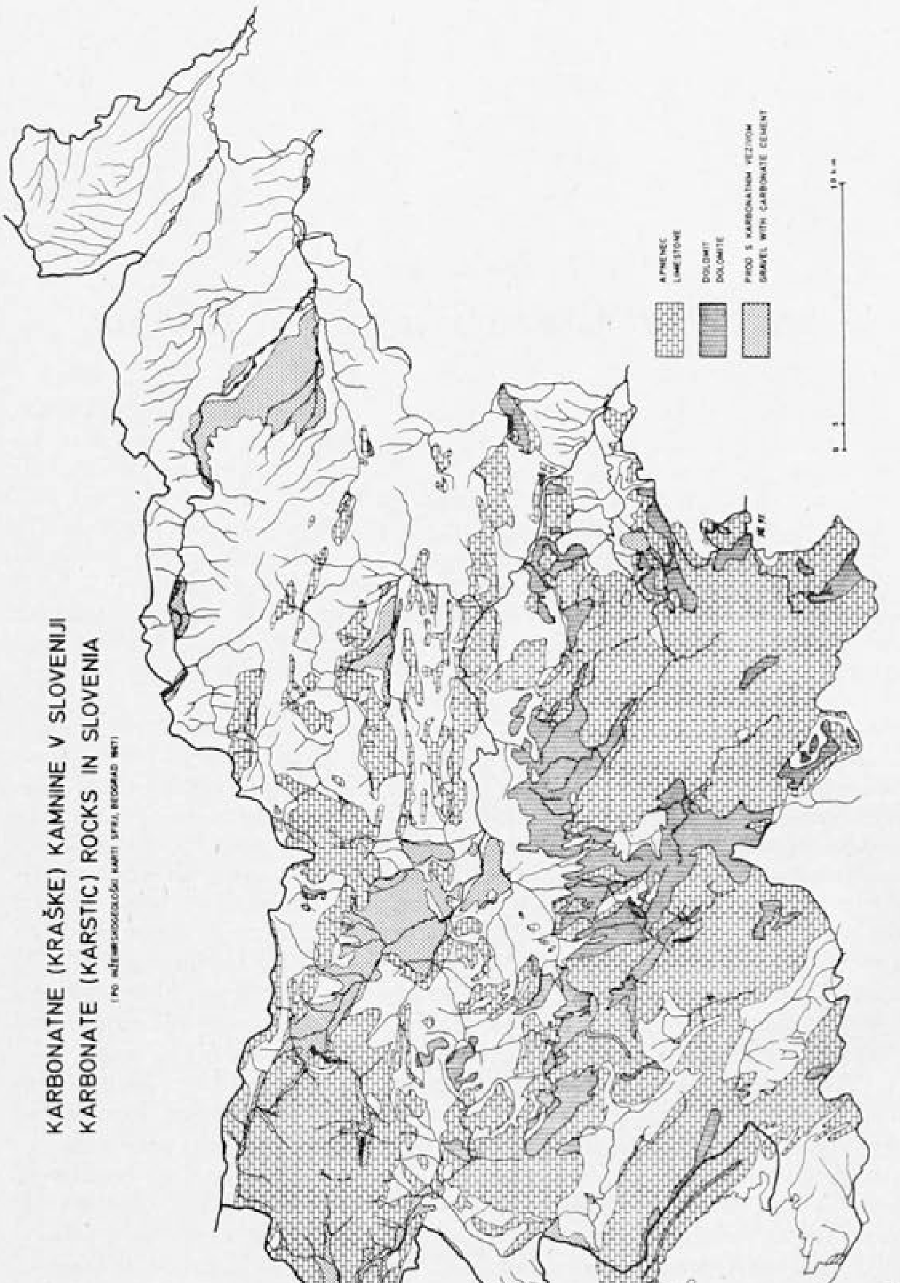
Ivan Gams

GEOGRAFSKO RAZISKOVANJE KRASA V SLOVENIJI

Raziskave slovenskega krasa vzbujajo razmeroma precej zanimanja, ker je Slovenija zlasti v tujini v geografskih krogih znana kot dežela krasa. Kras zavzema v okviru SR Slovenije tretjino ozemlja (okoli 7.000 km²). Večina ga je v južni Sloveniji, kjer geološko-tektonsko pripada Dinarskemu gorstvu (t. i. Zunanjim Dinaridom) in predstavlja večidel sredogorje. Večje zaplate zavzema v Julijskih Alpah in Kamniških Alpah, kjer tvori visokogorske planote in dolinasti relief. V Karavankah in v predalpskem sredogorju zavzema še daljše apneniške ali dolomitne gorske nize s kraško hidrografijo kot edinim kraškim pojavom, v subpanonskem gričevju pa le še osamljene površine. Absolutno je v prevladi karbonatni kras.

Bolj kot po razsežnosti je kras v Sloveniji znan zaradi zgodovine krasoslovja, saj iz njega izhaja mednarodni termin *karst*. Povzet je po pokrajini med Tržaškim zalivom in Vipavsko dolino, ki ji Slovenci pravijo Kras, v avstroogrski monarhiji pa je dobila nemško ime Karst. Ker je bila Slovenija pred nacionalno osvoboditvijo izpod Avstroogrske in nastankom Jugoslavije l. 1918 v veliki meri znanstvena provinca avstrijske geografije, se je preko nemške literature uveljavil termin »karst«. Pod vplivom dunajske geografske in geološke šole (A. Penck) so ga uporabljali tudi jugoslovanski raziskovalci (Cvijić, Gavazzi, 1904). Po njihovi zaslugi je postal slovenski kras »klasični« kras, sloves, ki ga uživa še danes (glej Wagner, 1954, Corbel, 1956), ustrezno pokrajino nad Tržaškim zalivom pa pogosto označujemo kot »matični« Kras.

