TEKTONSKA ZGRADBA SISTEMA POSTOJNSKIH JAM

TECTONIC STRUCTURE OF POSTOJNSKA JAMA CAVE SYSTEM

STANKA ŠEBELA

Stanka Šebela, rojena 11. januarja 1964 je znanstvena sodelavka na Inštitutu za raziskovanje krasa ZRC SAZU, kjer je zaposlena od leta 1988. Na Univerzi v Ljubljani, smer geologija je 1988 diplomirala pod mentorstvom prof. dr. Matije Drovenika z nalogo Petrografske značilnosti premogove plasti v Trbovljah in Zagorju. Magistrsko nalogo z naslovom Površinske geološke strukture in njihov vpliv na oblikovanje Predjame je zagovarjala v letu 1991. Tektonsko-litološke raziskave kraških jam je nadaljevala na primeru Postojnske jame. V letu 1994 je na Univerzi v Ljubljani oddala doktorsko nalogo z naslovom Vloga tektonskih struktur pri nastajanju jamskih rovov in kraških površinskih oblik ter jo uspešno zagovarjala v januarju 1995. Mentor magistrske in doktorske naloge je bil prof. dr. Jože Čar.

V času podiplomskega študija se je izpopolnjevala na številnih domačih in mednarodnih srečanjih, s čimer je dopolnjevala izkušnje tektonsko-litološkega kartiranja kraških terenov. S svojimi raziskavami je proučevala odvisnosti oblikovanja kraških rovov od geoloških strukturnih elementov, pri tem je posebno pozornost namenila oblikovanju podornih dvoran v slovenskih jamskih sistemih kot Predjami, Postojnski jami. Aktivno sodeluje pri kraških raziskavah v južnokitajski provinci Yunnan, na področju Kamnitega gozda. Kot štipendistka Slovenske Znanstvene Fundacije je v obdobju od 1996-1997 opravila 5 mesečno podoktorsko izpopolnjevanje v ZDA (US Geological Survey, Reston, Virginia in Desert Research Institute, University and Community College System of Nevada Las Vegas), kjer je aktivno sodelovala z ameriškimi znanstveniki pri raziskavah kraških terenov Missourija in Nevade. V letu 1998 je raziskave v ZDA nadaljevala v okviru Fulbrightove štipendije.

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Tectonic Structure of Postojnska jama Cave System

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ZAHVALA

Knjiga, ki je pred vami, je sinteza strukturno geoloških terenskih raziskav sistema Postojnskih jam, ki sem jih opravljala v obdobju od leta 1991-1997. V letih 1991-1994 je delo potekalo v okviru doktorske študije z naslovom »Vloga tektonskih struktur pri nastajanju jamskih rovov in kraških površinskih oblik« (Šebela, 1994 b) pod mentorstvom prof. dr. Jožeta Čarja (Naravoslovnotehniška fakulteta, Oddelek za geologijo, Ljubljana, Slovenija), ki me s koristnimi strokovnimi nasveti in napotki pri delu na Inštitutu za raziskovanje krasa ZRC SAZU spremlja že od leta 1988. Profesorju Čarju gre največja zasluga za mojo usmeritev v geologiji in krasoslovju, in sicer za tektonsko-litološko kartiranje jamskih rovov in kraškega površja.

Predstojnik Inštituta za raziskovanje krasa ZRC SAZU dr. Tadej Slabe me je vseskozi vzpodbujal, naj ugotovitve raziskovanja tektonske zgradbe sistema Postojnskih jam predstavim javnosti v obliki monografije. Najlepše se mu zahvaljujem za vsestransko vzpodbudo.

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Pri delu na terenu, kot tudi pri obdelavi podatkov v kabinetu so mi pomagali sodelavci Inštituta za raziskovanje krasa ZRC SAZU. Še posebna zahvala Juretu Hajni, Franju Droletu, Leonu Drametu. Knjižničarka Maja Kranjc mi je pomagala pri iskanju in izbiri potrebne literature.

