani minerali iz poplavne ilovice. Tako lahko na stalaktitu sledimo obdobja, ko se je odlagala siga, in obdoja poplav. Med rastjo stalaktita se lahko ti pogoji večkrat spremenijo.

Stalagmiti so konveksne oblike sige, ki zrastejo na tleh iz kapljajoče vode. Največkrat imajo nad seboj rastoč stalaktit. Stalagmiti so navadno večji kot stalaktiti in imajo bolj zaobljen vrh. Nasprotno od stalaktitov stalagmiti nimajo votlega kanala v sredini, ampak ležijo plasti sige druga čez drugo. Če voda kaplja z velike višine, se kapljica razprši in nastajajo stalagmiti, ki imajo vrh krožnikaste oblike. Kadar je višina curka manjša, se plasti sige odlagajo druga vrh druge. Med plastmi v stalagmitu je najti druge minerale zaradi spremembe v kemični sestavi raztopini ali pa zaradi poplav, ki so odložile na rastoči kapnik poplavno ilovico. Stalagmiti so najrazličnejših oblik. Nekateri so podobni cipresam, božičnim drevesom, orjakom, palčkom, kijem, pagodam in drugemu.

Stebri nastanejo takrat, ko se stalaktit in stalagmit zrasteta s konicama. Pri nadaljnjem izločanju sige steber debeli in pri tem nastajajo najrazličnejše oblike.

Zavese so značilen ornament v kraških jamah. Nastajajo na nagnjenih stropih ali stenah, po katerih voda mezi v določeni liniji. Glede na smer vode je lahko zavesa ravna ali pa močno vijugasta (nagubana). Kristali kalcita rastejo z daljšimi osmi pravokotno na smer polzenja vode. Plasti sige v zavesah so lahko različnih barv, odvisno od kemične sestave razstopine, iz katere raste.

Sigovi slapovi so zelo pogosta oblika nastopanja sige. Izloča se iz polzeče vode v obliki slapov, pri katerih se tanke plasti sige izločajo druga čez drugo. Posamezne plasti so lahko tudi pri taki obliki različnih barv, odvisno od raztopine. Med njimi se lahko odložijo tudi ilovnate plasti. Kadar sigovi slapovi ne dosežejo tal, ampak

Sigast steber v vhodni dvorani jame Vilenica.
Flowstone column in the entrance hall of Vilenica.

obvisijo v zraku, jih imenujemo baldahin.

Ponvice nastajajo iz vode, ki se preliva čez različne pregrade. So najrazličnejših velikosti, od nekaj milimetrov do nekaj metrov globoke in široke. Lahko zrastejo ob vznožju stalagmitov, na peščenih pobočjih ali pa v koritu podzemske reke.

Koralaste vrste siga se izloča v različnih oblikah iz mezeče in pršeče vode ter spominja na korale. Za svojo rast potrebuje precejšnjo vlažnost zraka v jami.

Helektiti rastejo v različnih smereh na že prej zraslih stalaktitih, stalagmitih, cevkah itn. Rastejo iz počasi mezeče kapilarne vode. Rastoči kristali sledijo načelom kristalizacije in ne gravitacije, zato so helektiti obrnjeni na vse možne strani, obenem pa so najrazličnejših oblik.

Včasih namesto sige iz raztopine zrastejo lepi **pravilni kalcitni kristali**, ki v jamah niso prav pogosti. Največkrat rastejo v skupinah in so veliki od nekaj centimetrov do enega metra. Kristali so tem bolj pravilnih oblik, čim bolj enakomerno priteka raztopina in čim več prostora ter časa imajo kristali za svojo rast. V naših jamah je pogosta rast kalcitnih kristalov v vodnih ponvicah. Kristali so lahko skalenoedrske ali rombične oblike. Ponavadi so majhni, bolj slabo razviti in obarvani.

FLOWSTONE IN THE CAVES IN KRAS

Nadja Zupan Hajna

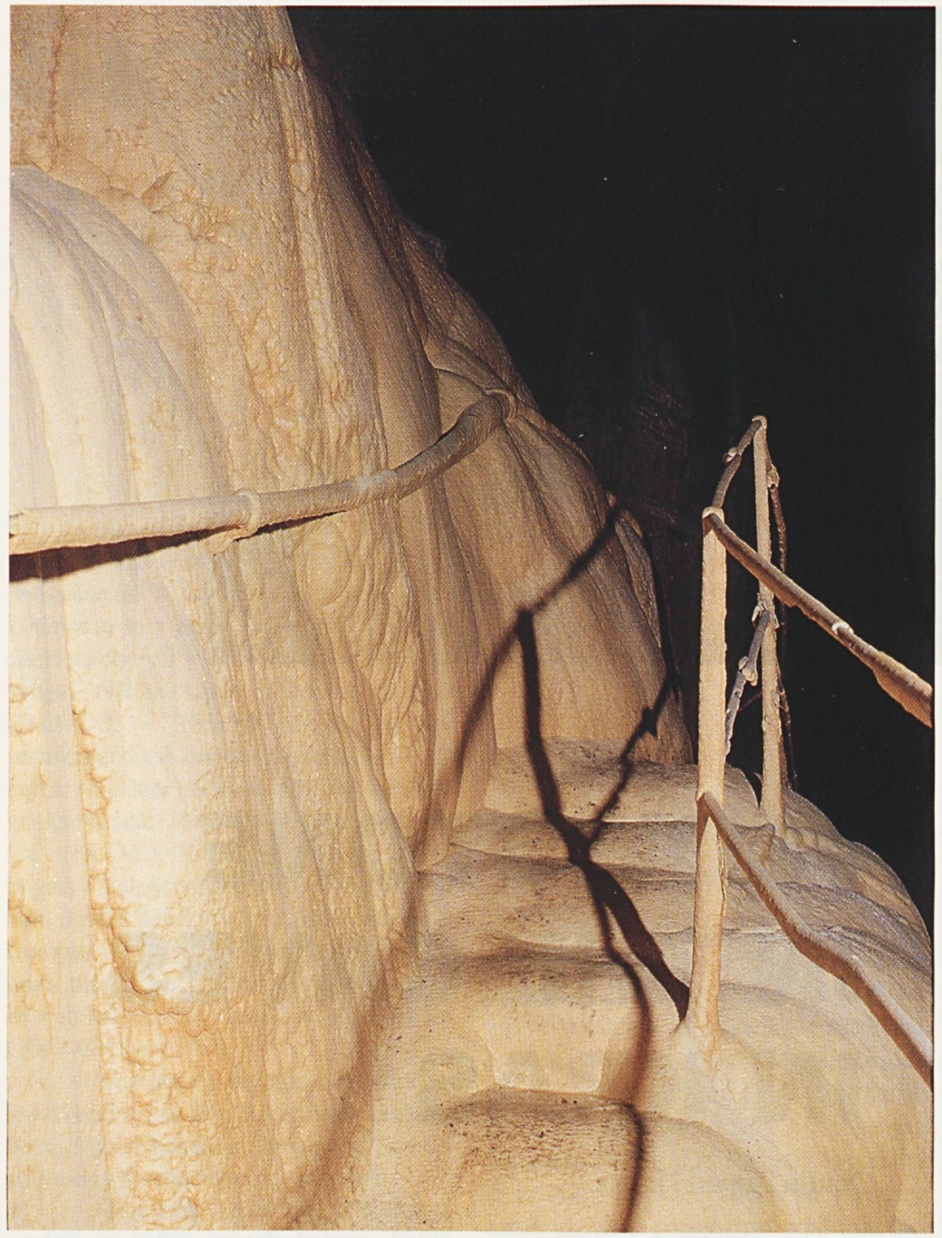
Flowstone is normally calcite precipitated from saturated mineral solution. According to the Slovene Karst Terminology it is a deposition of calcium carbonate from saturated ground water that had been aerated. The main controls being drip rate and height and saturation levels of the water.

The flowstone is the commonest form of calcite appearance. In karst caves it may be found in various forms. The shape of flowstone depends on the mode of the solution flow. Hydrologic mechanisms influence the shapes of flowstone: dripping, flowing, seeping, pooled and condensation water.

Flowstone deposition

In caves flowstone is deposited from a solution oversaturated by calcium carbonate. In the atmosphere and during the infiltration through the soil the rainwater is enriched by CO_2. These two components together form a weak carbonic acid ($H_2O + CO_2 = H_2CO_3$). While infiltrated through the carbonate rocks this acid dissolves the rock giving rise to calcium and hydrogencarbonate ions ($CaCO_3 + H_2CO_3 = Ca^{2+} + (HCO_3)^-$). When the solution rich in calcium and hydrogencarbonate ions reaches the cave space the equilibrium is no more achieved. Due to partial pressure of CO_2 and temperature the calcium carbonate starts to precipitate ($Ca^{2+} + (HCO_3)^- = CO_2 + CaCO_3 + H_2O$).

The form of the deposited flowstone depends on the changes of feedwater flow, and its mineral composition depends on presence of other ions in the solution.



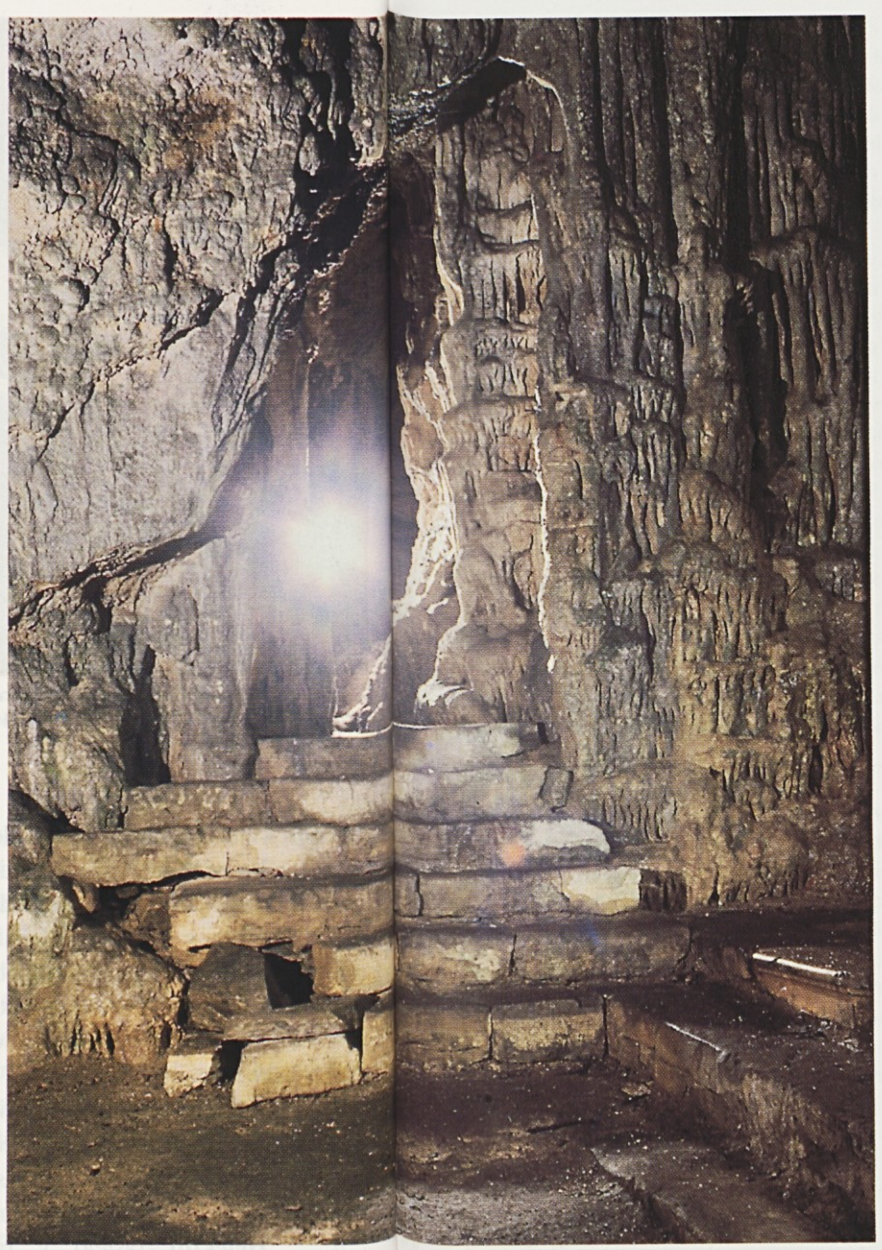
V Škocjanskih jamah je v sto letih prekrila stezo v Hankejevem kanalu več kot 10 cm debela plast sige.
In Škocjanske jame, more than 10 cm of flowstone deposited in hundred years on the path in Hankejev most.

Barva sige

Barva sige je lahko zelo različna, od popolnoma bele, drap, rumene, rdeče, rjave, sive do črne. Na barvo kalcitne sige vplivajo različni kationi v raztopini. Železo daje rumeno, rjavo in rdeče obarvano sigo, mangan sivo in črno, baker zeleno in žvepleno- rumeno. Sigo obarvajo tudi naneseni mulj, glina, prah in organsko gradivo. Drobnokristalna siga je ponavadi bela in zelo čista, medtem ko je debelokristalna siga rahlo rumeno ali rjavo obarvana.

Starost sige

Kdaj se je kalcitna siga izločila iz raztopine, lahko določimo z relativnimi in absolutnimi metodami. Relativno starost se določa glede na ostale plasti sige, vendar pove le to, katere plasti so starejše in katere mlajše. Absolutno starost sige določimo med drugim s ^{14}C in U/Th radioaktivnima metodama. Z deležem ogljikovega izotopa ^{14}C v kalcijevem karbonatu lahko določimo starost sige le, če vemo, da med izločanjem sige ni bilo v njej še nič izotopa ^{14}C. S to metodo lahko določimo starost do 35.000 let. Drugi način za določanje absolutne starosti sige je uran-thorijeva radioaktivna metoda, ki temelji na tem, da se sočasno z izločanjem sige v manjših količinah izločajo tudi kompleksni uranovi karbonati. Radioaktivni uran razpada in čim starejša je siga, več torija in manj urana vsebuje. Meja za določanje starosti s to metodo je 350.000 do 400.000 let. Metodi, s katerima lahko določimo tudi višjo starost, sta termoluminiscenčna in ESR metoda. Rezultati vseh predstavljenih metod imajo, seveda, določen odstotek napake. Najstarejša znana siga v Sloveniji je iz Pisanega rova v Postojnski jami.



Siga kot dekoracija oltarja v Sveti jami pri gradu Socerb. (Vse fotografije: J. Hajna)
Flowstone as a decoration for the altar in Sveta jama near the Socerb castle. (All photos: J. Hajna)

Oblika sige na matičnem Krasu

Skoraj vse jame na matičnem Krasu so obilno zakapane. V njih najdemo sigo najrazličnejših oblik; stalaktiti, stalagmiti, stebri nastopajo v vseh mogočih oblikah. V teh jamah so lepi cipresasti stalaktiti, velike ponvice, helektiti, čebulasti kapniki, ježki, koralaste sige in tudi posamezne palete, ki so v Sloveniji razmeroma redke. Največ sige je bele barve; posebno tiste, ki raste še sedaj. Relativno starostno določene starejše sige so pa rjavkaste, rumenkaste in rdečkaste barve.

The flowstone consists of very small, medium or large crystals of calcite. Large crystals in flowstone usually occur when the solution is very pure and water seeping, or at recrystalisation. The recrystalisation of fine-crystal flowstone occurs because all the substances tend to achieve more resistant form and large crystals are much more stable than the small ones.

The most common shapes of flowstone

The shape depends on quantity and mode of waterfeed flow. The most common is dripwater, providing growth of stalactite and stalagmite deposits in a longitudinal axis of a dripping trickle. The water flowing over walls and floor deposits flowstone in layers. Coral shapes of flowstone are deposited of seeping or splashing water, helictites from capillary water that seeps of tiny fissures. On pooled water in basins and ponds a rimstone-pools occur, other shapes of flowstone are due to various hydrological mechanisms.

Stalactites are the best known form of a speleothem formed by dripping water hanging from a cave roof. They display an enormous variety of sizes and shapes, from tiny to thick and massive and may be several metres long. Calcite is precipitated round the rim of the water droplet and continued deposition creates a hollow tubular straw stalactite. Additional deposition of calcite on the outside of the initial cylinder creates an ordinary stalactite. The water moves down the core and precipitate at the bottom slowly extending the length. Stalactites are banded concentrically to the center. Stalactites are usually of a pure calcite although sometimes they contain other minerals due to different conditions. When the composition of the solution changes instead of calcite the aragonite crystals may be deposited. When a flood occurs the minerals from flood loam may be mixed to speleothem. Such stalactites may evidence the periods of flowstone deposition and periods of floods. During the growth of a stalactite these conditions may change several times.