Raziskovalni dosežki slovenskih geografov (A. Melik, J. Rus) v času med obema vojnama so doživeli manj odzivnosti v tujini, ker so bili objavljeni v slovenskem jeziku in ker se je ozemlje njihovega raziskovanja skrčilo na polovico. Zmagovalka iz prve vojne, Italija, je namreč zasedla Primorsko Slovenijo z matičnim Krasom vred. V Postojni je osnovala vseitalijanski speleološki institut. Kot plod njegovega dela je bil l. 1926 objavljen kataster jam — *Duemila/Grotte* (Bertarelli-Boegan, 1926), dvatisoč jam, ki jih je večina na slovenskem etničnem ozemlju, mnoge s popačenimi imeni. Po drugi svetovni vojni je ostala Italiji samo še slaba tretjina matičnega Krasa, na tradiciji italijanskega speleološkega


KARBONATNE (KRAŠKE) KAMNINE V SLOVENIJI
KARBONATE (KARSTIC) ROCKS IN SLOVENIA
APNENEC
LIMESTONE
DOLOMIT
DOLOMITE
PROD S KARBONATNIM VEZIVOM
GRAVEL WITH CARBONATE CEMENT

instituta pa je Slovenska akademija znanosti in umetnosti l. 1947 osnovala Institut za raziskovanje krasa v Postojni. Njegov predstojnik A. Šerko bi istega leta pričel na geografskem institutu univerze v Ljubljani redna predavanja o krasu kot samostojnem učnem predmetu geografije, če ga ne bi doletela smrt (Ta predavanja so bila obnovljena šele l. 1967). Institut za raziskovanje krasa objavlja svoje, pretežno speleološke rezultate, v zborniku *Acta carsologica*, od katerih je od l. 1955 do l. 1971 izšlo pet knjig. Kraške študije izhajajo še v revijah Geografskega društva, »Geografskemu vestniku« in »Geografskem obzorniku«, v izdajah Inštituta za geografijo SAZU (»Geografski zbornik« in posebne knjige iz serije »Dela«,) v glasilu Društva za raziskovanje jam (zdaj Jamarske zveze Slovenije) »Naše jame« (od l. 1959), v aktih jugoslovanskih speleoloških in geografskih kongresov itd.

Pregled znanstvenih dosežkov 1922—1972 bo tu podan v dveh poglavjih. V prvem bodo tematske, v drugem regionalne raziskave.

Pri hidrografskih raziskavah so bila v ospredju ugotavljanja podzemeljskih vodnih zvez. Rezultate 45 barvanj izpred druge svetovne vojne je tabelarno podal Šerko (1946), novejših 23 barvanj pa Gams (1965). Po drugi vojni so mnoge opravili v zvezi s projektiranjem vodnih akumulacij, do zgraditve katerih pa v Sloveniji, v razliko z ostalim Dinarskim krasom, ni prišlo. Drobna izjema je v preteklih stoletjih zelo znano Cerkniško polje, kjer so po večstoletnih načrtih o temeljitejšem osuševanju polja in po delnih melioracijah vodnih tokov in požiralnih jam l. 1970 zgradili na odtočnih jamah zapornice, da bi vsakoletnemu periodičnemu jezeru podaljšali trajanje. Vsa barvanja so ugotovila sicer medsebojno komuniciranje vodnih tokov v podzemlju, ne pa tudi njihovega podzemeljskega križanja. Sicer redka vrtanja za pitno vodo, sloneča na postavki o sklenjeni vodni gladini, niso našla zadostnih pretočnih količin. Čeprav izkušnje pri gradnjah na Dinarskem krasu še niso dovolj teoretsko obdelane, vse kaže, da v globokem krasu, ki je visoko dvignjen nad erozijski nivo, v nasprotju z nizkim krasom v tujini in morebiti v obalnem krasu v Istri (Jenko, 1959), ni tolikšne sklenjenosti vodne gladine, da bi ekonomsko opravičila vrtanja za vodo.

Na globokem slovenskem krasu tudi ni odvisnosti med strmcem podzemeljskega toka (= razlika med ponorom in izvirom) in hitrostjo pretakanja (Šerko, 1946), ki je v razponu med 57 in 0,15 cm/sek. Višji vodostaj pomeni praviloma hitrejši pretok in domneve, da bi ob zelo visokih vodostajih na kraških poljih pretočnost izvirov upadala (Jenko, 1959), je bila omajana (Gams, 1970). Velike razlike so pri mehanizmu intermitentnih izvirov (Habič 1970), kakor tudi glede minimalnih specifičnih odtokov ob suši, ki mestoma zdrknejo na 2 l/sek/km² (Gospodarič-Habe-Habič, 1970). Razmeroma dobro so preučene hidrofacije in temperature kraških voda (Novak, 1970, Habe, 1957).

Prva kompleksna hidrološka delitev slovenskega krasa je bila izvedena s stališča načina vodnega odtekanja; opredeljene so bile enostavne odtočne regije, pretočno-odtočne regije globokega krasa, regije z menjavanjem površinskega in podzemeljskega pretakanja in regije

s podzemeljskim dotokom in površinskim odtokom v plitvem krasu (Habič, 1969).