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The book in your hands is a synthesis of my structural-geological field investigations of the Postojnska jama cave system, carried out in the 1991-1997 period. In the years 1991-1994, research was performed within the framework of my doctoral dissertation, entitled »The Role of Tectonic Structures in the Development of Cave Passages and Surface Karst Features« (Šebela, 1994 b). This was written under the guidance of my mentor, Prof. Dr. Jože Čar (Faculty of Natural Sciences and Technology, Department of Geology, Ljubljana, Slovenia), who with his useful expert advice has been guiding my work at the Karst Research Institute ZRC SAZU since 1988. The greatest credit is due to Prof. Dr. Čar for my orientation towards tectonic-lithological mapping of cave passages and the karst surface.

Dr. Tadej Slabe, Head of the Karst Research Institute ZRC SAZU, has encouraged me to present to the public the results of my investigations of the tectonic structure of the Postojnska jama cave system in the form of a monograph. I would like to express my greatest thanks for his many-sided support.

For his friendly remarks I would like to thank Prof. Dr. France Šušteršič (Faculty of Natural Sciences and Technology, Department of Geology, Ljubljana, Slovenia) as well as my co-workers at the Karst Research Institute ZRC SAZU: Dr. Andrej Mihevc, Mag. Metka Petrič, Dr. Martin Knez, Dr. Andrej Kranjc, and Bojan Otoničar, a graduate engineer in geology.

During my work in the field and the processing of data at the Institute I was assisted by my co-workers at the Karst Research Institute ZRC SAZU. I owe a great deal of thanks also to Jure Hajna, Franjo Drole, and Leon Drame. The librarian of the Karst Research Institute ZRC SAZU, Mrs. Maja Kranjc, helped me find and select the literature necessary for my work.

The text has been translated from Slovenian into English by Mag. Andrej Snedec (EURO translating agency) and Mojca Urankar. The English translation has been revised by Dr. Trevor R. Shaw, who has commented on several details. I wish to thank them sincerely.

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strstva za znanost in tehnologijo Republike Slovenije, v letih 1994-1997 pa v okviru temeljnih raziskovalnih projektov Ministrstva za znanost in tehnologijo Republike Slovenije, Kras v Sloveniji I in Kras v Sloveniji II.

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In the years 1991-1994, the research was carried out within the framework of the »2,000 Young Researchers« project, organized by the Ministry of Science and Technology of the Republic of Slovenia, and in the years 1994-1997 within the framework of the two basic research projects of the Ministry of Science and Technology of the Republic of Slovenia, »Karst in Slovenia I«, and »Karst in Slovenia II«.

Publication of the monograph was financially supported by the Postojnska jama - Turizem d.d., the Community of Postojna, the Ministry of Science and Technology of the Republic of Slovenia, and the COST project, Action 620 (Vulnerability and risk mapping for protection of karst aquifers), to all of which I am deeply grateful.

1

1.0. UVOD

Podatke za monografijo, ki je pred vami, sem s terenskimi raziskavami zbirala v letih 1991-1997. Tematske osnove pa so bile zastavljene že 1. avgusta 1988, ko sem nastopila redno delo na Inštitutu za raziskovanje krasa ZRC SAZU v Postojni. Takrat sem, kot mlada raziskovalka v okviru akcije 2.000 mladih raziskovalcev, ki jih financira Ministrstvo za znanost in tehnologijo Republike Slovenije, pod strokovnim mentorstvom prof. dr. Jožeta Čarja začela spoznavati geološke osnove oblikovanja kraških terenov.