Stalagmites are convex form of speleothem, formed by upward growth from a cave floor and are commonly found beneath stalactite. Stalagmites form when dripwater that is still saturated falls from a cave roof. Stalagmites are usually thicker and shorter than stalactites, with a rounded top. On contrary to stalactites thay have no central hollow core; the banding of stalagmites is parallel to the surface at the time of deposition of each band. When water drips from substantial height the droplet splashes and resulting stalagmites have plate-shaped top. Between the bands in stalagmite other minerals may be found due to changes in chemical composition of the solution or due to floods that had deposited flood loam. Stalagmites also display a variety of forms. Some of them resemble cypresses, Christmas trees, giants, dwarfs, clubs, pagodas and so on.

Columns occur when stalagmite and stalactite grow until they connect, thereby joining roof to floor. At continued growth the column becomes thicker and displays various forms.

Curtains are characteristic decoration in karst caves. This is hanging sheet of calcite stalactite. A curtain forms when percolation water flows down an inclined cave roof or wall in a certain direction. Due to feedwater direction the curtain may be either straight or folded. The calcite crystals grow with longer axis perpedicularly to the seeping water direction. They may be of different colours banded by mineral impurities within a solution.

Calcite flows are very common form of flowstone occurrence. The flowstone is deposited from a seeping water in a shape of cascades and thin layers of flowstone are deposited one on the other. The layers display different colours depending on solution. It normally appears banded when seen in cross-section, there may be some loam layers. When calcite flows do not reach the floor and remain hanging on the walls they are termed baldachin.

Gours are built up along the edge of a pool due to precipitation from a thin film of overflow water. They display a variety of sizes from some mm to several meters in depth and width. They may grow at the foot of a stalagmite, on sandy slopes or in a riverbed of an underground river.

Coralloid speleothem are splash deposits ressembling corals or are precipitated onto cave passage walls from mists or thin surface films of saturated water. For their growth a lot of air moisture in the cave is required.

Helictites form on stalactites, stalagmites and straws; they grow from a seepage capilary water. The helictite shape is created by crystal lattice distortion, with no apparent regard to gravity, their growth is twisted and contorted.

Sometimes, however, the solution gives rise to regular calcite crystals which are yet not common in the caves. They usually grow in groups ranging from some mm to one meter. Their uninterrupted growth may allow development of good crystals of regular forms when the solution inflow is uniform and when they have enough time and space for their growth. In our caves the occurrence of calcite crystals is frequent in pools, shaped as elongate scalenohedral pyramids of trigonal habit. Usually they are small, not well developed and coloured.

Najbolj poznane po svojem sigovem okrasju, predvsem ker so lažje dostopne, so Škocjanske jame, Divaška jama, Vilenica in Lipiška jama. Raznovrstne ter lepe sige so tudi v Jami na Prevali II, v Kačni jami, v Škamprlovi jami itn.

Škocjanske jame

Kot večina jam v matičnem Krasu imajo tudi Škocjanske jame veliko sigovega okrasja. V Tihi jami je značilna bela siga na podornih skalah, stenah in stropu. Starejša siga, kopasti in plastnati stalagmiti so rumeno in rjavo obarvani. Recentna siga se v Škocjanskih jamah izloča različno hitro; nekateri kapniki rastejo zelo počasi, v Hankejevem kanalu pa raste skorjasta siga čez nadelano pot zelo hitro, nekaj milimetrov v desetih letih. Starosti vzorcem bele sige iz Tihe doline se z U/Th metodo ni dalo določiti zaradi premajhne vsebnosti urana v vzorcih.

Veliko erodirane sige v Dvorani ponvic, v Schmidlovi jami, v Tominčevi jami ter v Brihta jami kaže, da so bile jame nekdaj še bolj bogato zasigane. Najbolje so ohranjene sige v Tihi jami, kjer se bela siga še sedaj odlaga čez obarvane starejše sige, naplavine in podorne skale.

Najbolj znane so v Škocjanskih jamah vsekakor sigove ponvice v Dvorani ponvic. Oblikovale so se na poševnem peščenem pobočju v polju s površino okrog 80 kvadratnih metrov. So najrazličnejših velikosti; večje so globoke od 10 do 40 centimetrov. Vseh ponvic je okrog 100. Največje so v srednjem pasu sigovega kupa; nižje se njihova velikost manjša.

Divaška jama

V Divaški jami vidimo veliko različnih sig. Veliko kapnikov je na tleh in na stenah; na stropu jih je malo. Najbolj pogosti so svečasti in cipresasti stalagmiti, tanke skorje, zavese in prevleke po tleh in stenah, ponekod stalaktiti na stropu. Te sige so belkaste, verjetno najmlajše. Največ jih je na podornih skalah v Modrijanovi, Pretnerjevi in Žibernovi dvorani. V to generacijo najmlajše sige naj bi spadali tudi helektiti, ki obraščajo starejšo sigo v Hramu in v spodnji Žibernovi dvorani ter koralaste izrastke na spodnjih delih kapnikov v Modrijanovi dvorani.

Starejše so rumenkasto, rjavkasto-rdečkaste grobokristalne sige, iz katerih so v Divaški jami oblikovno najbolj opazni kopasti kapniki, rebrasti stebri, plastnati baldahini in več metrov debele sige na tleh. Posamezne kope in stebri imajo ponekod čez meter premera in merijo do 15 metrov visoko. Plastnatost te sige je posebno dobro opazna v kopah Vhodne dvorane in Serpentin. Oblika in sestava te sige kažeta dolgo počasno rast z večkratnimi prekinitvami.

Najstarejša siga v Divaški jami naj bi bila rebrasta kristalna siga, pokrita z rjavo pasovito ilovico na koncu Žibernove dvorane. V Vhodni, Modrijanovi ter Reševerjevi dvorani, v Hramu in Hodniku so debeli in veliki stalagmiti ter stebri, ki so večinoma podrti. Najbolj izrazit pojav Reševerjeve dvorane je podrti stalagmit Harambaša, 12 metrov visok kapnik, ki se je prelomil in

The colour of a flowstone

Flowstone displays very different colours, from pure white over yellow, red, brown, grey to black. The colour of a calcite flowstone is controlled by various kations present in a solution. Iron gives yellow, brown and red coloured speleothems, manganese grey and black, copper green and sulphur yellow. The speleothems may be coloured by silt, loam, dust and organic matters. Fine-crystal flowstone is commonly white or colourless when pure, while coarse-crystal may be yellowish or brownish.

The age of flowstone

Determination of the age of calcite flowstone may be done by relative or absolute methods. Relative dating may be defined by correlation of other layers of flowstone, however it tells only which layers are older and which younger. Absolute datings in current use are among the others the Carbon-14 and U/Th radiometric methods. This type of dating is based upon a knowledge of the constancy of radioactive decay. By a rate of a carbon isotope 14C in calcium carbonate the age may be determined only if one knows that during the flowstone deposition there was no isotope 14C present. The radiocarbon method is applicable over the range from a few hundred years to about 35.000 years ago. The other technique for absolute dating of flowstone is the Uranium/Thorium radiometric method based on knowledge of the rates of decay of radioactive isotopes of Uranium to Thorium in stalagmites. The radioactive Uranium decays, hence, the oldest is flowstone the most it contains Thorium and the least Uranium. The age is determined in respect to Uranium Thorium ratio. This method allows measurements of ages from 350.000 to 400.000 years old. The methods by which even higher ages may be determined are the thermoluminiscence dating and the electro spin resonance (ESR) method. Obviously the results of all the mentioned methods have a certain degree of mistakes. The oldest known flowstone in Slovenia was dated from Pisani rov in Postojnska jama.

The shapes of flowstone in Classical Karst

Almost all the caves in Classical karst are richly decorated. The flowstone occurs in a variety of forms, there are stalactites, stalagmites, columns in every imaginable shape. In these caves are nice cypress-like stalactites, massive-gours, helictites, onion-shaped speleothems, coralloid speleothems and even cave shields or palettes which are rather rare in Slovenia. Most of flowstone is white in colour in particular the one which is currently growing. Relatively dated older flowstones are brownish, yellowish or reddish in colour. The most famous because of the speleothem decoration and due to easy access are the caves such as kocjanske jame, Divaška, jama, Vilenica, Lipiška jama. Various nice flowstones may be encountered also in Jama na Prevali II, Kačna jama, Škamprlova jama etc.

Škocjanske jame

As most of the caves in the Classical Karst also Škocjanske jame are well decorated. In Tiha jama white flowstone is found on breakdown blocks, on the walls and roof. Older speleothems, wide domes and layered stalagmites, are either yellow or brown in colour. The recent flowstone deposits in Škocjanske jame by differing velocity, some speleothems grow very slowly while in Hankejev kanal the flowstone deposits over a pathway extremely rapidly, some mm in ten years even. It was impossible to determine the age of white flowstone from Tiha jama by the U/Th method due to the low U content in a sample.

A lot of eroded flowstone, in Dvorana ponvic, Schmidlova dvorana, Tominčeva jama and Brihta jama, evidences that the caves in past were still more decorated. The best preserved are flowstones in Tiha jama where white flowstone is still nowadays deposited over older coloured flowstones, deposits and breakdown blocks.

By all means, the most famous speleothems in Škocjanske jame are massive-gours in the Dvorana ponvic. They are formed on sandy slope covering about 80 m2. The gours are of various sizes ranging from 10 to 40 cm. There are about 100 gours altogether. The largest are in the middle of a wide flowstone dome, lower down their size diminishes.

Divaška jama

In Divaška jama there is a lot of various flowstone, most of speleothems are found on the floor and on the walls, they are rare on the roof. The commonest are candle-like and cypress-shaped stalagmites, thin crusts, curtains and flowstone coatings on the floor and on the walls; there are few stalactites on the roof. This flowstone is almost white, probably it is young and most of it is found in chambers called Modrijanova, Pretnerjeva and Žibernova dvorana. The helictites also should belong to this generation of the youngest flowstone grown over older speleothems in Hram and in lower part of Žibernova dvorana as well as coral-like outgrowth on lower part of speleothems in Modrijanova dvorana.

Older are yellowish, brownish and reddish coarse-crystal flowstones occurring in Divaška jama in form of domed stalagmites, fluted pillars, layered baldachins and several meters massive sheet over the floor. Single domes and pillars have somewhere more than 1 m in diameter and up to 15 m in height. That this flowstone is banded is extremely well seen at the domes in Vhodna dvorana and Serpetine. The shape and the structure of this flowstone indicate long, slow growth with several interruptions.

The oldest flowstone in Divaška jama is supposed to be the fluted crystal flowstone covered by brown layered loam at the end of the Žibernova dvorana. In Vhodna, Modrijanova and Rešaverjeva dvorana, in Hram and Hodnik there are thick and tall stalagmites and columns which collapsed mostly. The most prominent form in Rešaverjeva dvorana is collapsed stalagmite called Harambaša, thick speleothem 12 m in height that had been broken and overturned to the calcited floor. On the place where it stood are now growing new candle-like and cypress-shaped stalagmites, up to 10 m in height. Richly decorated by several generations of speleothems is also the passage named Serpentine. In Modrijanova dvorana the flowstone domes, cypresses and candles prevail almost reaching the ceiling, 10 m high and stalagmites with coraloid outgrowths; on calcited slopes micro- and macro-gours developed. Also Žibernova dvorana is well decorated, pillars and stalagmites are almost reaching the ceiling which is 20 m in height. A meter tall stalagmites decorate the calcited slope and floor, and helictites add to general flowstone richness.

Vilenica

Vilenica is one of the most decorated caves in Slovenia. From the late-18th century to the 19th century it was our the most known and well visited show-cave famous for its beautiful and diverse flowstones. In almost entire cave, with exception the chambers Vilinska dvorana and Fabrisova dvorana, the speleothems are sooty and blackened due to use of torches and carbide lamps in the past. In the entrance part there are typical huge speleothem pillars, in Hodnik the speleothems are all over, on walls, roof and floor. The passage continues in Rdeča dvorana, well decorated again and the last chamber is Vilinska dvorana where speleothems preserved the original brown and reddish colours. In the chamber Fabrisova dvorana one may find not only usual flowstone decoration but also the crystals of calcite on the roof, helictites and onion-like speleothems and a peculiar form of loamy stalagmites with calcite needles. The samples of this flowstone were dated by the Carbon-14 method from 18.865 to 36.005 years. At the entrance to Fabrisova dvorana brown crusty flowstone was dated by the U/Th method to 80.200 years.

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prevrnil na zasigana tla. Na mestu, kjer je stal, so zrasli novi svečasti kapniki, poleg pa je še do 10 metrov visok cipresasti stalagmit. Bogato zasigan rov z več generacijami različno oblikovanih kapnikov, med katerimi izstopajo cipresasti kapniki, je tudi rov Serpentine. V Modrijanovi dvorani prevladujejo sigove kope, ciprese in sveče, ki segajo skoraj do 10 metrov visokega stropa, stalagmiti s koralastimi izrastki, v pobočjih sige pa so se oblikovale večje in manjše ponvice. Tudi Žibernova dvorana je močno zasigana, kopasti stebri in stalagmiti segajo do 20 metrov visokega stropa. Meter visoki stalagmiti krasijo sigova pobočja in tla, helektitne tvorbe pa pestrijo siceršnje sigovo bogastvo.

Vilenica

Vilenica je med najbolj zakapanimi jamami v Sloveniji. V 18. stoletju in v začetku 19. stoletja je bila to naša najbolj znana in obiskana turistična jama, ki je slovela predvsem po lepih, raznovrstnih in številnih sigah. Skoraj v vsej jami, razen Vilinske dvorane in Fabrisove dvorane, so kapniki sajasti in počrneli zaradi nekdanje uporabe bakel in karbidnih svetilk. V vhodnih delih so značilni veliki kapniški stebri, po Hodniku kapniških stebrov so kapniki na steni, stropu in tleh. Hodnik kapniških stebrov se nadaljuje v močno zakapano Rdečo dvorano. Zadnja dvorana je Vilinska dvorana, v kateri so kapniki ohranili prvotne barve, rjavo in rdečkasto, medtem ko so do te dvorane vsi kaniki sajasti. V Fabrisovi dvorani najdemo ob običajnem kapniškem okrasju še kristale kalcita na stropu, helektite, čebulaste kapnike in ježke, to je ilovnate stoječe kapnike s sigovimi bodicami. V tej dvorani je bila vzorcem sige s ^{14}C metodo določena starost med 18.865 in 36.005 let. Na vhodu v Fabrisovo dvorano je bila starostno določena rjava skorjasta siga na 80.200 let z U/Th metodo.

Lipiška jama

Lipiška jama je znana predvsem po izredno velikih stalagmitih, ki so različnih oblik. Med najvišjimi meri eden kakšnih 18 metrov. Ostali stalagmiti so najrazličnejših oblik in velikosti. V jami so tudi paletne kapniške tvorbe, zrasle vzporedno s steno, iz katerih rastejo cevčice.

Na začetku Kozinskega rova so posebnost tudi trikotni kapniki, ki so nastali s prekristalizacijo drobnozrnatih sig. Oblika nastane, ker snovi težijo k ureditvi, trikotni kapnik pa je v bistvu en sam trigonalni kalcitni kristal. Verjetno so to zelo stare sige, ker potrebuje taka pretvorba zelo veliko časa.

Pred prehodom v Kozinski rov je bila z U/Th metodo ugotovljena starost rumeno skorjaste sige, ki presega 35.000 let. V zgornjem delu istega rova pa je bila starost baze polomljenega trikotnega kapnika določena na 160.400 let.

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BURJA

Andrej Mihevc

Burja je gotovo eden izmed najbolj značilnih, včasih tudi neprijetnih vremenskih pojavov na Krasu, v Vipavski dolini in v Primorju. Pojavi močne burje so prišli v zgodovinske knjige, prilagoditev nanjo je pustila pomembne sledove v arhitekturi hiš in vasi na Krasu. Zaradi burje na Primorskem ne uspevajo številne rastline. Pozimi dela burja preglavice, kakršnih si prebivalci drugih delov Slovenije niti ne predstavljajo.

Tovorniki na Krasu, J.V.Valvasor
Transport by pack horses on Kras. J.V. Valvasor.

Prilagoditev naselij burji. Stara kamnita hiša s kamnito streho je za moč burje neobčutljiva.
Novejše opečne strehe pa že potrebujejo obtežitev; ta je lahko kamnita ali pri novejši strehi iz betonskih blokov. Podnanos.
Adaptation of villages to bora. Old stony house with stone-laid roof is insensitive to bora.
Modern tiled-roof houses need additional weight; this may be either stony or, the most recenty of concrete blocks. Podnanos.

Prvi opis burje izvira že iz antike. K zmagi cesarja Teodozija v bitki pri Ajdovščini 6. septembra leta 394 je pripomogel ledeni severni veter - burja. Ta je privršal z gora ter Teodozijevim vojakom trgal sulice iz rok in jih metal v sovražnike. Burjo omenja tudi Valvasor, ko opisuje podnebje dežele in težave, ki jih imajo tovorniki na Krasu. Burja je bila tedaj še močnejša od sedanje, saj je bil Kras zaradi paše brez drevja ali gozdov.