K l i m a t o l o g e je kras pritegnil najprej z vrtačami v gorskem svetu z obilico snega, od katerih nekatere, zlasti na Trnovskem gozdu in Snežniku, opozarjajo nase z vegetacijskim obratom (od roba proti dnu vrtače si sledijo bukov, nato iglast gozd, ruševje in ponekod še alpska, izjemoma celo snežna cona). Najstarejšo, enostransko razlago vegetacijskega obrata s temperaturno inverzijo so novejše meritve dopolnile in pokazale na pomen trajanja snežne odeje in specifičnih talnih pogojev. Udornice tipa Velika ledenica v Paradani pa pomenijo prehod k jamski klimi (Gams, 1972). Bolj kot dokazan je nakazan kras kot kompleksen klimatološki fenomen, ki se izraža v svojski geotermični stopnji, svojskem temperaturnem režimu tal in vlažnosti, svojskih ekoloških pogojih, nizki meji uspevanja kulturnih rastlin, kar vse še čaka nadalnjih raziskav. Več raziskav obravnava jamsko klimo: v Podpeški jami, v Postojnski jami (Crestani-Anelli, 1939, Gams, 1966, 1968), kjer je bila merjena rast kapnikov, in v Predjami, kjer nastaja v nekem dinamičnem rovu pozimi med toplim in mrzlim ustjem razlika do 31,6° C (Habe, 1970).

Ker se v Sloveniji goji *g e o m o r f o l o g i j a* prvenstveno v okviru geografije, je doprinos slovenske geografije k razvoju kraške geomorfologije najvidnejši. Do nedavna je bila v ospredju raziskovanja geomorfogeneza kraških oblik in reliefa. Prvi slovenski geomorfologi po prvi svetovni vojni so sledili tradiciji avstrijskih geologov. Rus (1921) je pripisoval za nastanek Ribniško-kočevskega polja največji pomen tektoniki. Melik (1928, 1931) je iskal razlago za nastanek večjih oblik notranjskega in dolenjskega krasa predvsem v predkraški fazi s površinskim rečnim odtekanjem, ki je pustila v današnjem reliefu suhe doline in podolja. Naziranje o predkraški fluvialni fazi je našlo v najnovejšem času novo potrditev v najdbah silikatnega kamninskega drobirja na brezvodnem krasu. Kar ga je bolj ali manj zaobljenega, ga štejejo za odkladnino predkraških površinskih tokov, manj zaobljen pa bi lahko ostal po erodiranih neprepustnih pokrovih, ki so pokrivali apnenec ali dolomit. Z najdbami teh »prodnikov« je bila podkrepljena shema o predkraškem površinskem toku Notranjske Reke preko matičnega Krasa, ki s svojimi zelo širokimi, domnevno suhimi dolinami vred visi proti Soški ravnini. Na antiklinorijumu, zgrajenem iz krednih in paleozojskih apnencev, je Reka na Krasu dobivala pritoke z eocenskega fliša na severu, ki tvori zdaj sinklinalo Vipavske doline (Radinja, v tisku). Postopno skrajševanje površinskega toka zaradi ponikev je pustila na severovzhodnem Krasu nivoje, ki preidejo v slepo dolino Notranjske Reke, ki ponika v Škocjanske jame (Radinja, 1967) ter je izvotlila vrsto votlin, ki jih dokazujejo številne udornice. S pomočjo silikatnih prodnikov je bila rekonstruirana tudi površinska vodna mreža na Trnovskem gozdu (Habič, 1968).

Čeprav so naziranja o tem, kateri procesi so na krasu poglavitni, tudi med povojnimi kraškimi geomorfologi na Slovenskem zelo različna, jim je skupno, da pripisujejo pleistocenski dobi večji pomen za se-

danjo oblikovanost krasa, kot doslej; bolj izstopa v ospredje selektivna erozija, manj poudarka pa dajejo tektogenezi.

Najobsežnejši opis slovenskih kraških polj je podal Melik (1935), ki jih je razlagal v glavnem kot fluvialne erozijske tvorbe. Zaradi povečanega mehaničnega preperevanja v glacialnih dobah so vode na poljih naplavile prod, pesek in ilovico, zatrpavale lastne ponore in povzročale trajnejšo ali periodično ojezeritev, kakršna je do danes ostala samo na Cerkniškem polju. Deloma zaradi premalega upoštevanja klimatskih nihanj v pleistocenu in zaradi avtomatskega prištevanja modrikastih glejev k jezerskim sedimentom, Melikova razprava, čeprav podprta z rezultati pelodnih analiz, ni doživela tolikega odziva kot bi sicer zaslužila. Kvartarne akumulacijske terase so se najlepše očuvale v tistih kraških poljih, na katere priteka reka z neprepustnih sedimentov. Tak primer je Postonjska kotlina, kjer je mogoče vzporejati terase z etažami Postojnske jame (Gospodarič-Habič, 1966). Drug primer je Dobro polje, kjer je Šifrer (1967) glede na preperelost in lego prodov razlikoval würmski, riški in mindelski (?) nasip. V Postojnski kotlini so oprli ugotavljanje starosti teras in jamskih etaž na arheološke ugotovitve in ločili mindelsko-riško erozijsko fazo, riško akumulacijsko teraso, erozijo v medledeni dobi R/W, würmsko aluvialno teraso in holocensko erozijo (Gospodarič-Habič, 1966). Tudi v jamah na obodu Sajevškega polja nudijo sedimenti in artefakti oporo za določevanje starosti nastanka (Habe-Hriber 1964).

Primerjava teras v slovenskih kraških poljih je privedla do trditve, da sta razviti v glavnem dve uravnavi, starejša iz starejšega pleistocena, ki je ohranjena v robnih terasah, in mlajša v dnu iz mlajšega pleistocena (od G/M do danes). Faze uravnavanja se ujemajo s povečano akumulacijo in ploskovnim uravnavanjem živoskalne osnove pod naplavino. V tem je razlika s fluvialnim erozijskim reliefom, kjer se zniževanje ujema z globinsko erozijo. Njeno vlogo na dnu kraškega polja ali slepe doline vrši podtalna korozija (Gams, 1972).