Osnovna metoda, ki sem jo uporabila za magistrsko nalogo (Šebela, 1991) je bila podrobno tektonsko-litološko kartiranje površja nad Predjamo v merilu 1:5.000, in sicer po klasifikaciji tektonsko pretrtih con na zdrobljene, porušene in razpoklinske, kot jo je uvedel Čar (1982). Njegova metoda je bila v moji magistrski nalogi tudi prvič zelo uspešno preizkušena v jamskih prostorih Predjame, in sicer v merilu 1:1.000. Z vzdolžnimi profili jame in površja nad njo sem na vertikalni razdalji okrog 100 m povezala nekatere tektonsko pretrte cone v jami z izdanki na površju. V rovih Predjame, in sicer v Stari jami in Vzhodnem rovu, me je zanimala skladnost poteka jamskih rovov s tektonsko pretrtimi conami, pri čemer je bila dokazana precejšnja medsebojna odvisnost.

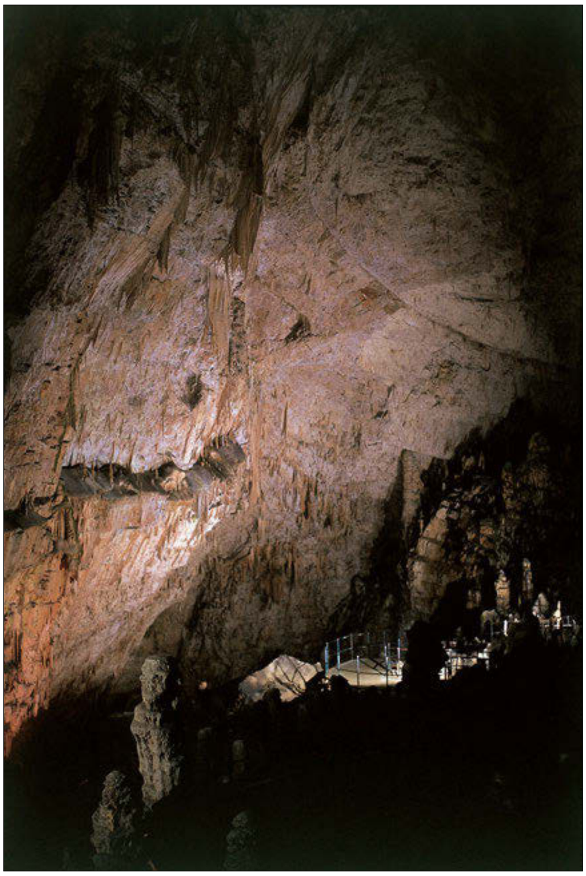
Sistem Postojnskih jam je najdaljši jamski sistem v Sloveniji. Z 19.555 m dolžine (Kataster jam IZRK ZRC SAZU) in dokazano vodno zvezo s Planinsko jamo bo v prihodnosti prvo mesto na lestvici le še utrdil. Del sistema Postojnskih jam - Postojnska jama je tudi turistično najbolj obiskana jama v Sloveniji, med tujci pa ena najbolj znanih. Najdaljši jamski sistem, dobre topografske karte jamskih rovov, ugoden dostop in zanimiva geološka zgradba so bili glavni izzivi, da sem se leta 1991 odločila za detaljnejše raziskave sistema Postojnskih jam. Do leta 1994 sem obdelala Postojnsko jamo, in sicer turistično urejeni del vključno s stranskimi rovi (Rov starih podpisov, Biospeleološka postaja, Kristalni rov, Rov brez imena, Pisani rov, Čarobni vrt) poleg tega pa tudi Zgornji in Spodnji Tartarus, Male jame in predel Podzemeljske Pivke do odcepa v Spodnji Tartarus. Do leta 1997 sem geološko raziskala še preostali del celotnega jamskega sistema.

1.0. INTRODUCTION

Data for this monograph was collected during my field investigations between 1991 and 1997. The bases for the subject of study were set already on 1st August 1988, when I started regular employment at the Karst Research Institute of the Scientific Research Centre of the Slovenian Academy of Sciences and Arts at Postojna. At that time, as a young researcher within the framework of the »2,000 Young Researchers« project, which is financed by the Ministry of Science and Technology of the Republic of Slovenia, I started to learn geological bases of the formation of karst terrains under the guidance of Prof. Dr. Jože Čar.