Burja je suh, hladen, sunkovit in pogosto zelo močan severovzhodni veter, ki se lahko pojavi v primorski Sloveniji v vsakem letnem času, zlasti močan in pogost pa je v zimski polovici leta. Kjer je burja močnejša, lahko vidimo njene učinke na poševno rastočih drevesih in njihovih nesimetričnih krošnjah. Burja nastane, kadar se zaradi razlik v pritiskih hladnejši, gostejši zrak preliva čez grebene Trnovskega gozda, Nanosa, Hrušice, Javornikov in Snežnika na primorsko stran. Enakega nastanka je tudi burja, ki se pojavlja na Hrvatskem, pod Velebitom in južneje vzdolž dalmatinske obale.

Kljub temu, da se zrak pri spuščanju nekoliko ogreje, je prodor hladnega zraka tako hiter in močan, da povzroči

BORA

Andrej Mihevc

The local wind bora is one of the most characteristic and sometimes even unpleasant meterological occurrences in Kras, in Vipava valley and in Littoral. The gusts of bora entered the historical books, the adaptation left important traces in local architecture of houses and villages in Kras. Due to bora several plants cannot thrive on Primorska. Under winter conditions bora causes troubles that cannot be even imagined by the inhabitants of other parts of Slovenia.

The first description of the wind bora derives from antiquity. The icy nord wind - bora helped caesar Teodosius to win the battle near Ajdovščina on September 6, 394. The wind had whistled from the mountains wrenching the lances from the hands of Theodosius's soldiers and throwing them into enemies. Also Valvasor mentions bora when describing the climate of the country and the troubles that it causes to cargo? on Kras. In that time bora was even stronger than it is today as Kras was bare landscape without trees or forests, due to pasture.

The bora is dry, cold NE wind with dangerously intensive gusts which may appear in southern Slovenia throughout the year, yet it is the strongest and the most frequent in its cold part. There where the bora is frequent one may see its effects on wind-shaped trees.

Bora is due to difference in pressure, when colder, more dense air blows over the ridges of Trnovski gozd, Nanos and Hrušica, Javorniki and Snežnik to the southern slopes. Similar origin may be attributed to bora that appears in Croatia, below Velebit Mts. and along the Dalmatian coast.

Although the air warms a little while descending, the cold air outbreak is so fast and strong that the wind causes the change in temperature and this is the reason that one cannot find in our littoral places numerous mediterranean plants that are thriving elsewhere where bora or similar wind do not exist. The warming of the descending air means that the air dries at the same time, the clouds disappear and dry, sunny, but fresh weather appears.

The most frequently the strongest bora appears in the winter half of the year when the differences between the continental part and the littoral are the highest. When it occurs after passage of the cold front it mostly blows for one or two days only; when there is above middle Europe strong anti-cyclon and in the west, above the Mediterranean, low air pressure, bora may blow for 5 days even.

The extreme velocities reached by gusts of bora are due to cold air falling and not to difference in pressure. The velocity of bora is thus controlled by the differences in air temperature on both sides of mountain chains, by altitude of air fall and by the topography of the relief, which may canalise the wind and intensify it locally. Distance from the slopes decreases the bora velocity, however it persists far from where it originated. At us the strongest bora appears below Nanos and Trnovski gozd where the air downfall is the greatest or, for example near Postojna where the air is directed by Postojnska vrata.

The second property of bora are its gusts. When the cold air blows over the ridges, mostly due to friction with ground, the air whirls and those whirlwinds may be felt as gusts of various intensity and direction. Thus the direction of bora varies up to 45°, but even larger deviations from the main direction were observed.

Bora is due to relief topography, yet its direction and strength vary from place to place, the altitude controls its temperature and the occurrence of snow and snow-drifts. Longer lasting systematic observations of bora were at Ajdovščina only, at some other places like at Divača, Ocizla, Tinjan and in Pivka basin the observations lasted shorter time only.

burja občasen padec temperature, kar je vzrok, da v naših primorskih krajih ne uspevajo številne mediteranske rastline, kakršne najdemo drugod, kjer burje ali podobnega vetra ne poznajo. Ogrevanje zraka pri spustu pa pomeni, da se ta zrak tudi osuši, oblaki se razblinijo, nastopi suho in sončno, a sveže vreme.

Burja največkrat nastane in je najmočnejša v zimski polovici leta, ko so temperaturne razlike med kontinentalnim delom in primorskim delom Slovenije največje. Kadar nastane po prehodu hladne fronte, ponavadi piha le dan ali dva dni, kadar pa se nad srednjo Evropo razprostre močan anticiklon, medtem ko je zahodneje, nad Sredozemljem, območje nizkega zračnega pritiska, pa lahko burja traja tudi do pet dni.

Izjemne hitrosti, ki jih burja dosega, so posledica padanja hladnega zraka in ne posledica razlik v pritiskih. Hitrost burje je tako odvisna od razlik v temperaturi zraka na obeh straneh gorskih pregrad, od višine padca ter od oblikovanosti reliefa, ki jo lahko kanalizira ali usmerja in lokalno močno ojači. Z oddaljenostjo od pobočij se hitrost burje zmanjšuje, vendar se ohranja še daleč od svojega nastanka. Pri nas je tako najmočnejša burja pod Nanosom in pod Trnovskim gozdom, kjer je padec zraka največji, ali pri Postojni, kjer se zrak kanalizira v Postojnskih vratih.

Druga značilnost burje je sunkovitost. Ko se hladen zrak prelije čez slemena, predvsem pa zaradi trenja s tlemi, se zrak vrtinči. Take vrtince zaznamo, ko potujejo čez nas, kot sunke različnih jakosti in smeri. Smer burje zato niha do 45 kotnih stopinj, poznani pa so še večji odkloni od glavne smeri.

Ker je burja posledica oblikovanosti reliefa, sta njena smer in moč od kraja do kraja različni, od nadmorske višine pa so odvisni tudi njena temperatura oziroma pojav snega in snežnih zametov z njo. Daljša sistematična opazovanja burje so bila le v Ajdovščini, na nekaterih drugih krajih, na primer v Divači, Ocizli, Tinijanu in v Pivški kotlini, pa so jo opazovali le krajši čas.

Najmočnejša burja se je pojavila v Vipavski dolini; pri Ajdovščini je bila izmerjena njena največja hitrost 170 kilometrov na uro (km/h), povprečna jakost njenih sunkov pa je bila 36,3 metra na sekundo (m/s), to je 94,5 km/h. Največja izmerjena hitrost burje oziroma hitrost njenega sunka je bila 47,4 m/s ali 170,6 km/s.

V Divači so hitrosti burje nekoliko nižje. Povprečna urna hitrost je bila 5,1 m/s (18,3 km/h) ob povprečni jakosti sunkov 19,5 m/s (70 km/h). Najmočnejši zabeleženi sunek pa je imel hitrost 45 m/s (162 km/h). Še manj močna je burja v Pivški kotlini, vendar burja tod pogosto piha med sneženjem. Posledica so snežni zameti na cestah med Postojno in Razdrtim in tudi naprej, prav do Divače. Močnejša burja se spet pojavi pod Kraškim robom in v Tržaškem zalivu. Kjer je burja najmočnejša, se pojavi nad vrhovi gorski oblak. Višina oblakove baze je odvisna od temperature in vlažnosti zraka. Tak oblak na Nanosu je znak za burjo na Krasu in v Tržaškem zalivu.

Burja se pojavlja v vseh letnih časih; redka je le v juliju in avgustu. Najpogostejša in najmočnejša je v januarju, februarju in decembru. Tedaj lahko piha močna burja tudi več dni zapored. V Ajdovščini lahko računamo na več kot 20 dni na leto z močno burjo s posameznimi sunki nad 20 m/s. Enako število dni na leto z nekoliko šibkejšo burjo pa je seveda pričakovati tudi na Krasu.

Moč burje je tako velika, da lomi drevje, odkriva strehe ali prevrača avtomobile na cestah. Naselja na Krasu so zato nastala tam, kjer je burja šibkejša; strani hiš, ki so izpostavljene burji, imajo manj odprtin; hiše so brez velikih napuščev. Ko so strme strehe s slamnato ali kamnito kritino v prejšnjem stoletju zgradili nadomestile položnejše strehe, krite z lahkimi opekami, so morali te dodatno obtežiti, kar daje prenekateri strehi nenavaden videz. Včasih so v Trstu ob najmočnejši burji po ulicah ob hišah napeli vrvi, da so bile ljudem v oporo.

Bolj kot naselja so burji izpostavljene ceste. Ceste v Vipavski dolini so zaprte tudi do deset dni na leto zaradi močnega vetra. Na avtocestah, ki prečkajo Kras, so na najbolj izpostavljenih mestih posebne zaščitne ograje in opozorila, ki nevajenim voznikom sporočajo nevarnost sunkovitega bočnega vetra.

Pojav burje pogosto spremljajo še sneg in snežni zameti, pogosto pa tudi žled. Sneg in zameti so najbolj pogosti v višjih legah na Krasu, med Razdrtim, Senožečami, Divačo in Sežano. Tu so tako pogosti, da resno ovirajo promet. Zaradi zametov so ob železniški progi čez Kras v prejšnjem stoletju zgradili visoke kamnite zidove. Tudi danes dela burja preglavice v cestnem prometu, pred zameti pa se branijo s postavljanjem palisad ali posebnih stalnih ograj.

Veliko gospodarsko škodo povzroča tudi žled. Je tudi pojav, ki pogosto spremljajo burjo. Žled nastane, kadar pri tleh piha hladna burja, nad njo pa zahodnik prinaša deževne oblake. Dež, ki pade skozi spodnji sloj hladnega zraka, se podhladi in takoj ob dotiku z drevjem ali s tlemi zmrzne. Tako nastanejo debele in težke ledne obloge, ki lomijo drevje, trgajo žice in povzročajo poledico na cestah.

Čeprav povzroča burja tudi številne težave, pa je ta hladni suhi veter tisto, kar daje tej pokrajini poseben čar in jo loči od ostalih kraških pokrajin v Sloveniji.

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Oblak burje nad Javorniki.
Zrak, ki pada z Javornikov se ogreva, zato se suši in oblak se razblinja.
Razcefrani robovi oblaka kažejo vrtinčast značaj burje.

The bora cloud above Javorniki.
The air falling from Javorniki warms up and therefore dries and the cloud vanishes.
Tattered borders of a cloud indicate the whirling character of bora.

The strongest bora appears in the Vipava valley, at Ajdovščina maximum reported velocity was 170 km/h. At Ajdovščina the average annual velocity of bora from NE direction in the period from 1975 to 1985 was 5,4 m/s (19,5 km/h), and the average intensity of gusts was 26,3 m/s (94,5 km/h). The strongest reported gust was 47,4 m/s (170,6 km/h).

At Divača the velocities are slightly lower. The average hourly velocity of 5,1 m/s (18,3 km/h) and the average velocity of gusts of 19,5 m/s (70 km/h) are reported. The strongest registered gust was 45 m/s (162 km/h). Slightly less strong is bora in the Pivka basin yet there it is very common during the snowfall. The results are snow-drifts on the roads between Postojna and Razdrto and even further to the south, to Divaèa even. Stronger bora reappears again below Kraški rob and in Trieste Bay. When the bora is the strongest a typical mountain cloud appears above the ridges. The altitude of the cloud's base depends on temperature and air humidity. Such cloud over Nanos indicates the bora on Kras and Trieste Bay.

Bora appears in all the seasons, it is only more rare on July and August. The most frequent and the strongest is on January, February and December. In these months strong bora may persist for several consecutive days. At Ajdovščina one may reckon to over 20 days with strong bora, maximum gusts of over 20 m/s. The same number of days with slightly weak bora may be expected on Kras.

The bora strength is such that trees are broken, houses unroofed, and cars overturned on the roads. This is why the villages on karst appear there where bora is weaker, the sides of the houses exposed to bora have less openings, they have short juttings. When steep tatches or stone-laid roofs were replaced in the past century by gentler tiled roofs that are lighter, people had to additionally put the load on them and it gives an odd appearance to many roofs. In Trieste in past the ropes were stretched on the streets during the most severe bora in order to provide a prop to people.

More than villages, the roads are exposed to bora. The roads in the vipava valley are closed up to 10 days per year due to strong wind. On motorway crossing Kras there are on the most exposed sections special protection railings and warnings for drivers against danger of lateral wind gusts. The bora is frequently accompanied by snow and snow-drifts as well as sleet. Snow and snow-drifts are the most common at higher locations on Kras, among Razdrto, Senožeče, Divača and Sežana. By their frequency they serious obstacle to traffic. Because of snow-drifts high stone walls were built along the railway over Kras in the past century. Still today bora makes trouble to road traffic, the roads are protected against the snow-drifts by palisades and special permanent railings.

A huge economic damage is done by sleet which also is one of the accompanying occurrences of bora. Sleet develops when cold bora blows near the ground and above it the western wind brings rainy clouds. The rain that falls through lower layer of cold air cools down and at the contact with ground or tree it freezes. Thick and heavy ice coatings appear, breaking trees, tearing wires and the roads are slippery.

Although bora makes trouble, nevertheless this cold dry wind gives special attraction to the landscape and is quite distinguished from all other karst areas in Slovenia.

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Življenje v JAMAH

Tanja Pipan

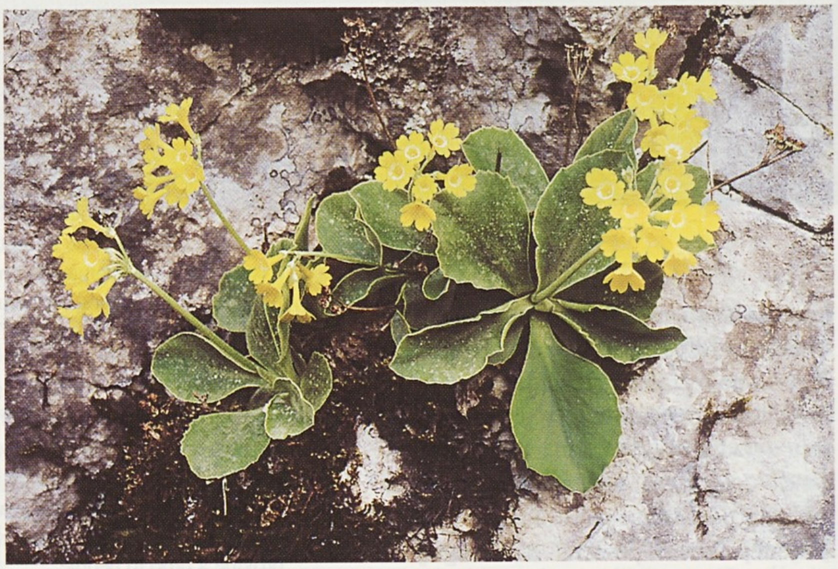
Podzemni kraški svet je svet tišine in teme, v katerega tudi sega življenje in ustvarja čudovito prilagojene hroščke in polžke, človeške ribice in netopirje. Nekatere jame skrivajo v svojih plasteh celo sledove davnega človeka. Organizme, ki živijo v jamah - posebno tiste, ki so se prilagodili podzemeljskemu življenju - proučuje jamska biologija ali speleobiologija. Delimo jo v speleobotaniko, ki se ukvarja z jamskim rastlinstvom, in speleozoologijo, ki proučuje jamsko živalstvo.

Ekološki dejavniki

Globoko v podzemskih jamah so abiotski ali brezživljenjski dejavniki zelo izravnani. V njih vladajo popolna tema, visoka zračna vlažnost (okrog 100-odstotna relativna vlažnost), temperatura zraka, ki se giblje okrog tamkajšnje zunanje srednje letne temperature (ki je za jame na Krasu okrog 10 stopinj C) in ozračje pogosto brez prepiha. Dnevna in letna spremenljivost teh dejavnikov je zelo majhna.

Ekološka opredelitev podzemnih živali

Tudi v podzemnem svetu so kopne in vodne živali. Med kopnimi prevladujejo vrste in skupine, ki so saprofage, kar pomeni, da se prehranjujejo z odmrlimi organizmi, fungivore in plenilske. Vrst, ki so izrazito fitofage, kar pomeni, da se prehranjujejo z deli cvetov in z nektarjem, v jamah ni. Lahko se v njih pojavljajo naključno ali če najdejo v vhodnih delih jam zatočišče. Če naštejem le nekaj jamskih prebivalcev, so to: hrošči brzci (*Anophtalmus schmidti in drugi), mrharji (Leptodirus hochenwarti, Aphaobius milleri, Bathyscia freyeri*, itn.), jamske kobilice (*Troglophilus cavicola, T. neglectus*), skakači (vrste *Sinella, Pseudosinella, Verhoeffiella, Tomocerus*) in druge nekrilate žuželke; nekateri pajki (*Stalita taenaria*), paščipalci (*Neobisium spelaeum, Chthonius spelaeophilus,* itn.), suhe južine (vrste *Ischyropsalis* in *Siro*), pajkovci (*Koenenia*),



Alpska rastlina avrikelj (Primula auricula) in sredozemska rastlina venerini laski (Adiantum capillus-veneris) na istem mestu, v udorni Veliki dolini Škocjanskih jam

The Alpine plant Primula auricula and the Mediterranean plant Adiantum capillus-veneris thrive in the same area, the collapse doline Velika Dolina, Škocjanske jame. (Foto/Photo: P. Skoberne).