Različna mnenja v povojni svetovni geomorfologiji o tem, ali je korozija najintenzivnejša v hladni subarktični (J. Corbel) ali v vlažni topli tropski klimi (H. Lehmann), so našla svoj odziv tudi v Sloveniji v kvantitativnem določevanju korozijskega procesa. Prvi izračuni korozije s pomočjo trdot rečnih voda in specifičnega odtoka, ki ga na večjih kraških rekah že vrsto let ugotavlja hidrometeorološka služba, so pokazali, da je neupravičeno istovetiti površinsko vodno dreniranje in predkraško fluvialno fazo s fazo erozije (in adekvatno kraške faze izključno s korozijsko fazo). Izven Alp je v Sloveniji na vodoneprepustnih, bolj ali manj karbonatnih kamninah (karbonatnih laporjih, skrilavcih in podobno) korozija kot proces odnašanja gmote domala tako intenzivna kot erozija (Gams, 1962). Hitrejše zniževanje reliefa v neprepustnih kamninah, ki je značilno za kvartarno dobo, je prvenstvena posledica selektivne erozije v hladnih pleistocenskih razdobjih, ki je na krasu bistveno manjša. Zato je kraški relief sredi neprepustnih sedimentov pridobival na relativni višini. Za porečja, kjer na krasu delujejo vodomerske postaje, znaša korozijska intenzivnost med 30 in 90 $cm^3/CaCO_3$/

km². Zaradi perhumidne klime je korozija razmeroma visoka in zato so fosilne forme tropskega krasa iz terciarne dobe težko razpoznavne. Reducirajo se v glavnem na tip t. i. kopastega krasa (Habič, 1968). Že pred razčiščenjem problema o intenzivnosti korozije v raznih klimah, ki ga izpričuje sodobna svetovna literatura, je bilo za slovenski kras ugotovljeno, da ima primarno vlogo specifični vodni odtok (Gams, 1966).

Vendar ti izračuni niso ničesar prispevali k direktni pojasnitvi nastanka kraških depresijskih oblik. Le-te nastajajo večidel zaradi lokalno pospešene korozije (pod pokrovom naplavine — podtalna korozija, kot robna korozija, korozija poplavišč, nadalje na stiku golega in poraslega sveta vzdolž odtokov z ledenikov in večjih snežišč- Gams, 1964)

Kvantitativnih metod določevanja korozije se je oprijela večina mlajših raziskovalcev kraškega površja (Radinja, Habič, Kunaver). Vkljub temu je pri njih ostala še živa dilema, v koliko so vrtače posledica udorov in v koliko lokalno pospešene korozije. Na Slovenskem sta bila prva protagonista obeh skrajnosti. T. Gruber in B. Hacquet s svojimi deli iz konca 18. stoletja. Večja enotnost je dosežena v naziranju, da je na slovenskem krasu vladala še ob koncu terciara pretežno površinska, v kvartarju pa pretežno kraška hidrografska mreža.

Razmeroma malo raziskav je najti v slovenski kraški literaturi o posameznih kraških oblikah. Čeprav so poleg kraških polj vrtače najbolj tipična kraška oblika slovenskega krasa, geneza vrtač ni pritegnila posebnih raziskovalcev. Zbranega je precej gradiva o pojavljanju tako imenovanih ugrezov (Horvat, 1953), ki nastajajo največkrat na ravnih kmetijskih površinah z debelejšo naplavljeno prstjo. Le krajevno je bila obdelana morfometrija vrtač (Radinja, 1969). Sistematske preučitve skalnih visokogorskih oblik in višinske conalnosti so le delno objavljene (Kunaver, 1961). Melik (1962-63) in Radinja (1969) sta poskušala izdvojiti tako imenovani »dol« ali »kraški dol« kot posebno kraško obliko, podobno podolgovati vrtači oziroma suhi dolini, nastali pretežno kot rečni dolini, potem pa je reka prestavila svoj tek v podzemje. Najbolj znameniti tak dol, v katerem leži kraj Čepovan, je bil doslej vedno preskusni kamen kraške teorije. Primerjalno so bile študirane slepe doline, pri katerih je bila dokazana odvisnost velikosti slepe doline in zlasti njenega končnega dela v apnencu od trdote reke in njene vodnatosti. Čim nižja je trdota in čim več vode ponira, tem večja je praviloma slepa dolina (Gams, 1962).

Tektonsko grezanje kot vzporedni vzrok nastanka kraškega polja na Slovenskem ni našlo toliko privržencev kot drugod, ker za to geološki profili ne dajejo osnove. V mišljenju, da so kraška polja heterogena po nastanku in sedanji hidrološki funkciji, je bila modificirana H. Lehmannova shema. Po njej se polja ločijo na: periferna polja (na stiku neprepustnih kamnin, ki so znotraj polja, in kraških kamnin), robna polja (z vododržnimi sedimenti na robu polja ali izven), pretočna ali prelivna polja (z izviri na enem in ponori na drugem kraju), polja v nivoju *Forfluterja* ter razne vrste netipičnih polj, ki jih lahko označujemo kot »psevdopolje« ali »parapolje« (piedmontska v gorah, polja na planotah in polja v sistemu podolja (Gams, 1972).

L. 1962 je Geografsko društvo Slovenije v sodelovanju z Geološkim društvom priredilo simpozij o slovenski kraški terminologiji ter rezultate tudi objavilo v Geografskem vestniku 1962. L. 1971 so slovenski geografi priredili jugoslovanski simpozij z namenom, vskladiti in objaviti komparativno terminologijo jugoslovanskih narodov.