The basic method used in my master's thesis (Šebela, 1991) was detailed tectonic-lithological mapping of the surface above the Predjama cave at a scale of 1:5,000. The mapping was carried out according to Čar's (1982) classification of tectonically fractured zones into crushed, broken and fissured. For the first time, his method was used experimentally in a cave also, and in my master's thesis I very successfully used his method in the cave passages and chambers of Predjama at a scale of 1:1,000. At a vertical distance of about 100 m, I connected some tectonically fractured zones in the cave with outcrops on the surface by means of the longitudinal sections of the cave and those of the surface above. In the cave sections of Predjama, more specifically in Stara jama and Vzhodni rov, I was interested in the conformity between the orientation of the cave passages and that of the tectonically fractured zones, and I proved considerable interdependence between them.

The Postojnska jama cave system is the longest cave system in Slovenia. With its total length of 19,555 m (according to the IZRK ZRC SAZU Caves Cadastre) and proven water connection with the Planinska jama cave, the system will establish its leading position even more in the future. One part of the Postojnska jama cave system - Postojnska jama itself - is also the most visited cave in Slovenia and among foreign visitors probably the best known. The length of the cave system, the good topographic maps of the cave passages and chambers, favourable access and an interesting geological structure presented the main challenges which in 1991 led to my decision to carry out detailed investigations of



1.1. Problematika

Osnovno vodilo v monografiji predstavljenih raziskav je bila določitev vloge tektonskih in litoloških strukturnih elementov pri nastajanju in oblikovanju jamskih rovov. V ta namen je izdelana podrobna tektonsko-litološka karta sistema Postojnskih jam (priloga 1). Jamski rovi pa niso samo označeni v geološki karti, ampak tudi geološko ovrednoteni po posameznih značilnostih oblikovanja, glede na sledove oblikovanja v freatični ali vadozni coni. Še posebno me je zanimalo formiranje danes aktivnih in neaktivnih jamskih rovov v odvisnosti od geološke strukture. Dejstvo je, da je v večini suhih kraških jam mogoče najbolj zanesljivo določiti recentno stanje oblike rovov, na začetno oblikovanje pa lahko zanesljivo sklepamo le v posameznih primerih. Zato sem na podlagi študija geološke zgradbe in morfološko različnih oblik prečnih jamskih profilov izdelala karto oblikovanja jamskih rovov (priloga 3) glede na strukturne elemente s poudarkom na različnih fazah oblikovanja, od inicialnih stadijev do podiranja.

Prednost izbire sistema Postojnskih jam je predvsem v njeni bližini inštitutu ter v dobrih kartografskih osnovah jamskih rovov, kot tlorisov, prečnih in vzdolžnih profilov v merilu 1:500, ki so jih naredili

the Postojnska jama cave system. Up to the year 1994, I investigated the Postojnska jama cave itself, i.e. its commercially arranged part including the side passages (Rov starih podpisov, Biospeleološka postaja, Kristalni rov, Rov brez imena, Pisani rov, Čarobni vrt) as well as Zgornji Tartarus, Spodnji Tartarus, Male jame, and part of Podzemeljska Pivka as far as the intersection leading to Spodnji Tartarus. By 1997, I had geologically investigated the rest of the entire cave system.

1.1. The Subject of Study

The main lead of my investigations presented in this monograph was to determine the role of tectonic-lithological structural elements in the origin and formation of the cave passages. For this purpose, I made a detailed tectonic-lithological map of the Postojnska jama cave system (Annex 1). The cave passages and chambers are not only marked on the geological map but also evaluated geologically according to the individual characteristics of formation, i.e. with regard to the traces of formation in either the phreatic or the vadose zone. I was particularly interested in the formation of currently active and non-active cave passages and their dependence on the geological structure. The fact is that in the majority of dry karst caves, only the recent development of passage shapes can be reliably determined; their initial formation may be reliably inferred only in individual instances. On the basis of the study of the geological structure and that of the morphologically different shapes of the cave cross-sections, I made a map of cave-passage formation (Annex 3) with regard to the structural elements, with emphasis on the various phases of formation, from initial stages to breakdown processes.