Pivška slepa postranica (Niphargus spoeckeri) je med pogostejšimi živalcami v dnu podzemeljske Pivke. Pogosto se znajde tudi na močerilovem jedilniku

Niphargus spoeckeri is one of the frequent animals living on the bottom of the underground river Pivka. With greatest delight, the creature is often consumed by the proteus.
(Foto/Photo: B. Sket).

mnoge pršice (*Eugamasus, Spelaeothrombium, Rhagidia gratiosa, Belba longipes*); stonoge (vrste *Brachydemus* in *Polydesmus*) strige (*Lithobius stygius*), kopenske mokrice (vrste *Porcellio* in *Armadillidium*) ter mnoge vrste polžev (vrste *Zospeum, Spelaeodiscus, Spelaeoconcha*). Občasno obiskujejo jame tudi netopirji (dnevno spanje, prezimovanje), glodalci (miši in podgane) ter ptiči. Netopirji in ptiči, ki lete globoko v temno podzemlje, se orientirajo z eholokacijo. Ekološki pomen občasnih prebivalcev je v vnašanju iztrebkov (gvano), ki so prehranjevalna osnova drugim živalskim organizmom. Navadno so kopice gvana centri naseljenosti saprofagih in koprofagih (govno uživajočih) členonožcih.

Po vrstah in sistematskih skupinah bogata je vodna favna podzemskih votlin, saj najdemo tod vrste iz večine rodov, ki živijo v površinskih vodah. Zelo pogoste vrste v podzemskih vodah kraških jam so praživali, vrtinčarji, polži (*Frauenfeldia, Belgrandiella, Lanzaia, Iglica, Hauffenia, Hadziella, Acroloxus tetensi* - čisti troglobiont ali prebivalec podzemlja, ki povezuje Ljubljanico in Krko), mnogoščetinci (*Marifugia cavatica*), pijavke (*Dina absoloni, Trocheta lykowski*), mnoge vrste rakov (*Asellus cavaticus, Monolistra, Microlista, Niphargus, Troglocaris, Speleocaris*) in od vretenčarjev v naših jamah močeril (Proteus anguinus). V delčku Bele krajine (izvir Dobličica) živi zelo enotna populacija črnih močerilov, ki je omeje-

LIFE IN CAVES

Tanja Čelhar

The underground world of karst is a world of silence and darkness into which reaches also life and creates wonderfully adapted beetles, snails, cave salamanders and bats. In their interior parts, some caves even hide the traces of prehistoric man. The organisms living in caves, particularly those which were adapted to the life underground, are studied by cave biology, i.e. speleobiology. It may be divided into speleobotany, dealing with cave plants, and speleozoology, which studies cave animals.

Ecological factors

Deeply beneath the surface, abiotic or lifeless factors are quite constant. In caves there are total darkness, high air humidity (about 100% relative humidity), the temperature of air which stays around the local external mean annual temperature (which is 10oC in the caves of the Kras), and the cave atmosphere with rare occurrances of draught. Daily and annual variations of the factors are very low.

Ecological clasiffication of underground animals

In the underground world there live land and as well as aquatic animals. Among land animals there prevail saprophagous (i.e. those which feed on dead organic matter), fungivorous, and predatory species and groups. In caves there are no distinctly phytophagous species which feed on parts of flowers or on nectar. These species may appear in caves only coincidentally or when they find shelter in the entrance parts of caves. Some of the cave inhabitants are the following: carabids (*Anophtalmus schmidti*, etc.), silphids (*Leptodirus hochenwarti, Aphaobius milleri, Bathyscia freyeri*, etc.), cave crickets (*Troglophilus cavbicola, T. neglectus*), springtails (*Sinella, Pseudosinella, Verhoeffiella, Tomocerus*), and other wingless insects; some spiders (*Stalita taenaria*), false scorpions (*Neobisium spelaeum, Chthonius spelaeophilus*, etc.), harvestmen (*Ischyropsalis* and *Siro*), arachnoids (*Koenenia*), several mites (*Eugamasus, Spelaeothrombium, Rhagidia gratiosa, Belba longipes*); millipedes (*Brachydemus* and *Polydesmus*), centipedes (*Lithobius stygius*), woodlice (*Porcellio* and *Armadillidium*), and several species of snails (*Zospeum, Spelaeodiscus, Spelaeoconcha*). Occasional visitors to caves are also bats (sleeping during the day, hibernation), rodents (mice and rats), and birds. Bats and birds, which fly deeply into the dark underground, are oriented by means of echolocation. Ecological significance of occasional cave dwellers is the deposition of guano which is the nutrition basis for other animal organisms. Heaps of quano are usually habitation centres for saprophagous and coprophagous (those feeding on dung) arthropods.

Rich in species and systematic groups is water fauna of underground caves. Here we can find species from most of the orders which live in surface waters. Very frequent species appearing in underground karst waters are protozoans, flatworms, snails (*Frauenfeldia, Belgrandiella, Lanzaia, Iglica, Hauffenia, Hadziella, Acroloxus tetensi* - a true troglobite, i.e. a permanently living cave creature, which connects the rivers Ljubljanica and Krka), polychaete worms (*Marifugia cavatica)*, leeches (*Dina absoloni, Trocheta lykowski*), several species of crustaceans (*Asellus cavaticus, Monolistra, Microlista, Niphargus, Troglocaris, Speleocaris*), and among the vertebrates in Slovenian caves the cave salamander (*Proteus anguinus*). In one part of the region Bela Krajina (the Dobličica spring) there lives a very uniform population of the black proteus, restricted to the ground waters below the north-eastern foot of Poljanska gora. Most interesting and unusual is also the following statement: The black salamander and the white one from the Dolenjska karst region are more related than the white salamander from the Dolenjska karst and the white one from the Notranjska karst region. The only true cave shell in the world is *Congeria kusceri*. Its shells were found also in the Krupa spring in Bela Krajina. Sources of food for all water animals are dead remains of plants and animals which are deposited by sinking rivers.

Due to ecological attachment of species to a hypogean, i.e. underground, environment, cave animals may be divided in: **true cave species**, i.e. **troglobites**, which evidence all characteristic adaptations to living underground and cannot be seen on the surface (except coincidentally in gushing springs, after stong water currents have carried them from caves to the surface). Among these there is a great majority of cave snails, beetles, crustaceans as well as cave salamanders. **Troglophiles**, i.e. **species which often enter the cave environment**, include cave ... which may be seen also beneath the bark of rotten tree stumps or in cellars, and surface living species of ... and insects which quite regularly choose entrance and initial parts of caves due to favourable microclimatic conditions. The third category is that of **trogloxenes**, i.e. **coincidental cave dwellers** which enter caves on occasions or are carried into caves by streams. Biospeleologists have found many troglobites also in the zone beneath na na podzemeljske vode pod severovzhodnim vznožjem Poljanske gore. Zanimiva in nenavadna je ugotovitev, da sta si črni in beli močeril z Dolenjskega Krasa bolj sorodna, kot si je beli z Dolenjskega Krasa z belim z Notranjskega Krasa. Edina prava jamska školjka na svetu je *Congeria kusceri*. Njene lupine so našli tudi v izviru Krupa v Beli krajini. Prehranjevalni viri za vse vodne živali so mrtvi rastlinski in živalski ostanki, ki jih naplavljajo ponikalnice.

Glede na ekološko navezanost vrst na hipogenično ali podzemeljsko okolje delimo jamske živali na **prave jamske vrste** ali **troglobionte**, ki kažejo vse značilne prilagoditve na življenje v podzemlju in jih zato ne srečujemo na površju (razen povsem naključno v bruhalnikih, v katerih jih izvrže iz jam močan vodni tok). Med te sodi velika večina jamskih polžev, hroščev, rakov in tudi močeril. Med **troglofile** ali **vrste, ki pogosto izberejo jamsko okolje**, spadajo jamske kobilice, ki jih srečujemo tudi za lubjem trhlih drevesnih panjev in v kleteh. Sem spadajo površinsko živeče vrste pajkovcev in žuželk, ki dokaj redno izbirajo vhodne in začetne dele votlin zaradi ugodnih mikroklimatskih razmer. V tretji kategoriji so **troglokseni** ali **naključni naseljenci**, ki zaidejo v jame ali pa jih tja prinesejo vodni tokovi. Sicer pa so mnoge troglobionte biospeleologi našli tudi v tleh zunaj jam. Ker živijo v drobnih prostorčkih tal, pravimo, da so **endogeične**. Znan je primer, ko so našli kopenske jamske polžke *Speleodiscus hauffeni* in *Zospeum schmidti* ter celo vodnega polža *Belgrandiella n.sp.* v zemlji ob sveže izkopanih cestnih odsekih. Primeri kažejo na dobro povezavo med endogeičnim in hipogeičnim svetom.

Po izvoru so vrste jamskih živali iz morja (na primer: *Marifugia*), iz površinskih vodá, prehod mnogih kopenskih vrst pa je potekal prek tal iz edafske ali talne favne (skakači, pršice, stonoge, itn.). Mnoge vrste so se razvijale v troglobionte po klimatskih spremembah, ki so nastajale v prehodu iz tericarja v kvartar (pleistocen) in pozneje. Ker so njihovi predniki našli v jamah ekološke pogoje za preživetje, govorimo o termofilnih, glacialnih in hidrofilnih reliktih (preostankih živalskih vrst iz prejšnjih časov). Prvi živijo v veliki toploti, drugi živijo v ledeniških razmerah in tretji živijo v vodnih in močvirskih okoljih.

Naravni življenjski prostor slepega jamskega močerila ali človeške ribice (Proteus anguinus) so težko dostopni vodni viri in globoka podzemska jezera Krasa
The natural habitat of the blind cave salamander, i.e. proteus, (Proteus anguinus) is hardly accessible narrow water sections and deep underground lakes of the Dinaric karst area.
(Foto/Photo: J. Hajna).

Prilagoditve jamskih živali

Ekstremnost jamskega okolja je prav v vplivu omenjenih dejavnikov. Pomanjkanje svetlobe je evolucijo jamskih živali, ki so po izvoru površinske, izbirno usmerjala v redukcijo oči, pogosto tudi kožnih pigmentov in v učinkovitejše mehanoreceptorje ter kemoreceptorje. Stopnja rudimentacije ali zakrnelosti vidnih organov je pri različnih vrstah različna. V mnogih primerih je zajela oko, optični živec in optični ganglij. Nadomestilo fotoreceptorjev, ki omogočajo orientacijo v temnih prostorih, so dolge tipalke in noge, posute s taktilnimi ali tipalnimi ščetinami (jamski raki, hrošči in pajki), za valovanje občutljivi sistemi bočnih linij in elektroreceptorji (jamske ribe, jamska dvoživka močeril (Proteus anguinus) ter kemoreceptorji. Zaradi visoke vlažnosti in enakomernosti temperature so mnoge vrste polistenohidre in oligostenotermne.

Pomanjkanje svetlobe preprečuje rast in razvoj večini fotoavtotrofnih rastlin, ki si s fotosintezo zagotavljajo prehranjevanje. Obstajajo samo heterotrofne in kemoavtotrofne bakterije, plesni in višje glive. Avtotrofna pridelava organske hrane je zato energetsko majhna. Glavni vir hrane so mrtvi organski ostanki, ki jih naplavljajo ponikalnice ali prihajajo v jame skozi špranje z vodnim izpiranjem tal na površju. Koncentracije organskih ostankov so tudi iztrebki netopirjev in ptičev, ki uporabljajo jamske votline za dnevni oziroma nočni počitek.

Škocjanske jame sodijo v submediteransko fitogeografsko območje. Sistem udornic, podzemeljskih jam in ponor Reke ustvarjajo edinstven ekološki sistem zaradi posebnih mikroklimatskih razmer, kar je svetovno znana posebnost. Tako, na primer, na izredno majhni medsebojni razdalji (60 metrov) uspevajo predstavniki

sredozemske flore (*Adianthum capilus - veneris* ali venerini laski) in reliktne alpske vrste (*Primula auricula* ali lepi jeglič). Med vrstami, ki sodijo med ogrožene in ki se jih uvršča v kategorijo redkih vrst za Slovenijo, izstopa *Orobanche hederae*, saj so ga našli v Sloveniji samo v Veliki dolini.

Prehranjevalni splet in razmnoževanje

Osnova prehranjevalnih verig v hipogeičnem ali podzemeljskem okolju niso žive zelene rastline, temveč so njihovi odmrli ostanki (odpadlo listje, les, pelod) in semena, ki dotekajo v podzemlje pasivno. Največ alohtone ali tuje, drugotne organske snovi doteka po ponornicah z naplavljanjem živih vodnih organizmov in njihovih odmrlih ostankov. Mnogo manj prinaša pronicajoča voda skozi razpoke. Njihove izmerjene količine v kapniški vodi dosegajo poleti 0,7 miligrama na liter in v jesenskem času 1,35

the surface. Since the creatures live in tiny voids within the ground they are regarded as **endogean**. Known is an example when the land cave snails (*Spelaeodiscus hauffeni* and *Zospeum schmidti*) as well as the aquatic snail (*Belgrandiella n.sp.*) were found in the ground near newly excavated road cuttings. The example evidences good connection between the endogean and hypogean environments.

In origin, the species of cave animals derive from the sea (e.g. *Marifugia*) and surface waters. The transition of several surface species was carried out over land from the edaphic fauna, i.e. ground fauna (springtails, mites, millipedes, etc.). Several species developed into troglobites after climatic changes which appeared in the transition period between the Tertiary and the Quaternary (the Pleistocene), and during some other periods. Since their ancestors encountered ecological conditions in caves favourable for survival, we may speak about thermophilic, glacial and hydrophilic relicts (the remains of animal species from previous times). Thermophilic relicts live at extreme temperatures, glacial relicts live in glacial conditions, and the latter in water and marshy environments.

Adaptation of cave animals

The extremity of the cave environment is evidenced by the influence of the previously mentioned factors. A lack of daylight has oriented the evolution of cave animals, which in their origin are land animals, to the reduction of eyes and frequently to that of skin pigmentation as well as the development of more efficient mechanoreceptors and chemoreceptors. The level of rudimentation of eyes differs with different species. In many cases, rudimentation reached the eye, optical nerve and optical ganglion. The substitution of photoreceptors which enable orientation in dark cave sections are long antennae and legs dotted with tactile bristles (cave crustaceans, beetles and spiders), systems of lateral lines which are sensitive to vibration, electroreceptors (cave fish, the cave amphibian *Proteus anguinus*), and chemoreceptors. Cave animals are well adapted to high humidity and constant temperature in their environment.

A lack of daylight prevents the majority of photoautotrophic plants, which provide nutrition by means of photosynthesis, from growing and developing. There are only heterotrophic and chemoautotrophic bacteria, moulds and fungi. Autothrophic production of organic food is thus low in energy. The main source of food is dead organic remains deposited by sinking rivers or carried into caves through fissures by percolation waters. Organic remains are concentrated also in the excrement of bats and birds which use caves during the day or night.

The caves Škocjanske are part of the sub-Mediterranean phytogeographical area. The system of collapse dolines, underground caves and the Reka ponor create a unique ecological system due to specific microclimatic conditions, which is one of the world's curiosities. In this way, representatives of the Mediterranean flora (*Adianthum capilus-veneris*) and some relict Alpine species (*Primula auricula*) thrive only 60 m one from the other. Among the threatened species, which are in the category of rare species in Slovenia, *Orobanche hederae* is of special interest, since within the entire region of Slovenia it can be found only in the collapse doline Velika Dolina.