Spričo razmeroma številnih krasoslovnih razprav in drobnih opisov je presenetljivo malo pregledov čez ves slovenski kras. Največ strokovnega gradiva je zbranega v obliki strokovnega potopisa[1], izdanega v francoskem in angleškem jeziku ob priliki 4. mednarodnega speleološkega kongresa, ki je bil od 12.—26. IX. 1965 v Sloveniji in Dalmaciji. Ob tej priliki je izšel tudi v svetovnih jezikih napisani zvezek revije Naše jame (1965, 1—2) s preglednimi članki o jugoslovanskem krasu in o krasu v posameznih republikah. Razsežnejše monografske opise najdemo za nekatere jame (Postojnsko, Logarček, Predjama-Habe, 1970). Uspelo morfološko in morfogenetsko obdelavo je doživelo planotasto sredogorje Trnovski gozd-Hrušica-Nanos med Vipavsko dolino in Idrijco (Habič, 1968). Ko bo za opisom slepe doline — Vremske doline, Dobrdobskega krasa in Senožeškega podolja (Radinja, 1967, 1969,) izšel še opis preostalega dela matičnega Krasa, bo zaokrožena podoba njegovega razvoja - modela kraške morfogeneze neke pokrajine. V pripravi je obsežnejša študija o delu Julijskih Alp — Kaninu, (Jurij Kunaver) in v tisk je predana primerjalna morfogenetska študija o vsem slovenskem krasu (Radinja, v tisku).

Navedene monografije so geomorfološke, redke pa so, ki bi obravnavale vsestransko fizično geografijo. Splošne geografske opise kraških pokrajin obsegata ustrezni Melikovi knjigi »Posavska Slovenija« (Ljubljana 1939) in »Slovensko Primorje« (Ljubljana 1960). Toda kompleksnih znanstvenih analiz določenega kraškega predela skoraj še ni. Eden prvih poskusov, oprt na moderne metode, je proučitev prirodnih pogojev in agrarnega izkoriščanja kraških tal v eni od vasi na matičnem Krasu (Gams-Lovrenčak-Ingolič, 1970). Odprla je nove dimenzije kraškega raziskovanja. Pokazala je, kako bistveno se je površje v svoji drobni oblikovanosti spremenilo pod vplivom kmetijskega izkoriščanja v zgodovinski dobi. Ko je kmetovalec otrebil površinsko kamenje, na travnikih do nivoja zemlje, na ornih površinah do globine lemeža, je spremenil na razsežnih površinah polgoli kras v pokritega, obdelovanje pa je po drugi strani znižalo nivo prsti in izzvalo erozijo. Študij podtalnih kraških oblik (Gams, 1971) je odprl metodo, ki omogoča, po drobni oblikovanosti kamnitega površja določevati erozijo prsti. Trebljenje kamenja na površju v preteklih stoletjih in intenzivno ozelenjevanje in ogozdovanje zadnjih sto let je spremenilo tipični videz primorskega slovenskega krasa, ki je po prvih opisih v tuji literaturi zaslovel kot sinonim za kamnito polpustinjo s kraškimi pojavi. Kmetovalci so spremenili tudi obliko številnih vrtač: zemljo, ki so jo nastrgali po obodu vrtače, so nasuli in dvignili dno

[1] Guide de l'excursion à travers le Karst Dinarique-Guide - Book of the Coigress Excursion through Dinaric Karst. Ljubljana 1965

za širšo njivo. Bolj lijakaste vrtače so postale tako bolj skledaste in plitve. Vkljub ogromnemu vloženemu delu je na krasu orne zemlje malo in teže jo je strojno obdelovati. K temu se pridružujejo še težave s pitno in industrijsko vodo. Tudi to je vzrok, da spadajo v najnovejši dobi kraške pokrajine med tiste predele Slovenije, ki gospodarsko komaj ali le počasi napredujejo, pač pa doživljajo intenzivno preslojevanje prebivalstva in depopulacijo.

Zadnja leta narašča število raziskovalcev krasa, ki tudi vedno bolj uporabljajo modernejše raziskovalne metode. Ko bodo izšle nekatere že navedene raziskave v tisku, bo dokončno ob veljavo trditev, ki je bila izrečena o razvoju kraške morfologije v Jugoslaviji v prvi polovici tega stoletja, označujoča ta rzvoj kot epigonstvo (Blanc, 1938).

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GEOGRAPHICAL RESEARCH OF KARST IN SLOVENIA

Considerable attention has been paid to the research of karst phenomena in Slovenia since the country is known abroad to geographers as the classical karst area. About one third of the surface of the Socialist Republic of Slovenia is indeed a karst landscape (some 7.000 square kilometres). Most of it is to be found in the southern part of the country and is, with regard to the structural geology, part of the Dinaric mountain system (viz. of the so called Outer Dinarids). Most of the karst area of Slovenia is at moderate heights above sea-level. There are also large patches of the karst in the Julian Alps and the Kamnik Alps, in high plateaus between valleys. In the Karavanke mountains karst is found on the limestone and dolomite ridges only as a hydrological phenomenon. Karst is limited, however, only to a few spots in the sub-pannonian hill-country in the east. The carbonate type of karst is absolutely predominant in Slovenia.

The karst of Slovenia is better known for the history of karst exploration and research than for the area affected by karst phenomena. This exploration has, in fact, introduced the international term of karst into general use. It refers to the area between the Gulf of Trieste and the Vipava valley which is called »Kras« by the Slovenian population living there and which appeared in the germanized form as »karst«. As the area was explored largely by Austrian geographers and geologists prior to World War I the latter term became widely used in German literature and, following A. Penck, also by some Yugoslav researchers (Cvijić, Gavazzi, 1904). Owing to their writings the Slovenian region Kras above the Gulf of Trieste has become and has remained the »classical« karst area (see: Wagner, 1945; Corbel, 1956).