An advantage of choosing the Postojnska jama cave system is particularly its proximity to the Institute and good cartographic bases of the cave passages and chambers - ground plans, cross-sections and longitudinal sections at a scale of 1:500 which were made by Gallino, Petrini and Sartori in 1933-34, and supple-

Gallino, Petrini in Sartori 1933-34, jih v letih 1948-60 dopolnila Hribar in Michler, v letu 1972 ter 1983-84 Kenda ter v obdobju 1989-98 Drole (Kataster jam IZRK ZRC SAZU). Poseben izziv in vzpodbudo predstavlja tudi dejstvo, da je sistem Postojnskih jam z različnih vidikov (geološki, speleološki, datacije sig in jamskih sedimentov, speleogenetski, klimatski, hidrokemični, arheološki) že v obdelavi, vendar predvsem kot celoten sistem odpira še mnogo zanimivih vprašanj.

Raziskovala sem kraške podzemeljske rove, in sicer v prvi vrsti posamezne odseke jame in šele kasneje tudi jamo kot celoto. Tudi Palmer (1991) meni, da je pomembno proučevati posamezne rove preden lahko razumemo celoto. Že v naslovu monografije sem, kot vzrok nastajanja in vzrok za današnje oblike jamskih rovov, izpostavila predvsem tektonske strukture. V Sloveniji se je v zadnjih letih (Čar, 1982; Čar & Gospodarič, 1984; Habič, 1982 in 1984; Šebela & Čar, 1991) uveljavilo stališče o pomenu tektonike pri oblikovanju kraškega podzemlja in površja. Za Alpsko-Dinarski prostor je značilna tektonska razgibanost terena, kar je voda na svoji poti v podzemlje skozi karbonatne kamnine s pridom uporabljala.

Kjer je bilo v jami le mogoče, sem določevala tudi horizontalne in vertikalne premike ob prelomnih ploskvah. Ti so seveda odraz in del načina tektonskih premikov širšega ozemlja.

Za razliko od podrobnega tektonsko-litološkega kartiranja Predjame, v primeru katere me je zanimala predvsem določitev geoloških elementov, ki so jamo oblikovali, sem v primeru sistema Postojnskih jam opazovala posamezne odseke rovov in kasneje, s pomočjo oblike prečnih profilov, poskušala genetsko povezati njihove posamezne odseke. Glede na celotni jamski sistem sem podala geološke osnove speleogeneze. Obdelala sem 96 prečnih profilov, ki sem jih razvrstila v glavne vrste in podvrste, in sicer na podlagi njihove oblikovanosti glede na geološke značilnosti.

Z vzdolžnimi profili sem želela prikazati možno povezanost določene tektonsko pretrte cone v jami z izdanki na površju. Posebno sem se osredotočila tudi na različne debeline stropa in tako sledila tektonsko pretrte cone iz jame na površje in obratno na vertikalnih razdaljah od 20 do 110 metrov. S tem sem prikazala stopnjo korelacije določene tektonsko pretrte cone na površju z isto cono v jami.

S podrobnim geološkim kartiranjem sem zajela celoten dostopen sistem Postojnskih jam in okrog 3 km^2 površja nad jamskimi rovi, saj je za kompleksno razumevanje geološke zgradbe terena poleg jamskih rovov pomembno tudi razumevanje površinske geologije. Dobršen del terena pripada apnencu zgornje kredne starosti ter le manjši del eocenskemu flišu ter flišni naplavini in preperini. Del površja nad Črno in Pivka jamo je geološko podrobno kartiral že Čar (1983).