Food chain and reproduction

The basis of the food chain in a hypogean, i.e. underground, environment is not living green plants, but their dead remains (fallen leaves, wood, pollen) and seeds which are introduced into the underground in a passive way. The majority of allochthonous, i.e. secondary, organic matter is carried along by sinking rivers which deposit living aquatic organisms and their dead remains. Considerably less organic matter enters the caves in waters percolating through fissures. The quantities measured in percolation waters reach 0.7 mg/l in summer, and 1.35 mg/l in autumn. Locally, considerable amounts of food can be found in the guano of bats and birds. With regard to the quantity and energetic value, the significance of the existing chemosynthesis of bacteria (autochthonous, primary, local production) has not been estimated so far. A function of the production may be in the products which are active in small quantities. Production of heterothrophic microbes, especially mould, which feed on organic remains, is significant as a source of food. A habitual activity of several protozoa, nematodes, snails, amphipods, woodlice, millipedes and springtails is to scrape and swallow cave loam which contains microorganisms. Feeding on loam, i.e. geophagy, was observed with young proteus larvae in the Subterranean Laboratory at Moulis, France. Measurements indicated that the underground river Pivka contains 0.23% of organically bound nitrogen, which approximately matches the amount in the river Reka. Bacteria, especially thiobacteria, which synthesize vitamins (nicotinic acid, riboflavin, vitamin B12) and actinomycetes (carotenes), are needed by animals for their successful development. It may be concluded that geophagy is also a way of satisfying the need for vitamins required by the animals living in underground caves and mining shafts.

Do danes znana najdišča proteusa v Sloveniji; več avtorjev: 1993: Proteus - skrivnostni vladar kraške teme; Vitrum, Ljubljana, 50.

Known proteus locations in Slovenia; several authors: 1993: Proteus - the mysterious ruler of Karst darkness; Vitrum, Ljubljana, p. 50.

mg/l. Lokalno so izdatne koncentracije hrane v gvanu netopirjev in ptičev. Pomen obstoječe kemosinteze bakterij (avtohtone primarne ali prvotne, domače osnovne produkcije) količinsko in energetsko še ni ocenjen. Seveda pa je lahko funkcija te proizvodnje v izdelkih, ki delujejo v majhnih količinah. Kot vir hrane je važna pridelava heterotrofnih mikrobov, posebno plesni, ki se hranijo z organskimi ostanki. Navada mnogih praživali, glist, polžev, postranic, mokric, stonog in skakačev je strganje in požiranje jamske ilovice, ki vsebuje mikrobe. Prehrano z ilovico ali geofagijo so opazovali pri mladih močerilih v jamskem laboratoriju v Moulisu. Merjenja so pokazala, da vsebuje, na primer, podzemna Pivka 0,23 % organsko vezanega dušika, kar se približno ujema z njegovo vsebnostjo v Reki. Bakterije, še posebno tiobakterije, ki sintetizirajo vitamine (nikotinsko kislino, riboflavin, vitamin B_{12}) in aktinomicete karotene, kar potrebujejo živali za uspešen razvoj. Zato je geofagija tudi način zadovoljevanja vitaminskih potreb živali, katerih življenjsko okolje so podzemeljske jame in rudniški rovi.

Prehranjevalni splet v podzemlju tako temelji na saprofagih, bakteriovorih in fungivorih ter geofagih porabnikih (mnoge vrste polžev in členonožcev), ki so potem plen predatorskih vrst. V splošnem prevladuje pri votlinskih živalih polifagija. Mali plenilci, kot so mezostigmatske in trombidiformne pršice, paščipalci, opilioni in pajki ter hrošči brzci lovijo talne gliste, saprofage pršice in nimfe drugih pršic ter skakače. Veliki plenilci, jamske ribe in močeril ter druge dvoživke lovijo rakce in polže. Hrana naših protejev ali človeških ribic so raki nifargi, jamski polži in maloščetinci. S slabšimi prehranjevalnimi razmerami je povezana telesna velikost jamskih živali. Z izjemo močerila in jamskih rib so troglobionti ostali majhni.

Metabolna aktivnost kavernikolnih živali je mnogo nižja kot pri sorodnih vrstah, ki živijo na zemeljskem površju. Respiracijska intenzivnost površinsko živeče postranice *Gammarus pulex* je, na primer, desetkrat do petnajstkrat večja v primerjavi z njeno jamsko vrsto *Niphargus virei* pri temperaturi 10 stopinj Celzija.

Ogroženost

Ogroženost jamskih ekosistemov je povezana s polucijo površinskih voda na kraškem svetu. S ponornicami pritekajo v podzemno okolje komunalno in industrijsko onesnažene vode, zaradi česar propadajo občutljivi troglobionti. V nekaterih jamah, ki so bile poznane po številčnosti protejevih populacij, so postali močerili redkost ali so iz njih povsem izginili. Številna brezna na Krasu so postala smetišča, v katera ljudje odmetujejo odpadke in poginule živali. Pač pa so, na primer, v Podpeški jami po organskem onesnaževanju voda ugotovili celo povečanje številčnosti populacij rakov *Monolistra coeca* in *Niphargus orcinus longiflagellum*. Našteli so do 1000 primerkov na kvadratni meter.

V organsko onesnaženih ponikalnicah lahko uspešno vdirajo v notranjost podzemskih tokov površinske živali, kot so ličinke enodnevnic, hironomid, površinske postranice (vrste *Gammarus*) in vodni osliči (*Asellus aquaticus*), saj so energetsko preskrbljeni z organsko snovjo, ki jo plavi voda. Te in druge površinske živali so potem kompetitorji, ki izpodrivajo jamske postranice (vrste *Niphargus*) in jamske vodne osličke (*Asellus aquaticus cavernicolus*) in druge. Nekoč v podzemski Pivki zelo redek površinsko živeči osliček *Proasellus istrianus* je dosegel z jamskim *Asellus aquaticus cavernicolus* razmerje 1:1. Številčnost jamske vrste se zmanjšuje. Proces lahko ogrozi bogato in zanimivo jamsko favno ne le v posameznih jamah temveč tudi v mnogih drugih jamah našega Krasa.

Jame na Krasu so postale in dolgo ostale prava biološka Mecca. Jamske živali so pozneje začeli odkrivati tudi drugod, vendar pa je slovenski Kras, zlasti s Škocjanskimi jamami, z Divaško jamo, z Dimnicami in z Vilenico, še vedno najradodarnejši z novimi odkritji. Povečana onesnaženost podzemlja je pogubna za podzemeljsko živalstvo. Z onesnaževanjem Krasa izgubljamo delček dragocene naravne dediščine. Izgubljamo živalske vrste, ki živijo le tod in nikjer drugje po svetu. Izgubljamo tudi bogat vir novih znanstvenih spoznanj. Pa tudi, če se na živalstvo samo ne bi preveč ozirali, je njegovo izumiranje znak, da z okoljem, predvsem pa z vodo, nekaj ni v redu. Dostopne vode je na Krasu malo in prav zato je nadvse dragocena. Ohranjanje čistih kraških vodâ je zato nujno tako za živali kot za človeka, ki na Krasu živi. Ne pozabimo, da vsaka nesnaga, odvržena v jamo ali v njeno bližino, prej ali slej pride z deževnico v kraški podzemeljski vodotok!

Kako človek ogroža okolje, kaže tudi primer človeške ribice, ki v svojem naravnem okolju nima prav nobenega sovražnika in odrasla žival lahko brezskrbno plava v podvodnih labirintih. Pa vendar, najhujši in najbolj neusmiljen med vsemi sovražniki tega simbola slovenskega matičnega Krasa je prav človek. Če je bilo treba pred leti v neki jami na Kočevskem skoraj pri vsakem koraku paziti, da ne bi stopili na človeško ribico, danes ni tam niti ene.

Mnogo podzemnega okolja in živali je bilo uničenih zaradi gradnje hidrocentral na kraških rekah, zaradi spreminjanja kraških polj v umetna jezera, zaradi česar se spreminja vodostaj in utečen ritem vodnih nihanj v podzemskem prostoru, pa tudi zaradi gradnje avtocest. V turistično obiskovanih jamah (Postojnska jama, Škocjanske jame, jama Dimnice, Divaška jama) povzroča škodo stalen nemir z gradnjo poti, z osvetljevanjem, z vožnjo jamske železnice ter s hojo obiskovalcev.

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The food chain of the underground world is based on saprophagous, bacteriovorous, fungivorous and geophagous consumers (several species of snails and arthropods), which become victims of predators. In general, polyphagia prevails with cave animals. Small predators, such as mesostigmatic and trombidiform mites, false scorpions, harvestmen, spiders, and carabids catch ground nematodes, saprophagous mites, nymphs of other mites, and springtails. Large predators, cave fish, cave salamanders, and some other amphibians catch crustaceans and snails. The Slovenian cave salamander, i.e. proteus, feeds on different crustaceans (*Niphargus)*, cave snails, and oligochaete worms. Bad nutrition conditions are reflected in the size of cave animals. Troglobites have been preserved as small animals, except for the proteus and cave fish.

Metabolic activities of cavernicoles are much lower than those of their related species living on the surface of the earth. At a temperature of 10ºC, respiratory intensity of the surface living (*Gammarus pulex*) is as much as ten to fifteen times larger in comparison to that of the cave species *Niphargus virei*.

Threat to the cave environment and life

Threat to the cave ecosystems is connected with the pollution of surface waters in karst areas. Sinking rivers carry communally and industrially polluted waters into the underground environment and in this way cause the destruction of vulnerable troglobites. In some of the caves which have been known for a large number of the proteus population, cave salamanders have become a rarity or have completely disappeared. Numerous potholes of the Slovenian karst areas have become sites for the disposal of refuse and dead animals. On the other hand, organic pollution of water resulted in a sudden growth in the number of the crustacean population of *Monolistra coeca* and *Niphargus orcinus longiflagellum* in the cave Podpeška jama. On that occasion, up to 1000 specimens per square metre were counted up in the cave.

Organically polluted sinking rivers are favourable sites for the penetration of surface animals into underground streams (larvae of mayflies and chironomids, surface-water amphipods (genus *Gammarus*), and isopods (*Asellus aquaticus*)). In this case the animals are provided with energy from organic matter which is carried along by water. These and other surface creatures are competitors which supplant cave amphipods (genus *Niphargus*), cave isopods (*Asellus aquaticus cavernicolus*), etc. The *Proasellus istrianus*, once in the underground river Pivka one of the rare surface-water living creatures, and the cave-dwelling *Asellus aquaticus cavernicolus* reached a ratio of 1:1. The number of cave species has constantly been decreasing. Cave fauna, rich and interesting in species, may be threatened not only in individual caves but also within the entire area of the Slovenian karst.

Caves of the Slovenian Classical Karst became and for a long time remained a true biological Mecca. Subsequently cave animals were discovered also in some other countries, but nevertheless the Slovenian karst and the Kras area (e.g. Škocjanske jame, Divaška jama, Dimnice, and Vilenica) are still the most generous with regard to recent discoveries of cave animals. An increased rate of pollution of the underground is fatal to the cave fauna. By polluting the karst, part of the precious natural heritage, cave animals which live nowhere but in this region and are a rich source of new scientific acknowledgements, is being lost as well. Although for some people unimportant, the animal world which has been dying out is a clear indicator that the environment, especially the water, is being threatened too. In the Slovenian karst there is a lack of accessible water sources, which makes the water very precious. Therefore it is necessary to preserve karstic waters and keep them clean for animals as well as the people living in the karst areas. It should be taken into consideration that any form of waste material dumped in a cave or its vicinity sooner or later reaches the underground stream by means of precipitation waters.

Human impact on the environment can also be illustrated by the following example. In its natural environment, the proteus does not have any enemies, so an adult animal can carelessly swim in underground water labyrinths. The worst and most ruthless enemy of this symbol of the Slovenian Classical Karst is man. Some years ago, visitors to a cave in the Kočevje region had to mind every step they took not to damage the animals; unfortunately, no single proteus would be seen in these days.

The major part of the underground environment and cave fauna has been destroyed by the construction of motorways, the construction of hydro-power plants on some karst rivers, or by the modification of some poljes into artificial lakes. Such interventions result in some changes of the rhythm of water oscillations underground. In show caves (Postojnska jama, Škocjanske jame, Dimnice, Divaška jama), damage is caused by continuous construction of paths, illumination, the cave railway, and visitors.

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KAMNOLOMI

Stanka Šebela

Čeprav je slovenski Kras med svetovnimi krasoslovci izredno znan in cenjen, ga Slovenci še vedno nismo znali dovolj zaščititi in predstaviti svetu. Tako v preteklosti kot tudi sedaj gradimo čez Kras železnice, ceste, na njem lomimo kamenje v kamnolomih, marsikje so neurejena smetišča, potegujemo se za avtomobilske tekmovalne steze. Vsi taki posegi spremenijo ne le pokrajinski videz ampak tudi vegatacijske značilnosti, kraške pojave (škraplje, žlebiče, jame, griže) in vodni režim.

QUARRIES

Stanka Šebela

The Slovene Kras is famous and highly thought of karstologist from all over the world nevertheles the Slovenes do not succeed to protect it and to introduce it to the world. In past and even today we construct railways and roads over the Kras, we exploit rocks in quarries, there is a lot of illegal dumps, we even try to built a race-course. Subsequently, these changes can seriously impact not only upon the landscape appearance but also on vegetation, karst properties (limestone pavement, grikes, caves, karren) and water regime.

In 1975 in Kras there were 25 quarries of decorative stone. The quarries in Kras are ative for 2000 years already. Today the biggest quarries of freestone in Slovenia are the quarries Lipica Near Sežana. In a quarry Lipica-1 more than 1000 cubic metres of blocks are extracted annualy.

However, now few new regulations exist: the area must be explored in detail ant the impact on nature and environment due to stone exploitation must be foressen before a new quarry may be opened. For a planned quarry Lokvica detailed speleological researches werw nade focused upon three caves in the vicinity of the foreseen quarry: Pečina (8 m lenght and 4 m in depth), Pečinka (180 m in lenght and 25 m in depth) and Jama pod pečino or Leopardova jama (125 m in lenght and 30 m in depth).

By a municipal decree the Leopardova jama was declared a natural monument and is ranged among natural places worth seeing in Slovenia. In the cave there are rare flowstone formations, notably helistites and straws; it was decided that the blasting ina new quarry should not cause such vibrations whish might break the speleothems. The opening of the quarry was foressen in sequences, the blasting ahould start with minimal quantities of explosives which might be increased slowly and the effects must be monitored bay transportable seismograph near the cave with at least one sound in the cave. At the same time the affects of vibrations must be observed at the most delicate flowstone formations.

Apecial care must be paid to the impact on a direct karst drainage; it means that eventual oil spills and other toxic or harmful substances must be prevented as such accidents may in long run influence on the karst water in the recharge area of water supply and on karst springs, either Timavo springs or karst aquifer deep below the surface is pumped near Brestovica fot water supply.

Due to great cavernosity og karst one may expect opening of new caves during the quarry's operation and concordantly the appropriate administrative services should be informed to explore the eventual cave and to determine their importance as a natural phenomen and their role in karst hydrology.

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Leta 1975 je bilo na Krasu 25 kamnolomov okrasnega kamna. Sicer pa so kamnolomi na Krasu v rabi že 2000 let. Kamnolomi Lipica pri Sežani so sedaj največji kamnolomi naravnega kamna v Sloveniji. V kamnolomu Lipica-1 letno nakopljejo več kot 1000 kubičnih metrov blokov.

V novejšem času je treba pred odprtjem novega kamnoloma okoliško ozemlje temeljito raziskati in poskušati predvideti posledice na naravi in okolju, ki nastanejo zaradi izkoriščanja kamnine. Tako so bile opravljene za načrtovani kamnolom Lokvica tudi podrobnejše speleološke raziskave, osredotočene na tri jame v neposredni bližini načrtovanega kamnoloma. Te jamme so: Pečnica (8 metrov dolga in 4 metre globoka), Pečinka (180 metrov dolga in 25 metrov globoka) in Jama pod Pečino ali Leopardova jama (125 metrov dolga in 30 metrov globoka).

Leopardova jama je z občinskim odlokom razglašena za naravni spomenik in je uvrščena med naravne znamenitosti izjemnega pomena za Slovenijo. Ker so v jami redke sigine tvorbe, med katerimi najbolj izstopajo heliktiti ter cevčice, je sklenjeno, da množična miniranja ne smejo povzročati takšnih vibracij ali tresenj, ki bi polomile kapnike. Odpiranje kamnoloma naj bi potekalo postopno in minirati naj bi se začelo z najmanjšimi možnimi količinami razstreliva ter te počasi stopnjevati, učinke eksplozij mertiti s prenosnim seizmografom pri jami in z vsaj eno sondo v njej, obenem pa opazovati učinke vibracij na najbolj občutljivih siginih tvorbah.

Posebej je treba biti previden z vplivom na neposredni kraški odtok, kar pomeni, da je treba skrbno paziti na preprečevanje izlivov nafte in olj ter drugih strupenih ali škodljivih snovi, saj bi vsakršno njihovo izlitje lahko daljnosežno vplivalo na kraško vodo v zaledju vodovodnega zajetja in izvirov tako na izvire Timave kakor tudi na kraško vodo globoko pod površjem, ki jo pri Brestovici črpajo za Kraški vodovod.