The research conducted after the liberation in 1918 by Slovenian geographers (A. Melik, J. Rus) is less well known abroad since the findings were published in the Slovenian language. Also about half of the area mentioned above has become unaccessible to them because of the inter-war international boundary. The western half of the Slovenian karst area — including the Kras region — came under the Italian rule. In Postojna (renamed then Postumia) an Italian central speleological institute was set up. A cave inventory, published on this basis a few years later, illustrates the work done until 1926 (See: Bertarelli-Boegan, Duemila Grotte). Most of the caves mentoined — often under distorted names — are located within the Slovenian speaking territory. After the World War II only one third of the classical Kras region remained under Italy. In 1947 the Slovenian Academy of Arts and Sciences (SAZU) established at Postojna a new Institute for Karst Research that has continued the tradition of its predecessor. In the same year the director of the institute, Alfred Šerko, had to start also a regular course in karst

studies at the Department of geography at the university of Ljubljana. In the same year, however, Šerko suddenly died and the course was not reassumed before 1967. The results of research done by the institute (mostly in speleology) are published since 1955 in a new serial »Acta carsologica«. Five volumes are out by 1971. Kars studies are also published in the two rewievs (»Geografski vestnik« and »Geografski obzornik« edited by the Geographical Society of Slovenia) and in »Geografski zbornik« and »Dela« (monographs) published by the Institute of Geography of the Slovenian Academy of Sciences and Arts. The periodical »Naše jame« published by the Speleological Society also brings articles related to karst research since 1959. Some studies were also published in the Proceedings of the Yugoslav geographical or speleological congresses or in other publications.

A survey of the scientific findings during the 1922—1972 period and concerning research on karst will be presented in two sections. The first deals with thematic research and the second with regional studies of karst areas.

The hydrological research was focused on the underground courses of water in the karst areas. The results of the 45 tracings made before World War II are summarized in a table by Šerko (1946) and of the 23 tests performed later, by Gams (1965). Many specific explorations were undertaken after World War II in connection with the projects for water reservoirs for power-plants which, however, were never carried out in Slovenia, in contrast to other parts of the Dinaric karst. A small exception is the once famous polje of Cerknica. After centuries of plans for the draining of the periodic lake and after more recent reclamation efforts concerned with water courses and sink-holes, the sluices were built at the main sink-holes after 1970 in order to prolong the duration of that seasonal lake. All tracings performed until now have proved that the interference of underground water courses are interrelated, but have not established any unconnected crossings of the channels used by the water. Following the assumption of a contiguous underground water-table a few borings for drinking water were made but no sufficient amounts were discovered. Although the experience gained in the construction of dams and reservoirs in the Dinaric karst areas have not yet been evaluated from a theoretical view-point, all bits of evidence suggest that there are no areas of contiguous underground water-table large enough to justify the costly search for water in the deep karst areas which are at high elevation above the erosion base-level. This is in contrast to findings in the low karst areas abroad and, possibly, in the coastal zone of Istria (Jenko, 1959).

There is, in the deep karst of Slovenia, also no relation between the gradient of the underground water-flow channels (i. e. the difference in height between the source and the swallow-hole) and its velocity (Šerko, 1946). The latter is within a range of 57 and 0,15 cm/second. A higher water-level means, as a rule, a swifter current and the assumption that the flow capacity might be decreased when high waters occur in the

poljes (Jenko, 1959), has been shaken (Gams, 1970). Differences in the mechanisms affecting intermittent sources were noted (Habič, 1970) as well as in the minimal specific run-offs in dry seasons when they can be as low as 2 seconds/l per square kilometre (Gospodarič-Habe-Habič, 1970). The temperature and hydrofacies are rather well established (Habe, 1937, Novak, 1970).

The first comprehensive hydrographical classification of the karst areas of Slovenia was made on the basis of different modes of the water circulation and run-off. The first hydrographical type includes the areas of the deep karst with no surface streams and an entirely underground run-off; the next type is represented by areas with predominant underground circulation but with some surface tributaries; the intermediate type includes areas with short intermittent streams on the surface and with an underground out-flow of waters. The last type includes areas of surface in-flow and surface run-off in the shallow karst at low altitudes near sea-level (Habič, 1969).

The small karst depressions, — dolines in the highland areas with abundant snow-cover during the winter attracted the climatologists' attention to the karst regions. Some of these dolines — in the Trnovski gozd and the Snežnik mountains — are remarkable for the marked vegetation inversion (beech, conifers' scrubs, the alpine and eventually even the nival zones follow in succession). The original simple explanation of the vegetation inversion supposedly due to the temperature inversion has been expanded and modified as a result of new measurements which have revealed the importance of the long snow cover and of the specific soil conditions. Large collapsed »dolines« like Velika Ledenica near Paradana indicate a transition to the true cave climate (Gams, 1972). The karst as a complex climatic phenomenon — that is expressed in a peculiar geothermic degree, in specific temperature in the soil and its moisture variations, in specific ecological conditions, low altitude limits for cultivation etc. — is rather indicated than fully proved and still awaits further research. Several studies are concerned with the cave climate in Podpeška jama (Podpeč cave) in Dobro polje and in the Postojna caves (Crestani-Annelli, 1939; Gams, 1966, 1968) where the growth of stalagmites and stalactites was measured; and in Predjama, where temperature fluctuations in a dynamic vertical cavern are as much as 31.0°C during the winter (Habe, 1970)