Podrobno sem kartirala tudi površje nad Postojnsko jamo, saj je bilo to območje zaradi vojaških poligo-

mented by Hribar and Michler in 1948-60. Additional modifications and impovements were made in 1972, 1983-84 by Kenda, and were supplemented in 1989-98 by Drole (IZRK ZRC SAZU Caves Cadastre). Particularly challenging and stimulating is also the fact that the Postojnska jama cave system has already been investigated from different aspects (geology, speleology, the dating of flowstones and cave deposits, speleogenesis, climate, hydrochemistry, archaeology), but the system as a whole still offers many interesting questions to be discussed in the future.

I investigated the karst underground passages and chambers of the Postojnska jama cave system - in the first place the individual sections of the cave system and then, the system as a whole. Also Palmer (1991) is of the opinion that it is vital to an understanding the whole cave system to study the individual cave sections first. Already in the title of my monograph, I have emphasized particularly tectonic structures being the reason for the formation of the cave passages and for their present shapes. In recent years (Čar, 1982; Čar & Gospodarič, 1984; Habič, 1982 and 1984; Šebela & Čar, 1991), Slovenia has established its own views about the significance of tectonics for the formation of both the karst underground and karst surface. Characteristic of the Alpine-Dinaric region is tectonic diversity of the terrain, which has been gratefully used by water during its flow underground through carbonate rocks.

In the cave, whenever possible, I determined also horizontal and vertical displacements along the fault planes. The movements are a reflection and part of the character of the tectonics of a wider territory.

In contrast to the detailed tectonic-lithological mapping of the Predjama cave, where I was interested particularly in determining the geological elements which had formed the cave, in the case of the Postojnska jama cave system I observed individual sections of the passages and subsequently tried to connect these individual sections genetically by means of the shapes of the cross-sections. I determined the geological bases of speleogenesis with regard to the whole cave system. Ninety-six cross-sections were studied. On the basis of their shapes being a consequence of the geology, I classified the cross-sections into groups and subgroups.

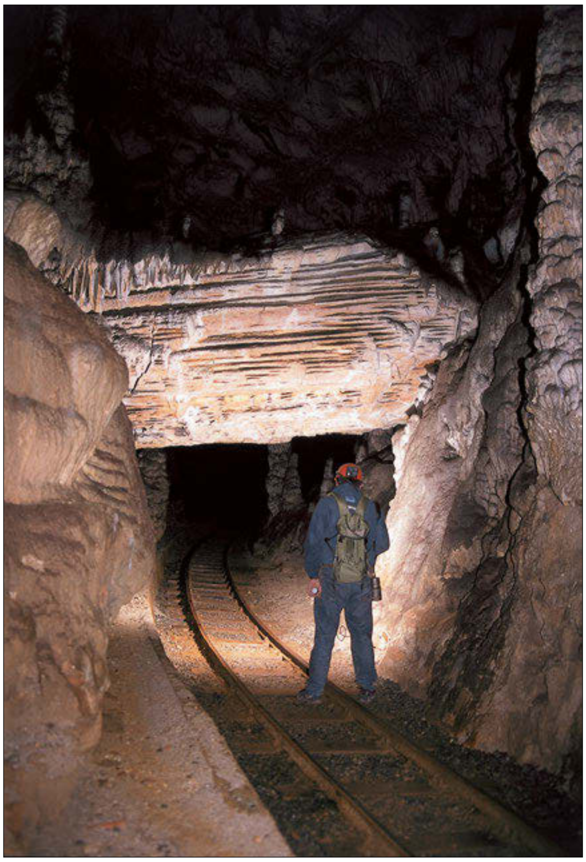
With the longitudinal sections I tried to demonstrate possible connections between individual tectonically fractured zones in the cave and outcrops on the surface. I particularly focused my attention on the difference between the thicknesses of the ceilings and followed the tectonically fractured zones from the cave system to the surface, and conversely, at vertical distances of 20 m to 110 m. In this way I demonstrated the level of correlation between a particular tectonically fractured zone on the surface and the same zone in the cave.