Zaradi velike prevotljenosti krasa je treba pri obratovanju kamnolomov predvideti sprotna odpiranja novih jam ter skladno s tem obveščati ustrezne strokovne službe, da jih raziščejo in ugotovijo njihov pomen v smislu naravnega pojava kakor tudi vloge v kraški hidrologiji.

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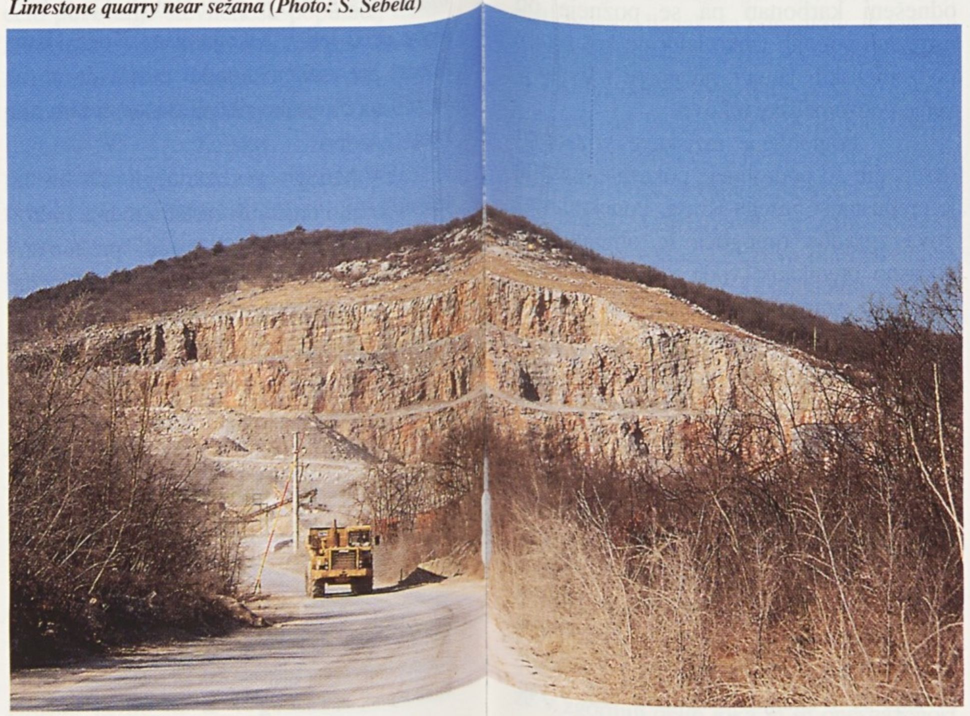
Apnenčev kamnolom blizu Sežane (Foto: S. Šebela)
Limestone quarry near sežana (Photo: S. Šebela)



GRADNJA AVTOCEST NA Krasu

Tadej Slabe

Med osrednjimi slovenskimi načrti je dokončanje prometnega križa, to je povezati državo s sodobnimi cestami. Po krasu bo potekalo 120 kilometrov avtocest. Velika vodna propustnost in povezanost podzemeljskih vodnih poti, ugotovljena s številnimi sledenji vodâ, in slabe samočistilne sposobnosti krasa so glavne značilnosti kraške pokrajine.

V jamah, ki so blizu pomembnejših prometnic, smo v stoječi vodi ugotavljali povečane deleže mineralnih olj. Sklepamo, da so s prometnic. V izvirih Malnov, ki so blizu avtoceste, je povečan delež težkih kovin. Skoraj vsako leto se pripeti prometna nezgoda z nevarnim izlitjem škodljivih snovi, predvsem nafte, na prepustno površje. Ob nenačrtovanem ravnanju s krasom se bodo posledice kmalu izrazito poznale v kraških izvirih, ki so pomembna zaloga vode za oskrbo. Dosegli smo, da so naše nove avtoceste neprepustne, da torej neprečiščene vode s cestišča ali škodljive snovi ob morebitnih nezgodnih izlitjih ne bodo dosegale kraškega površja. Vanj se bodo stekale le prečiščene vode.

Krasoslovci sodelujemo pri načrtovanju tras in pri gradnji avtocest. V načrtih se izogibamo večjim in lepšim površinskim kraškim oblikam, kot so vrtače, udornice in kraške stene, ter jamam. Pri razgaljanju kraškega površja in pri zemeljskih delih se odkrivajo številni kraški pojavi. To so različne vrtače in jame. S kraškega površja je treba na območju tras odstraniti vso zemljo. Te je največ v vrtačah. Dna vrtač, še zlasti, če se v njih odpirajo brezna, se potem prekrije s skalami, ki se jih poveže z betonom, vrtačo pa potem zasuje s plastmi gruščа, ki jih utrdijo z vibracijskim valjarjem.

Odprle so se številne nove jame. To so stare jame, ki so votle ali pa zapolnjene z naplavinami in gruščem, ki so danes že več kot 200 metrov globoko. Stare votle jame, ki se odpirajo s posedanjem stropa pri miniranju kamnine v usekih ali pa so ohranjene v bokih usekov, in jame, ki so zapolnjene z drobnoznato naplavino, so najstarejše sledi podzemeljskega pretakanja vode skozi kraški vodonosnik. Jame brez stropa, ki so zapolnjene z drobnoznato naplavino in s sigo, se kot dolge zajede vijejo po kraškem površju. Spričo starosti je njihova krovnina že odnešena. Nastale so v zaliti coni, ko je vodonosnik še obdajal flišni jez. Pozneje so nekatere preoblikovali hitri vodni tokovi, ki so občasno zalili rove, na stenah vrezali manjše fasete in odlagali prod, ali pa je manjša količina vode vijugasto razčlenila tla rovov. V suhih obdobjih jamskega razvoja se je odlagala siga. Po izrazitih klimatskih spremembah so poplavne vode zapolnile jame z drobnoznato naplavino. Našli smo le jamsko naplavino in ne ostanke površinskih vodnih tokov iz časa, ko je bil kras še visoko obdan s flišem. Krasoslovci pa pogosto pričajo o sledeh, bodisi v reliefu bodisi v naplavinah površinskih vodnih tokov.

Manjše jame in brezna, ki so imele le tanek strop, je bilo treba zaradi gradnje varne ceste razminirati in zasuti. Večja brezna pa smo poskušali ohraniti pod betonskimi pokrovi. Vanja še vedno priteka voda skozi številne kamnine, ki jih sestavljajo.

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THE MOTORWAY CONSTRUCTION IN KRAS

Tadej Slabe

One of major projects in Slovenia is a realization of so called "road cross", designed to connect the country with modern motorways. 120 km of motorways is planned to be located in the karst. High permeability and connection of the underground water flows assessed by numerous water tracing tests and poor self-purification capacity in karst are diagnostic characteristic of this landscape.

In the caves close to major traffic roads an increased rate of mineral oils was assessed in a stagnant water. We infer that it comes from the roads. In the Malni springs located near a motorway a rate of heavy minerals is being increased. Almost each year a traffic accident occur, involving accidental spills of harmful substances, oil in particular, to the impermeable karst. Unreasonable dealing with karst may cause the consequences in the karst springs which provide an important resource for water supply. We achieved that new motorways will be impermeable, it means, that untreated water from the roadway and harmful substances due to accidental spillage will not reach the karst surface. Only treated waters will flow into karst.

Karstologists take part in motorway planning and construction. At planning already they try to avoid major and more important karst features as are dolines, collapse dolines, karst walls and caves. However, unearthing the karst surface and during earthworks necessary to road construction, a lot of karst features are still discovered. These are various dolines and caves. At earthworks all the soil must be removed from the karst surface. The most of it is in dolines. When a doline is cleaned its bottom, in particular there where is a shaft opening, is filled up with rocks tied up with concrete, and then a doline is filled up by layers of rubble, each layer consolidated by a vibration roller.

Several unknown caves opened. These are fossil caves, either void or filled up by sediments and rubble, and avens. The water from the surface infiltrates through these shafts towards the underground flows which are now more than 200 m deep below the surface. Old void caves, opened by roof collapse during blasting in road-cuts or preserved in the flanks of the roadway and also the caves filled up by fine-grained sediments are the oldest traces of the underground drainage through a karst aquifer. The caves without roof filled up by fine-grained sediments and flowstone are meandering over the karst surface. Due to their great age the above-material had been already removed. They developed in phreatic zone when the aquifer was still encompased by a flysch dam. Later some of them were transformed by water flows that occasionally flooded the passages and incised on the walls smaller scallops and deposited gravel or by smaller quantity of water that incised oxbow passages in the floor. In dry periods of the cave development a flowstone was deposited. After climatic changes the flood waters filled the passages by fine-grained sediments. We found only the cave sediments and no remains of superficial water flows from the time when Kras was highly encompassed by flysch. However, there are karstologists frequently reporting about the traces, either in topography or in sediments which may evidence the superficial water flows.

Smaller caves and shafts that had a thin roof only were, due to road safety, blasted and filled up. Major shafts we tried to preserve below the concrete covers. The water still flows through numerous chimneys which are their constituent part.

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Vpliv

Janja Kogovšek

Vsi, ki na krasu ali z njim živijo, delajo ali se z njim kakorkoli ukvarjajo, vedo, kako občutljiv je ta življenjski prostor. Znana je velika prepustnost kraških kamnin, saj si padavinska voda na kraškem svetu neposredno utira pot s površja v kraško notranjost, tako da na Krasu ni površinskih tokov.

Zaradi onesnaženosti zraka že padavinska voda vsebuje nekaj raztopljenih kislin, pri prehodu skozi plasti vegetacije in prsti pa se navzema še drugih snovi, tako da pri nadaljnjem prenikanju skozi karbonatne kamnine te tudi raztaplja ter tako veča prepustnost krasa. Tako kamnina, ki pride v stik s to vodo, prehaja v raztopino do nasičenja. Zaradi težnosti prodira voda z raztopljenimi karbonati vse globlje v kras. Tako se na eni strani širijo vodne poti, odnešeni karbonati pa se pozneje ob ustreznih pogojih lahko izločajo kot siga v podzemeljskih jamah, ali pa se izlivajo v večje podzemeljske tokove.

Poglobljene raziskave v zadnjih desetletjih so podrobneje pokazale, kakšna je prepustnost našega Krasa. Ponekod njegova zgradba omogoča le omejeno in počasno prenikanje vode v bolj ali manj vertikalni smeri, drugod pa voda lahko prenikne skozi 100 metrov debelo kamninsko plast že v nekaj več kot uri. Prenikajoča površinska voda se v kraški notranjosti izliva v vodoravne tokove in se z njimi pojavlja v kraških izvirih.

Viri onesnaževanja krasa

Raziskovanje pretakanja vode v krasu, tako smeri kot dinamike, je nadvse pomembno zaradi vse večje človekove aktivnosti na kraškem površju. Človekovo bivanje se v zadnjih letih kaže tudi v vse

POSELITVE IN INDUSTRIJE na kraško vodo

večjih količinah odpadkov. V Sloveniji nastane letno kakšnih 400 kilogramov odpadkov na prebivalca, kar je nad evropskim povprečjem. V Sloveniji je 53 legalnih odlagališč odpadkov, vendar je kar 37 takih, ki niso sodobno zgrajena, ki nimajo lokacijskih ali gradbenih dovoljenj, ki nimajo zbiranja in čiščenja izcednih voda, zato onesnažujejo okolje, tudi kraško. Seveda v tem niso všteta tista številna črna odlagališča, ki jih v zimskem in zgodnjem pomladanskem času, ko ni bujne vegetacije, da zakriva človekovo nesmotrno ravnanje, opazimo skoraj za vsakim ovinkom lokalnih cest. Problem so tudi odpadne vode, ki jih v Sloveniji čistimo le 53 %, biološko le 6 %, medtem ko jih kemijsko čistimo le 0,005 %. Torej gre za neposredne izpuste preostalih odpadnih voda v naravo.

Tako imamo na Krasu na eni strani neposredno onesnaževanje zaradi onesnaževanja kraškega površja, kot so najrazličnejša odlagališča odpadkov, iz katerih spirajo onesnaženje v kras padavinska voda, in lokalni odtoki odpadnih voda iz gospodinjstev, saj večina manjših in tudi večjih naselij nima urejene kanalizacije ter čiščenja odpadnih voda, pa odpadna voda iz slabše ali boljše vzdrževanih greznic odteka neposredno v kras. Drugi vir onesnaževanja krasa so onesnažene reke ponikalnice, saj ne sprejemajo samo onesnaženja na območju krasa, ampak lahko veliko količino onesnaženja prinašajo z bližnjih nekraških območij, od koder pritekajo (primer Reke, še zlasti pred zaprtjem Tovarne organskih kislin v Ilirski Bistrici!). V reke odtekajo velike količine odpadnih voda, ne le že očiščenih; pogosto tudi neočiščene komunalne in industrijske odplake. Kljub določeni samočistilni sposobnosti naših rek prihaja do kritičnih razmer ob nizkem vodostaju, ko ponikalnice pogosto ponikajo že v zgornjih delih toka in se onesnaženost zato tako zelo zgošča, da se dogajajo celo pomori rib.

V človekovi naravi je, da vodni izvir pomeni nekaj čistega; da pomeni vodo, ki jo lahko pijemo. Na krasu pa moramo biti previdni. Ponikalnice se lahko kar večkrat zapovrstjo pojavljajo v različnih izvirih, vendar niso dosti čistejše - učinek samočiščenja - kot so čiste tam, kjer odtekajo skozi ponore v podzemlje. Iz tega sledi, da pomeni skrb za kakovost zadnjega izvira skrb za kakovost ponikalnice od njenega izvira navzdol. Podobno velja na krasu za kraške izvire, ki se pojavljajo na obrobju, na stiku z neprepustnim svetom. Vse onesnaženje, ki se spira s površja v kraško notranjost, slej ko prej doseže kraško vodo, ki jo skozi vrtine črpajo za oskrbo prebivalstva, ali pa se pojavlja v kraških izvirih, ki so pogosto prav tako zajeti za oskrbo prebivalstva s pitno vodo. Torej gre na Krasu za sklenjen krog vode (odpadne in čiste),

THE IMPACT OF POPULATION AND INDUSTRY ON KARST WATER

Janja Kogovšek

People who live in karst and with it, work on it or are in any way involved with it, know how sensible this living sphere is. Karst rocks are very permeable and rainwater directly flows from the surface into the karst underground; there are no superficial streams in karst.

Due to air pollution the meteoric water already contains some dissolved acids, during its way through the layers of vegetation and soil it absorbs other substances and during the infiltration through the carbonate rocks the rocks are dissolved and the karst permeability increased. Thus the rock when comes in contact with this water passes into solution up to saturation. Due to gravity the water with dissolved carbonates penetrates deeper into karst. On one hand the water routes are widened and transported carbonates at favourable conditions may be later deposited as flowstone in the underground caves or the water flows into bigger underground streams.

osnovne in nujne surovine za bivanje, zato človeku ne preostaja nič drugega, kot za njeno kakovost čim ustrezneje skrbeti.

Kakšno je onesnaženje zaradi poselitve?

Onesnaženje, ki ga povzroča človek že samo s svojim bivanjem, obsega odpadne vode in trdne odpadke, ki jih ponekod že sortirajo. Biološke odpadke kompostirajo in jih takoj vračajo v naravo. Steklo, papir in kovine se lahko ponovno uporabi. Preostale odpadke pa je treba odlagati na urejena odlagališča. S sortiranjem se zmanjša količina odpadkov, ki sodijo na odlagališča. Če so osnove odlagališč za odpadke prepustne, padavine spirajo v kras topne sestavine odloženih odpadkov, kar pomeni počasnejše, a vendar dolgotrajnejše onesnaževanje. Najpomembnejša vrsta odpadkov pa so težje razgradljive snovi ter strupene, karcogene ali rakotvorne in mutagene ali na dedne lastnosti delujoče snovi, ki ne sodijo na komunalna odlagališča odpadkov.

Odpadne vode zelo hitro prodirajo v kras, zato je zelo pomembna njihova sestava oziroma stopnja onesnaženosti. Z uporabo najrazličnejših biološko razgradljivih pralnih sredstev so vode, ki odtekajo iz naših stanovanj in hiš, onesnažene z organskimi, razmeroma lahko razgradljivimi snovmi. Takšno onesnaženje se ob razpoložljivem kisiku dokaj hitro razgradi do neorganskih sestavin, nitratov, kloridov, fosfatov in sulfatov. Zato je smiselno take vode, če se jih ne čisti v čistilni napravi, odvajati v večprekatne greznice, kjer se usedajo, tako da se iz takih greznic odtekajoča in znatno manj z onesnaženjem obremenjena odpadna voda pri prenikanju skozi karbonatne kamnine očisti zaradi njihovih učinkovitih samočistilnih procesov. Seveda pa je nujno prazniti usedlino iz greznic. Usedlina je primerna za gnojenje travnikov, na katerih so taki oksidacijski pogoji, da organske snovi v usedlini mineralizirajo.