Because in Slovenia geomorphological research was carried out by geographers their share in karst geomorphology is also most notable. Until recently the research was focused on the origin of karst topography and land-forms. First research done by Slovenian geomorphologists was on the lines established already by Austrian geologists before World War. I. Rus (1925) considered that the Ribnica - Kočevje polje was formed largely due to structural geology of the area. Melik (1928, 1931), however, came to the conclusion that the larger karst landforms in the Lower and Inner Carniola are to be attributed to the processes in the pre-

karst stage of evolution, when surface drainage was still effective, as indicated by dry valleys of various size left in the present relief. The assumption of a prekarst fluvial stage were recently confirmed by the discoveries of flints in the water-less karst areas. The more rounded pieces are explained as surface deposits of the pre-karst streams, while angular and unworm pieces may be considered as remainings of the eroded impervious rocks once covering the exposed limestones and dolomites. The discovery of this »river gravel« has strengthend the concept of the pre-karst course of Notranjska Reka (called Timavo by Italian explorers) across the classical Kras region with its broad flat stretches of assumed dry valleys which are on the whole oriented toward the Soča plain. The river (Reka) in its course on this syclinorium consisting of cretaceous and old tertiary rocks was fed by tributaries from a belt of the eocene flysch to the north which now forms part of the Vipava valley (Radinja, in print). The surface water courses that were getting shorter because of emerging sink-holes left terraces at the eastern rim of the Kras region; they are continued in the blind valley of the Notranjska Reka which now disappears underground at Škocjan caves (Radinja, 1967) where many caverns were formed (which are also indicated on the surface by subsided portions of the roof above them). The flints found on the high karst area of Trnovski gozd and discovered only recently also helped to trace the courses of the former river net-work there (Habič, 1968).

Although the views of the karst geomorfologists in Slovenia about the dominance of particular processes in karst areas vary, they agree that the pleistocene period is more important for contemporary landforms in carst areas than it was considered earlier; they single out the role of the selective erosion and put less stress on that of the structural geology.

The most exhaustive account of karst poljes in Slovenia was given by Melik (1955). In his view, they were largely formed by fluvial erosion. Because of the increased mechanical weathering during glacial periods the rivers deposited clay, sand and gravel on the floor of the poljes, thus filling in the sinkholes and causing lasting or periodical formation of the lakes; the last of them remained until the present time only in the Cerknica polje. Because too little attention was paid to climatic fluctuations during the pleistocene period Melik's statements, although supported by pollen analysis, did not meet the reponse that they deserved. The aggraded terraces formed during the pleistocene period are best preserved in those karst poljes which are transversed by rivers originating in impervious sediments, as it is the case in the basin of Postojna where terraces can be correlated with different levels of channels in the Postojna caves (Gospodarič-Habič 1966). In another case (Dobro polje) Šifrer (1967), taking into consideration the position as well as the amount of the weathering of gravels, could discern three layers related to the Würm, Riss and Mindel stages. In the basin of Postojna, the age of the terraces was ascertained by (paleo) archeological evidence. The succesive stages are: Mindel-Riss erosion period, Riss aggraded terrace, Riss-

Würm erosion period, Würm alluvial terrace and the holocene erosion period (Gospodarič-Habič, 1966). The sediments and artefacts in the caves along the edge of Sajevško polje also provide evidence for dating their origin (Habe, Hribar, 1964).

The comparison of the terraces in the (karst) poljes of Slovenia led to the conclusion that there are two main levels to be found. The older dates back to the early pleistocene period and is preserved in the lateral terraces while that found on the bottom of the karst depressions dates from the younger pleistocene period (from the Günz-Mindel period onwards). The stages of levelling coincide with increased aggradation and with the applanation of the solid rock under the mantel of alluvial deposits. This is the contrast with the fluvial erosion relief where the lowering coincides with downward erosion. This role is taken, on the bottom of (karst) poljes or dry valleys, by the subsoil corrosion (Gams, 1972).

The differences of opinion among geomorphologists in the world as to whether corrosion is most intensive in the cold sub-arctic climate (J. Corbel) or in the humid tropical climate (H. Lehmann) triggered of quantitative measurements in Slovenia in order to determine the corrosion process. The first calculations concerning the amount of corrosion on the basis of the hardness of river water and of the specific run-off (that is regularily measured by the Weather Bureau) have shown that it is not justified to draw paralels between the surface water drainage and the erosion stage, and between karst drainage and an exclusively corrosion stage. Outside the high Alps the corrosion in impervious rocks of more or less carbonate type (marls, shales and similar rocks) is almost just as effective in the removal of rock mass (bed-rock) as the (normal) erosion (Gams, 1962). Quicker lowering of the relief consisting of impervious rocks that is the characteristic of the quarternary period is primarily the result of the selective erosion in cold pleistocene periods which in karst areas is much less effective. As a consequence, the karst relief amidst areas of impervious sediments was relatively gaining in height. In those karst drainage areas where regular observations are made the corrosion intensity is between 30 and 90 m^3 of $CaCO_3$ per year on a square kilometer. Due to the perhumid climate, corrosion is comparatively strong and therefore the fossil forms of the tropical karst that have remained from the tropical period are hardly discernible. They are mostly reduced to the type of the so called rounded mountain tops karst (Habič, 1968). Even before the problem of the intensity of corrosion in different climates was settled, as reported in recent literature obroad, it was established that in the karst areas of Slovenia the major role is played by the specific run-off of the waters (Gams, 1966).

The measurements, however, did not directly throw any new light on the origin of specific forms of karst depressions. These came into existance largely because of local accelerated corrosion (corrosion under the mantle of deposits — subsoil erosion; lateral corrosion; corrosion in often flooded sectors; also corrosion on the contact between the open

and the wooded terrain, on the tree-line along the water courses from glaciers and snow-fields (Gams, 1964). Most younger researchers of the karst phenomenon adopted the quantitative methods for assessing the amount of corrosion (Radinja, Habič, Kunaver). Even among them the old dilemma whether the dolines are primarily the result of rock-collapse above caves or of locally accelerated corrosion is still open. The two students which in their writings dealt with the problem as early as in the late 18th century, F. Gruber and B. Hacquet were protagonist of both extreme views. By now the researchers generally agree that at the close of the tertiary age there was a predominantely normal fluvial river network in the karst areas of Slovenia while karst hydrography took upper hand in the pleistocene period.