By detailed geological mapping I covered the entire accessible cave system of Postojnska jama and about 3 km^2 of the surface above the cave system - not nov jugoslovanske vojske še pred sedmimi leti povsem zaprto. Prav zato teren nad jamo še ni bil podrobno geološko kartiran, razen na geološki karti 1:100.000, list Postojna (Buser, Grad & Pleničar, 1967) in sta tako Čar in Gospodarič (1984) na možne geološke razmere sklepala po geoloških kartah ozemelj severneje in južneje ter geoloških podatkih iz jame.

S končno sintezo dobljenih podatkov sem statistično določila delež oblikovanja jamskih rovov v odvisnosti od tektonskih elementov, pri čemer je bilo pomembno tudi oblikovanje v lezikah, in sicer predvsem takih, ki so poudarjene z medplastnimi zdrsi.

Razdelitev prečnih profilov glede na različne vzroke oblikovanja je lahko, poleg opazovanja skalnih oblik, datacije jamskih sedimentov in sig ter speleomorfologije, pomožna metoda za razlago speleogeneze posameznih odsekov jame ter jame kot celote. Glede na obliko prečnih profilov iz jam v katerih še niso bile opravljene take raziskave, a jih prikazujejo jamski načrti, lahko z določeno verjetnostjo sklepamo na oblikovanje prečnih profilov po geoloških strukturnih elementih na podlagi izkušenj iz drugih geološko raziskanih jam.

Dobljene podatke iz jame in s površja sem tudi statistično obdelala in tako ovrednotila glavne vzroke oblikovanja jamskih rovov in površja nad sistemom Postojnskih jam. Ker je v jamskem sistemu veliko raziskoval že Gospodarič (1965, 1976), na površju nad Črno in Pivka jamo pa Čar (1983), sem svoje ugotovitve primerjala tudi z njunimi rezultati.



only the cave passages but also geology of the surface contribute to a complex understanding of the geological structure of the terrain. A considerable part of the terrain consists of Upper Cretaceous limestone and the remaining part of Eocene flysch, flysch deposits and weathered flysch material. Part of the surface above the caves Črna jama and Pivka jama has already been geologically mapped in detail by Čar (1983).

I mapped the surface above the Postojnska jama cave in detail. Since the area, which was used as a military training ground by the Yugoslav Army, was completely closed until seven years ago, it had not been geologically mapped in detail previously, except for the 1:100,000 geological map, Postojna Sheet (Buser, Grad & Pleničar, 1967). For that reason, Čar and Gospodarič (1984) had inferred possible geological conditions from the geological maps of the areas to the N and the S as well as from geological data on the cave.

With the final synthesis of the obtained data, I determined the statistical proportion of the formation of the cave passages according to the tectonic elements, an important aspect of which was formation in bedding planes, particularly those which are deformed with interbedded movements.

Besides observing cave rocky relief features, the dating of cave deposits and flowstones, as well as observing speleomorphology, an additional method for interpreting the speleogenesis of the individual cave sections and that of the cave system as a whole in detail, may be classification of the cross-sections with regard to various reasons for the passage formation.

In the caves where cross-section investigations have not been carried out by me, but the cross-sections are presented on cave maps, their formation along structural geological elements may be inferred on the basis of the experience gained in other geologically studied caves.

I processed the obtained data on the cave system and the surface statistically, and thus evaluated the main reasons for the formation of the cave passages as well as the surface above the cave system. Since a lot of work had been done already in the cave system by Gospodarič (1965, 1976), and on the surface above the caves Črna jama and Pivka jama by Čar (1983), I compared my findings with their results.