Zaradi naselja Škocjan nad Škocjanskimi jamami se v Mariničevi jami in Mahorčičevi jami pojavlja onesnažena voda.
Because of Škocjan village located above Skocjanske jame, the polluted water appears in Mariničeva jama and Mahorčičeva jama.

Kakšno je onesnaženje industrije?

Vsaka vrsta industrije proizvaja posebno, značilno vrsto odpadkov - tako trdnih kot tekočih; odvisno od tega, kakšne surovine uporablja in kaj so njeni končni proizvodi. Tako povzročata lesna in živilska industrija pretežno veliko organsko, biološko razgradljivo onesnaževanje. V industriji, v kateri uporabljajo veliko barv, lakov in organskih topil ali drugih težko razgradljivih snovi, je nujno nekatere odpadne snovi zbirati in jih ponovno uporabljati ali pa jih na razne ustrezne načine za okolje neškodljivo uničevati. Vendar je to običajno zelo drago. Osnovno vodilo pri uvajanju novih vrst proizvodnje in novih postopkov mora biti težnja po čim manj nevarnih odpadkih in po čim manjših njihovih količinah. Ker pa se določeni nujni količini odpadkov le ni mogoče izogniti, je zelo pomembno pravilno ravnanje z njimi!

Stanje voda na Krasu

Večletno spremljanje prenikle vode, to je padavin, ki s kraškega površja neposredno prodirajo v kraško notranjost in se pojavljajo v podzemnih jamah Krasa, v Vilenici, Divaški jami in v Škocjanskih jamah, so pokazala, da v večini primerov prevladujejo še čiste vode zaradi neposeljenosti površja.

Ponekod je kamninska zgradba taka, da omogoča le počasno pretakanje vode z močnim dušenjem hidroloških ekstremov ali skrajnosti. V takih porimerih, še zlasti med poletno in zimsko sušo, ko je pretakanje vode najpočasnejše, bi lahko pričakovali, da onesnaženje s površja le počasi prodira v kraško notranjost. Skozi 100 metrov debele plasti kamnine bi prenikalo mesec ali celo več mesecev. Drugod pa je prepustnost kamnin za vodo večja in bi med izdatnejšimi padavinami, ko je prenos snovi tod najhitrejši, lahko pričakovali morebitno onesnaženje s površja že v nekaj dneh, v primeru zelo prepustnih prevodnikov pa še znatno prej.

Vendar smo z našimi raziskavami kakovosti voda na območju Krasa že tudi zabeležili primere močnejšega onesnaženja, ki je bilo vselej vezano na poselitev oziroma na onesnaženje zaradi odtoka odpadnih voda neposredno v kras. V Škocjanskih jamah smo v vodi curka na Golgoti določili nekoliko povečane nitrate, kar smo razlagali z intenzivno obdelano njivo na površju. Opaznejše onesnaženje pa smo določili v Mariničevi in Mahorčičevi jami. Na površju, prav nad jamo, je naselje Škocjan. Njegove odpadne vode odtekajo skozi 50 do 80 metrov debel jamski strop in se pojavljajo v jam. Očitno gre za zelo hiter in neposreden odtok z minimalnimi samočistilnimi učinki, saj je imela prenikla voda v jami močno povečano vsebnost nitratov (do 85 miligramov na liter), sulfatov (do 53 mg/l), fosfatov (do 5,5 mg/l) in kloridov (do 16 mg/l), bila pa je tudi organsko onesnažena (KPK do 8,7 mg O_2/l in BPK5 do 2 mgO_2/l).

Ti rezultati kažejo obseg onesnaženja v kraškem podzemlju, ki ga povzroča življenje majhne vasi na površju, tako da si lahko predstavljamo posledice v podzemlju, kjer so na površju nad njim naselja in ki imajo običajno tudi industrijo.

Podobno onesnaženje, ki prihaja s površja z vodo, smo zabeležili tudi v Ponikovski dragi. Tudi tod je prepustnost karbonatnih kamnin velika in prodiranje vode ter onesnaženja s površja, ki je poseljeno, je zelo hitro.

In last decades the profound researches indicated the rate of permeability of our Kras. Somewhere its structure enables limited and slow water infiltration in more or less vertical direction, elsewhere the water percolates through 100 m thick rocky layer in one hour already. The superficial percolation water joins horizontal streams in the karst interior and reappears in karst resurgences.

The sources of karst pollution

The study of water percolation in karst is very important because of increasing activity of man at the karst surface. The human influence is felt in augmented quantity of wastes. Statistically Slovenia produces 400 kg of wastes per inhabitant and this is above the European average. In Slovenia there are 53 waste disposal sites, but 37 out of them are not properly built, they do not have location or building licences, they do not collect and treat the waste water, consequently they pollute the karst water. In this number are obviously not included numerous illegal dumps, which may be seen in winter or in early spring time, when there is no green vegetation to disguise this type of human activity. Another problem are waste waters which are treated in Slovenia by 53% only, out of them 6% biologically and 0,005% chemically. It means direct outlet of waste substances into nature.

Thus we have in Kras on one hand direct pollution due to karst surface pollution, as are for instance various types of waste disposal sites where the rainwater and local outlets of households drain directly into karst; most of smaller villages or even bigger places do not have appropriate canalisation or waste water treatment and thus waste water penetrates through better or worse kept septic-tanks directly into karst.

The second source of karst pollution are polluted sinking streams; they do not receive the pollution only in karst areas but may transport a considerable qauntity of pollution from nearby non-karstic areas from where they came (the example of Reka, in particular before the liquidation of the factory of Organic Acids). The rivers are burdened by a lot of waste waters, not only treated but also untreated communal and industrial sewage. In spite of certain self-purification capacity of our rivers critical conditions appear during low water level when the sinking rivers disappear in upstream parts of the flow and the pollution is concentrated in such a degree that even fishes are killed.

The human nature accepts the water spring as something clear, something that can be drunk. But in karst one must be careful. The sinking rivers reappear several times in different springs, but they are not considerably more pure (due to the self-purification effect) as they were at the swallow-holes where they disappeared into underground. The conclusion is, caring for the quality of the last spring means care for the sinking stream quality from its first spring downstream. The same may be said for karst springs that appear at the contact with impermeable areas. All the pollution washed from the surface into karst interior sooner or later reaches the karst water; this water is either pumped through the bore-holes for water supply or it reappears in karst springs and they too are frequently captured for water supply. In Kras there is a closed circle of water (waste and pure); water is the most important matter for living and we must take care for its quality.

What kind of pollution is due to population?

The pollution due to human living includes waste waters and solid dumps which are somewhere sorted. Biological wastes are composted and returned to nature, glass, paper and scraps can be reused, other wastes must be deposited on properly organised waste disposal sites. By sorting the quantity of wastes meant for waste disposal site, is reduced. If the base of a waste disposal site is permeable the rainfall washes soluble components into karst and it means slower, but longer pollution. Anyway, the kind of wastes is the most important, in particular dangerous are non-degradable, toxic, cancerogeneous and mutageneous substances which do not belong to communal depony.

Waste waters penetrate into karst rather rapidly this is why their composition and degree of pollution are so important. Using various biologically degradable washing powders the waters leaving our houses are polluted by organic, mostly degradable substances. If there is enough of oxygen such pollution is relatively quickly degraded up to anorganic components, such as nitrate, chloride, phosphate and sulphate. If the waters are not treated at the water treatment plant, it is reasonable to use cess-pits with several compartments, where the impurities are sedimented and the water flowing out is considerably less burdened and effective self-purification processes may be in the process. However, the pumping of the residual sludge is urgent. The sediment may be used for meadows manuring where the oxidation condition allow the mineralisation of organic matters.

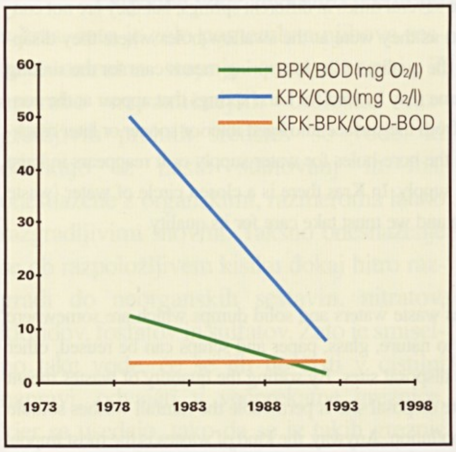
What kind of pollution is due to industry?

The industry produces a specific, special sort of wastes, solid or liquid depending on used raw materials and on final products. The food industry and woodworking industry mostly produce a lot of organic, biological degradable pollution. In the industry where a lot of dyes, varnishes and organic diluents or other non-degradable substances are used the collecting of them is urgent is order to reuse them or to destroy them by various methods less harmful for the environment; these methods are usually very expensive. The basic rule at introducing a new production or technology should be tendency to have as less as possible of wastes. However one may never avoid a certain amount of wastes and it is very important how we deal with them.

Reka, ki ponika v Kras v Škocjanskih jamah, je bila pred časom "mrtva" reka, ker je pogosto vsebovala minimalne količine kisika ali pa je bila sploh brez njega, kisik pa je nujen za obstoj in razvoj življenja v reki. Organsko onesnaženje je bilo tako veliko, da je za svoj delen razkroj porabilo ves razpoložljivi kisik v vodi.

Sprejetje Škocjanskih jam v Unescov Seznam svetovne naravne dediščine je bilo povezano s pogojem, da je treba kakovost Reke izboljšati. In ko so na srečo jeseni 1990 zaprli Tovarno organskih kislin v Ilirski Bistrici, se je pokazalo, kako velika onesnaževalka okolja je bila. Ko njenega onesnaževalnega deleža ni bilo več, je Reka svojo strugo hitro sprala in že v januarju 1992 se je kakovost njene vode v ponoru v Škocjanske jame znatno izboljšala.

Za primerjavo predstavljam povprečno organsko onesnaženje Reke na ponoru v Škocjanske jame (po določitvah KPK in BPK) pred zaprtjem Tovarne organskih kislin in po letu 1991, ko se je njena kakovost izboljšala (Slika 1).



Slika 1: Organsko onesnaženje (KPK in BPK5) Reke na ponoru v Škocjanske jame pred letom 1991 in po njem, ko je prenehala proizvodnja v Tovarni organskih kislin.
Fig.1:Organic pollution (COD and BOD) of the Reka at the swallov-hole into Škocjanske jame before and after 1991, when the production in factory of organic acids stopped.

Vidno je znatno zmanjšanje težje in lahko razgradljivega organskega onesnaženja po letu 1991 (KPK in BPK). Vendar pa razmerje med obema vrstama določb ne upada; v posameznih meritvah je opaziti celo povečanje KPK, kar pomeni, da se količina težje razgradljivega organskega onesnaženja povečuje (Tabela 1):

Reka ob vstopu v Škocjanske jame odnaša s seboj v kraško podzemlje tudi vse onesnaženje, ki ga sprejme na svoji površinski poti.
The river Reka at the entrance to Škocjanske jame transports into karst underground all the pollution that it receives during its superficial way.

Meritve Reke na ponoru v Škocjanske jame: povprečne vrednosti v letih od 1992 do 1995 in trenutna vrednost v juniju 1993.
The Reka measurements at the swallov-hole into Škocjanske jame: the average value from to 1995 and instantaneous value in June 1993.

Tabela 1:
Table 1:

	SEP	kloridi chlorides	nitrati nitrates	fosfati phosphates	sulfati sulphates	KPK COD	BPK BOD	KPK/BPK COD/BOD
	µS/cm	mg/l	mg/l	mg/l	mg/l	mgO_2/l	mgO_2/l	
povprečki averages 1992-95	345	3.7	4.5	0.03	14.5	6.6	1.8	3.7
junij June 1993	341	4.0	5.3	0.01	12.0	12.0	2.0	6.0

Kaj lahko storimo?

Območje Krasa je zaradi dobre zakraselosti brez površinskih voda. Voda se je umaknila v kraško podzemlje, v katero zatekajo vode Reke, Raše, Senožeškega potoka in Sajevškega potoka, pa tudi vode Vipave in Soče. Tako je kakovost vode v podzemlju odvisna tudi od kakovosti teh vtokov. Podzemeljske vode Krasa bogatijo še padavine, ki neposredno prodirajo vanj.

Zaradi razpršene poselitve kraškega površja, zaradi onesnaževanja s pretežno razgradljivim organskim onesnaženjem ter zaradi razredčevalnih in samočistilnih procesov v krasu zaenkrat še ni znakov onesnaženja kraške vode v večjem obsegu, vendar posamezni primeri narekujejo veliko previdnost.

Vemo, da je vzrok za onesnaževanje vodâ v kraški notranjosti onesnaževanje na površju, oziroma da se neposredni izpusti odpadnih voda na krasu, izlivi raznih tekočin v prometnih nezgodah in tudi odtok onesnaženih voda s cestišč ter izcednih voda z odlagališč odpadkov odražajo v onesnaženju voda v kraški notranjosti v bližnji okolici. Zaradi poselitve se veča onesnaževanje kraške vode predvsem z nitrati, sulfati, fosfati in kloridi, pa tudi z organskimi snovmi. Pri izlivih v prometnih nezgodah, v katerih so udeležena vozila, ki prevažajo nafto, njene derivate in druge nevarne snovi, pa grozi velika nevarnost onesnaženja s temi težko razgradljivimi snovmi. Obseg in nevarnost onesnaženja sta odvisna od vrste in količine onesnaženja in od zgradbe kamnin, saj te določajo način in hitrost prodiranja vode globlje v kras in tudi možnost oksidacijskih razgrajevalnih procesov v primeru biološko razgradljivega onesnaženja. Raziskave vse bolj potrjujejo veliko prepustnost Krasa, saj s površja v njegovo notranjost, kjer so vse razpoložljive zaloge vode, vodijo tudi zelo prepustni prevodniki, ki vodi omogočajo in z njo tudi onesnaženju, da prodre v globine več sto metrov v času, merljivem v urah. Druga možnost za onesnaževanje podzemeljskih vodnih rezerv pa so površinski vodni tokovi, ki pritekajo z neprepustnega sveta in zatekajo v kras. Zato moramo spremljati in preverjati tudi kakovost teh voda.

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The state of water in Kras

Several years monitoring of the percolation waters that directly flow from the karst surface into karst interior and appear in the underground caves, Vilenica, Divaška Jama and Škocjanske Jame has shown that in most cases pure waters prevail due to sparsely inhabited surface.

Somewhere the rock structure allows only slow water infiltration with strong suffocation of hydrologic extremes. In such cases one would expect that the water percolation is the slowest during summer and winter drought when water recharge is the lowest and, in case of pollution it would slowly penetrate into karst interior. The percolation through 100 m thick rock beds would take a month or several months even. Elsewhere the water permeability is higher and during abundant rain when the transport of substances is rapid, the eventual pollution from the surface could appear after some days, at certain conduits even earlier.

However, during our researches of water quality within the Kras area we recorded cases of stronger pollution which was in all the cases due to human impact - either due to villages or pollution due to runoff of waste waters directly into karst. In Škocjanske jame we recorded slightly increased nitrate level in a trickle at Golgota due to intensively manured field at the surface, major pollution was detected in Mariničeva and Mahorčičeva jama, the latter two forming part of the Škocjanske jame system. At the surface, just above the caves, lies the Škocjan village. The waste waters flow through 50 to 80 m thick cave roof and appear in the cave. Obviously the drainage is fast and rather direct with minimal self-purification effects; the percolation water in the cave had strongly increased nitrate (up to 85 mg/l), sulphate (up to 53 mg/l), phosphate (up to 5,5 mg/l) and chloride (up to 16 mg/l) levels and it was organically polluted (COD up to 8,7 mg O_2/l) and BOD_5 up to 2 mg O_2/l). These results indicate the range of pollution in a karst underground caused by life of a tiny village at the surface and one may only imagine the consequences in the underground if there are towns including industry at the surface.

Similar pollution due to water infiltration from the surface was recorded in Ponikovska Draga. Here too the permeability of carbonate rocks is high and water infiltration and pollution from populated surface very fast.

The Reka river sinks into Kras at Škocjanske jame; some time ago it was "dead" river containing minimal quantities or even none of dissolved oxygen which is indisipensable for existence and development of life in the river. The organic pollution reached such an extent that for its partial degradation it used all the available oxygen in the water. When Škocjanske jame were included into UNESCO World Natural Heritage List it was conditioned that the river's quality must improve. Fortunately in autumn 1990 the factory of organic acids in Ilirska Bistrica was closed and then it was clear how important pollutant this factory was. When its great share of pollution disappeared the Reka riverbed was rather fast rinsed and in January 1992 a considerable improvement of the Reka quality at its swallow-hole to Škocjanske jame was recorded. Just for comparison look to the following table of average organic pollution (COD and BOD) of the Reka at its swallow-hole to Škocjanske jame in the time before the factory of organic acids was closed and after 1991 when the Reka improvement took place (Fig. 1).