Comparatively few studies are published in Slovenian karst literature on particular karst landforms. Apart from (karst) poljes the dolines are most typical forms to be found in Slovenia, but only a few researchers paid more attention to their origin. A lot of evidence was assembled about the recently subsided dolines (Horvat 1953) which are mostly found on flat agricultural land consisting of thick layers of inundation alluvial soil. The morphometric measurements of the dolines were carried out only here and there (Radinja 1969). Systematic research was done on karst landforms and zonal differences in the rocky areas of the high mountains results have been published only partially (Kunaver, 1961). Melik (1962/63) and Radinja (1969) tried to single out »dol« (or »karst dol«) as a special karst landform, similar to an elongated »dolina« or a dry valley that could come into existance basically as a (normal) valley of a small river which has later disappeared underground. The most outstanding example of such a »dol« is to the north of Gorica at Čepovan and was all the times one of the testing stones for karst theory. A comparative study was made of the blind valleys and it has been proved that their size, in particular at the end in the limestones, depends on the amount of water and of its hardness. The lover the hardness is and the greater is the amount of water that filters down the larger is — as a rule — the blind valley (Gams 1962).

The notion of the tectonic origin of (karst) poljes was generally not held by so many researchers in Slovenia as elsewere, as the geological profiles in Slovenia do not provide sufficient evidence. The widely held view that (karst) poljes are heterogenous with regard to their origin and to their present hydrological function has led to a modification of the concept developed by H. Lehmann. According to that concept the (karst) poljes may be classified as: peripheral poljes (formed on the contact between impervious rocks within poljes and karst rocks), border poljes (with water-tight sediments at the edge of poljes or at the rim outside); over-flow poljes (with water sources at one end and sink-holes on the other end); poljes at the level of the »Vorfluter« and different kinds of atypical poljes which may be described as »pseudo-poljes« or »para-poljes« (e. g. peidmont poljes in the mountains, poljes on plateaus and poljes within large valley-like depressions (Gams, 1972).

In the year 1962 a joint symposium about the karst terminology was organized by the Geographical and Geological Societies in Ljubljana; the proceeding were published in Geografski vestnik (1962). In the year 1971 the Slovenian geographers organized a Yugoslav symposium with the same objective to coordinate and publish a comparative terminology used in the Yugoslav languages.

Only a few overviews of the karst phenomenon in Slovenia were published inspite ob the rather numerous carstological studies and minor descriptions. Most of the pertinent information is collected in a guidebook published — in English and French — at the occasion of the 4th International speleological Congress held between 12—26 September 1965 in Slovenia and Dalmatia. The magazine Naše jame (1965 vol., No. 1—2) also published a series of general articles on the karst phenomenon in Yugoslavia viz. about karst areas in particular republics. Several sizeable monographs exist on some caves (that of Postojna, of Logarček, of Predjama; Habe, 1971). A good morphological and morphogenetic monograph was published on the plateau-like mountainous area of Trnovski gozd — Hrušica — Nanos, lying between the Vipava and Idrijca valley (Habič, 1968). As soon as the regional studies in karst topography-now published for the area of blind valley of Vreme, for the Doberdob and Senožeče areas — will be completed by studies on the remaining part of the Kras region (Radinja, 1967, 1969), we shall have a rounded-off picture of its evolution; a model of the karst morphogenesis of that region. A study on Kanin area in the Julian Alps is in preparation (J. Kunaver) and a comparative morphogenetical study about the entire karst area of Slovenia (Radinja, is in print).

The monographs just mentioned mainly focus on geomorphology and are only seldom concerned with wider aspects of physical geography. The general geographical characteristics of the karst areas of Slovenia are described in two books by Anton Melik »Posavska Slovenija«, »Slovensko Primorje« (Ljubljana 1959, 1960). But there are few complex regional analyses of the karst areas. Using contemporary methods a small village in the »classical« Kras region has recently been studied in such a way from the point of view of the natural conditions and the land use and has opened new dimensions in karst research (Gams-Lovrenčak-Ingolič, 1970). The study has shown how basic were changes in the microrelief due to the agricultural land-use during the historical period. After the cultivators have removed the rocks sticking out of soil, which did to the depth of the plough-share for arable land and to the surface level for meadows, the half-barren karst surfaces have turned into the covered patches; but the cultivation has, on the other hand, reduced the soil-level and started erosion. The research on subsoil karst topography (Gams, 1971) introduced a method that enables to determine soil-erosion by the consideration of the tiny surface landforms. The removal of rocks on the surface which went on for centuries and intensive afforestation of the Kras region has produced a remarkable change in the typical

karst landscape in the sub-mediterranean part of Slovenia, which became famous, ever since the first descriptions in the foreign literature as a synonym for barren semi-desert area with karst features. Also, the shape of many »doline« was changed: the soil that was scratched from the rim was accumulated at the bottom which thus has been raised to make possible a larger field. The funnel shaped »doline« took rather the form of more shallow bowls. Inspite of the tremendous amount of work performed there is still very little arable land in karst areas and can hardly be worked by machines. An additional handicap is the lack of water for drinking and industrial use. This is another reason for most intensive depopulation, social transformation and slow economic growth of karst areas in Slovenia.

The impact of the recent increase in the number of researchers on karst phenomena and of the use of more and more sophisticated methods of research, is more and more evident. When the studies now in print and mentioned earlier will be available the statement made some years ago about the lagging evolution of karst morphology in Yugoslavia during the first half of the century (Blanc, 1958) will finally be refuted.

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