A considerable decrease degradable organic pollution after 1991 (COD and BOD) was recorded. However, the ratio between both does not decrease, at some measurements the increase in favour of KPK was recorded; it means that the burden of slowly degradable organic pollution is in increase (Table 1).

Conclusion

The Kras landscape is due to karstification without supeficial streams. The water disappears into karst underground, there flow the waters of Reka, Raša, Senožeški and Sajovški potok, but also Vipava and Soča. The water quality in the underground depends on quality of these inflows. The underground waters on karst are enriched by rainwater which directly infiltrate into karst.

Due to sparsely populated karst surface, due to mostly bio-degradable organic pollution and due to dilution and self-purification effects present in karst for the moment there are no signs of karst water pollution in greater extent, however single cases warn that we must be cautious.

All the recorded cases of pollution were found to have their origin at the surface and we know that the reason for water pollution in the karst underground lies in direct outlets of polluted water from roads and waste disposal sites. Groundwater risk assessment undoubtedly shows that due to increased population the pollution of karst water by nitrate, sulphate, phosphate and chloride but also by organic matters increases. An important potential risk of pollution by non-degradable matters threatens in the event of road accident when the vehicules transporting oil and derivates or other dangerous substances are involved. The extent und danger of pollution depends on type and quantity of pollution but also on rock structure that controls the mode and the velocity of water infiltration deep into karst and also the possibility of oxydation processes in the case of biodegradable pollution. The researches more and more confirm great Kras permeability; from the surface into the underground very permissible conduits lead and all the available resources of water are stored there; these conduits allow that water together with pollutants penetrate into the depth of more than hundred meters in time, measured in hours. The second possibility to pollute the underground water storage are superficial water flows that flow from the impermeable landscape and disappear into karst. This is why we must record also the quality of these waters.

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INŠTITUT ZA RAZISKOVANJE krasa

ZNANSTVENORAZISKOVALNI CENTER SLOVENSKE AKADEMIJE ZNANOSTI IN UMETNOSTI

Tadej Slabe

Po priključitvi Slovenskega Primorja leta 1947 Jugoslaviji je bil ustanovljen slovenski speleološki inštitut in v okviru Slovenske akademije znanosti in umetnosti se je začelo razvijati krasoslovje. Speleološka dejavnost na območju Slovenskega Primorja, ki je leta 1920 pripadlo Italiji, pa je bila že od leta 1929 združena v italijanskem državnem speleološkem inštitutu v Postojni*. Kot upravniki inštituta so se zvrstili: dr. Alfred Šerko (do leta 1948), dr. Srečko Brodar (1948-1971), dr. Maks Wraber (1971-1972), dr. Svetozar Ilešič (1972-1976), dr. Peter Habič (1976-1987), dr. Franc Šušteršič (1987-1988), dr. Andrej Kranjc (1988-1995) in dr. Tadej Slabe (od konca leta 1995).

Prvi raziskovalci **dr. Roman Savnik**, **Egon Pretnar** in **France Hribar** so raziskovali kras v okolici Postojne, Idrije, Hotedršice, Divače in Sežane. Uredili so speleološko zbirko in kataster kraških pojavov. V drugem desetletju se je z novimi sodelavci, ki so bili: **France Leben**, **Rado Gospodarič**, **dr. Ivan Gams**, **Peter Habič** in **France Habe**, povečala raziskovalna dejavnost. Organizirali so 4. mednarodni speleološki kongres in ustanovljena je bila Mednarodna speleološka zveza. Raziskovalno delo je bilo poglobljeno s teoretičnim znanjem in z njegovim prenašanjem v prakso. Raziskali so vodne vire na Notranjskem in Primorskem, opravili speleološke raziskave pri gradnji prve slovenske avtoceste, sodelovali so pri poskusih trajne ojezeritve Cerkniškega jezera, mednarodno odmeven je bil sledilni poskus v porečju Ljubljanice. Z novima sodelavcema **Andrejem Kranjcem** in **Francetom Šušteršičem** so pričeli pripravljati speleološko karto. V speleobiološkem oddelku so delali **Božo Drovenik**, **Tone Novak** in **Valika Kuštor**. V četrtem desetletju delovanja IZRK, ko so se mu pridružili **Jože Čar**, **Janja Kogovšek**, **Andrej Mihevc** in **Tadej Slabe**, so zasnovali nove študije kraškega površja, voda in podzemlja na Notranjskem, Primorskem in Dolenjskem krasu. Izmerili so prenikanje vode ter raztapljanje in odlaganje apnenca v Planinski jami, Postojnski jami in Škocjanskih jamah. Odprli se nove poglede na oblikovanje kraškega reliefa z večjim poudarkom na mladi tektoniki. Spoznanja so oprli na geološko kartiranje med Postojno in Cerknico. Preučevanje sedimentov je pripomoglo k časovni opredelitvi razvoja kraških votlin. Razčlenili so procese izvotljevanja, zasipanja in podiranja jam. Vse bolj je bila v ospredju skrb za ohranitev čistega krasa in vode.

Z mladimi raziskovalci geologi **Nadjo Zupan Hajno**, **Stanko Šebelo**, **Martinom Knezom**, **Metko Petrič** in **Bojanom Otoničarjem**, biologinjo **Tanjo Pipan** in pripravnikom fizikom **Francijem Gabrovškom** se je inštitut ne le številčno temveč tudi predvsem strokovno okrepil. Raziskovanje poglablja temeljno znanje v večini najbolj pomembnih krasoslovnih področij: od kraške geomorfologije, speleologije, hidrogeologije do ekologije. Podzemeljskim vodam, bodisi vodnim tokovom bodisi prenikajoči vodi, sledimo z barvili in ugotavljamo njihovo kakovost. Proučujemo geomorfološke značilnosti kontaktnega krasa. Določili smo dejavnike, ki v različnih pogojih z značilnimi procesi oblikujejo kraške votline. Uspešno smo naredili več laboratorijskih poskusov oblikovanja skalnih oblik na mavcu. Določamo izvor mineralov v mehanskih jamskih sedimentih. Določili smo odvisnost nastanka in oblikovanja kraških pojavov od geološke zgradbe. Ugotavljamo začetke zakrasevanja na podlagi litologije. Začeli smo proučevati paleokraške oblike jadransko dinarske karbonatne platforme. Redno speleološko raziskujemo za varovanje in ohranjanje Škocjanskih jam, ki so spomenik v Unescovem Seznamu svetovne dediščine. Rešujemo probleme varstva in urejanja reke Krke na odsekih z intenzivno rastjo lehnjaka. Pripravljamo nove informacijske krasoslovne zbirke. Poglabljamo znanje o zgodovini krasoslovja in speleologije. K temu veliko prispeva tudi naš zunanji sodelavec **Trevor R. Shaw**.

Skratka, razširja in poglablja se spoznavanje kraške naravne dediščine. Inštitutski delavci pa se učinkovito vključujemo tudi v načrtovanje in opravljanje posegov v občutljivo pokrajino ter njeno varovanje. V ospredju našega zanimanja so preučevanje vodonosnikov in vodnih virov ter gradnja avtocest na krasu. Na trasah avtocesat preučujemo nove odkrite jame, ki so najstarejše sledi podzemeljskega pretakanja vode skozi kraške vodonosnike, in opozarjamo na varovanje podzemeljske vode. Sodelujemo pri načrtovanju odlagališč odpadkov in pri odpiranju novih kamnolomov. Raziskujemo posledice izlitij škodljivih snovi na prepustno kraško površje.

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* Zgodovina inštituta je povzeta po sestavku P. Habiča ob 40. obletnici IZRK v Acti carsologici, 16, 1987.

Nekdanja "Nova graščina" na osrednjem trgu v Postojni, sedaj sedež Inštituta za raziskovanje krasa ZRC SAZU.
The former "New Castle" on the central square at Postojna, today a set of the Karst Resesrch Institute ZRC SAZU.

Širimo zbirke podatkov v katastru jam, ki ga ureja **Jurij Hajna**, in krasoslovno knjižnico, ki jo vodi **Maja Kranjc**. **Leon Drame** ureja kartografsko zbirko. **Franjo Drole** meri najbolj pomembne jame in riše njihove načrte. V laboratoriju delata raznovrstne analize **Mateja Zadel** in **Alenka Leskovec**. Za dobro delovanje inštituta skrbita **Sonja Franetič** in **Stanka Tomšič**.

Mednarodna krasoslovna šola, ki jo že več let pripravlja inštitut, je del Slovenskega parka znanosti in tehnologije.

Sodelujemo v številnih mednarodnih raziskovalnih projektih: IGCP-UNESCO Project No. 379 Karst Processes and Carbon Cycle (sodelovanje organizacij iz držav vsega sveta); COST Action No. 65- Hydrogeological Aspects of Groundwater Protection in Karstic Areas (sodelovanje organizacij iz držav Evcropske skupnosti ter srednje in vzhodne Evrope); ATH - 7.SWT - Tracers and models in various aquifers, Investigation in Slovenia 1993-1996 (sodelovanje organizacij iz Slovenije, Avstrije, Nemčije in Švice); U.R.A. 903 C.N.R.S. - Proučevanje perimediteranskega krasa (U.R.A. 903 C.N.R.S. s sedežem v Laboratoire de Geographie physique a Aix-en-Provence ter Laboratoire souterrain du C.N.R.S., Moulis); ALIS Link No. 12 (Britanski svet in MZT), IZRK ZRC SAZU in Limestone RESEARCH group, Department of Geographycal & Environmental Sciences, University of Huddersfield; PECO "MEDIMONT" - Desertification risk assesment and land use planning in Mediterranean coastal area; Karst Environment Protection and Exploration of Cave Resouces z Inštitutom za geologijo kitajske Akademije znanosti iz Pekinga; A cooperative Research on Karst Phenomen's Preservation, Protection and Large Cave System's Exploration in Yunnan Province z Yunnanskim inštitutom za geografijo. Tvorno sodelujemo z Muzejem varstva narave in jamarstva iz Liptovskega Mikulaša (Slovaška).

V okviru evropske znanstvene fundacije pridobiva inštitut vlogo mednarodnega središča za krasoslovne študije.

Inštitutska vrata so odprta krasoslovcem, Kraševcem, študentom, šolarjem in vsem, ki jih zanima ta čudežna pokrajina - Kras.

Dr. Tadej Slabe, , dipl. geograf in dipl. sociolog
višji znanstveni sodelavec na Inštitutu za raziskovanje krasa ZRC SAZU, 6230 Postojna, Titov trg 2

KARST RESEARCH INSTITUTE

CENTRE FOR SCIENTIFIC RESEARCH OF THE SLOVENE ACADEMY OF SCIENCES AND ARTS

Tadej Slabe

When the Slovene Littoral in 1947 came back under Yugoslavia the Slovene speleological institute was founded and within the frame of the Slovene Academy of Sciences and Arts the karstology started to develop. However, in the region of the Slovene Littoral the speleological activity started in 1929 already by the Italian speleological institute at Postojna because in the years 1920 and 1945 this area belonged to Italy*. Since the beginning the heads of the Institute were the following: Alfred Šerko (by 1948), Srečko Brodar (1948-1971), Maks Wraber (1971-1972), Svetozar Ilešič (1972-1976), Peter Habič (1976-1987), France Šušteršič (1987-1988), Andrej Kranjc (1988-1995) and Tadej Slabe (since the end of 1995).

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* The history of the Institute after P. Habič, At the 40th anniversary of the Institute for Karst Research, Acta carsologica, 16, 1987.

The study area of the first researchers **Roman Savnik**, **Egon Pretnar** and **France Hribar** was karst near Postojna, Idrija, Hotedršica, Divača and Sežana. They organised the speleological collection and the Cave Register. In the second decade they were joined by new researchers **France Leben**, **Rado Gosopodarič**, **Ivan Gams**, **Peter Habič** and **France Habe** and the research activity developed further. They organised the 4th International Speleological Congress and at this occasion the International Speleological Union was founded. The research work was enriched by a theoretical knowledge and by implementation into practice. The water resources in Notranjska and Primorska were studied, speleological control during the construction of the first motorway in Slovenia was carried out, the researchers took part at the experiments how to retain water on Cerkniško polje for longer time, internationally sound was the water tracing test in the Ljubljanica water system. Helped by two new researchers **Andrej Kranjc** and **France Šušteršič** the Institute started to prepare the Speleological Map of Slovenia. Speleobiological department included **Božo Drovenik**, **Tone Novak** and **Valika Kuštor**. In the fourth decade the Institute was joined by **Jože Čar**, **Janja Kogovšek**, **Andrej Mihevc** and **Tadej Slabe** starting the integrated studies of the karst surface, water and underground on Notranjska, Primorska and Dolenjska. The measurements applied to percolation water, solution and deposition of flowstone in Planinska jama, Postojnska jama and Škocjanske jame were done. New aspects associated to neotectonics in terms of karst relief development arose. The knowledge is based on geological mapping between Postojna and Cerknica. The study of sediments contributed to better time control of the karst caves development. The processes of cavitation, filling and collapse of caves were assessed. The concern to preserve unpolluted karst and water came to the front.

By new researchers in geology **Nadja Zupan Hajna**, **Stanka Šebela**, **Martin Knez**, **Metka Petrič**, **Bojan Otoničar** and in biology **Tanja Pipan** and in physics **Franci Gabrovšek** the Institute grew not only in terms of number but also in terms of professionalism. The basic knowledge of most important karstological spheres from karst geomorphology, speleology, hydrogeology to ecology is deepened. Underground waters, either water flows or percolation water are water traced and their quality asessed. The geomorphological properties of contact karst are studied. The factors controlling the karst caverns development in different conditions by characteristic processes and the origin of minerals in mechanical cave sediments is studied. The dependence of origin and development of karst features upon the geological structure is determined. On the base of lithology the origin of karstification is assessed. The paleokarstic features of the Adriatic Dinaric carbonate platform started to be studied. Regular items are studies undertaken on protection and safeguarding of Škocjanske jame, a natural monument listed in the UNESCO World Natural Heritage. The problems of safeguarding and use of the river Krka in the sections where calc-tufa is intensively deposited are tried to be solved. New karstological information collections are under preparation. The knowledge about the history of karstology and speleology is being deepened with an important contribution of our research associate **Trevor R. Shaw**, Ph.D.

In short, the issues regarding the karst natural heritage is widened and deepened. The Institute co-workers are successfully involved into planning and implementations of interventions into this sensible landscape and its safeguarding. Our interest is concentrated on study of karst aquifers and water sources and on construction of motorways over karst; we are studying newly discovered caves that bring the oldest traces of underground water drainage through karst aquifers and we are calling the public attention to the fact that the underground waters must be protected. We are cooperating at design of waste disposal sites and at opening of new quarries. We are studying the effects of accidental harmful substances spills into permeable karst surface.

Our collections as for example Cave Register, **Jurij Hajna** is in charge of it and karstological library, **Maja Kranjc** in charge are growing each year. **Leon Drame** is in charge of the cartographical collection. **Franjo Drole** surveys the most important Slovene caves and draws the plans. In the laboratory **Mateja Zadel** and **Alenka Leskovec** are in charge of various analyses. **Sonja Franetič** and **Stanka Tomšič** take care that the Institute as a whole functions well.

The International Karstological School that had been organised by the Institute makes part of a Slovene Park of Science and Technology.

Also, we cooperate at numerous international research projects: IGCP-UNESCO Project No. 379 Karst Processes and Carbon Cycle (cooperation among the institutions from all over the world); COST Action No. 65, Hydrological Aspects of Groundwater Protection in Karstic Areas (cooperation of institutions from European Union and countries from Central and East Europe), ATH-7th SWT - Tracers and models in various aquifers, Investigation in Slovenia 1993-1996 (cooperation of organisations from Slovenia, Austria, Germany and Switzerland); U.R.A. 903 C.N.R.S., Studies of Perimediterranean Karst (Laboratoire de Geographie Physique a Aix-en-Provence and Laboratoire souterrain du C.N.R.S, Moulis); ALIS Link No. 12 (British Council and Slovene Ministry of Science and Technology) between our Institute and Limestone Research Group, Department of Geographical & Environmental Sciences, University of Huddersfield; PECO "MEDIMONT", Desertification Risk Assessment and Land Use Planning in Mediterranean Coastal Area; Karst Environment Protection and Exploration of Cave Resources together with Institute of Geology of the Chinese Academy of Sciences, Beijing; a Cooperative Research on Karst Phenomenon's Preservation, Protection and Large Cave System's Exploration in Yunnan Province together with Institute of Geography, Yunnan, China. We have an active cooperation with the Museum of Nature Protection and Speleology, Liptovsky Mikulaš, Slovakia. Within the European Scientific Foundation the Institute is taking the place of international centre for karstological studies.

The door of the Institute is opened to all karstologists, students and pupils and to all that are in any way interested in this miraculous landscape - Karst-

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