2

2.0. IZBIRA TERENA

2.1. Topografski opis ozemlja nad sistemom Postojnskih jam

Ozemlje nad sistemom Postojnskih jam, ki sem ga zajela z raziskavami (priloga 6), obsega 3 km^2. Kontakt med eocenskim flišem in zgornjekrednim apnencem je dobro opazna morfološka stopnja. V pasu 300 do 400 m od morfološke stopnje proti severu je Otoška gmajna. V tem delu je najvišji vrh Kacul z nadmorsko višino 598,4 m. Jugovzhodno od vhoda v Postojnsko jamo je hrib Sovič (676,5 m), ob cesti k Pivka jami pa slepa dolina Risovec.

Severno in severozahodno od Soviča lahko zaradi več deset letnega izkoriščanja terena v vojaške namene še danes opazujemo močno spremenjen teren, kjer je geološko kartiranje zelo oteženo. Najvišji vrh predela je v nadmorski višini 642,5 m.

Okrog 600 m severno od Otoške gmajne se teren imenuje Postojnska gmajna. Najvišji vrh je v nadmorski višini 654 m, geodetska točka pa je na Nemčjem vrhu v nadmorski višini 632,7 m. Najnižja točka terena je v dnu Velike Jeršanove doline na nadmorski višini 535 m. Določili smo jo sodelavci Inštituta za raziskovanje krasa ZRC SAZU z laserskim teodolitom (Šebela, 1994 a).

Teren severno od Otoške in Postojnske gmajne je večinoma gozdnat, travnat ali porasel z nizkimi grmičastimi bori. Še pred prvo svetovno vojno je bilo ozemlje Otoške in deloma tudi Postojnske gmajne zaradi pašništva precej manj zaraščeno. Tudi ponorni vhod reke Pivke v Postojnsko jamo kaže pred 100 leti precej drugačno podobo, kot je danes.

2.0. SELECTION OF TERRAIN

2.1. Topographic Description of the Area Above the Postonjska jama Cave System

The territory above the Postojnska jama cave system, which I included in my investigations (Annex 6), has a surface area of 3 km^2. The contact between Eocene flysch and Upper Cretaceous limestone is a distinct morphological feature. Within a belt 300 to 400 m N of the morphological feature there is Otoška gmajna, with the highest hill Kacul, situated at 598.4 m a.s.l. SE of the entrance to the Postojnska jama cave there is a hill called Sovič (676.5 m). The blind valley Risovec is located by the road leading to the Pivka jama cave.

N and NW of Sovič there is an area which in the past was heavily used for military purposes for several tens of years. As a consequence of military activities the area is highly modified, which makes geological mapping very difficult. The highest elevation is situated at an altitude of 642.5 m.

About 600 m N of Otoška gmajna there is an area called Postojnska gmajna. The highest elevation is situated at 654 m a.s.l. A geodetic station is on top of the hill Nemčji vrh at an altitude of 632.7 m. The lowest station of the area, at 535 m a.s.l., is at the bottom of the doline Velika Jeršanova dolina and has been determined by means of a laser theodolite by the workers of the Karst Research Institute ZRC SAZU (Šebela, 1994 a).

The area N of Otoška gmajna and Postojnska gmajna is mostly covered with wood, grass or low bushy pine trees. Before World War I, the area of Otoška gmajna and partly that of Postojnska gmajna were considerably less overgrown as a consequence of pasture economy. The picture of the ponor entrance section of the Postojnska jama cave one hundred years ago is very different from that of the present sink of the Pivka to Postojnska jama.

3

3.0. DOSEDANJE RAZISKAVE

Tako v svetovni kot v slovenski literaturi številni avtorji poudarjajo vlogo različnih geoloških elementov, predvsem pa tektonskih in plastnatosti, pri nastajanju jamskih rovov in kraških površinskih oblik. Tudi pri uporabi letalskih posnetkov za interpretacijo geološke zgradbe terena je opravljenih že mnogo zelo zanimivih raziskav. Z oblikovanjem prečnih profilov v jamah so se običajno ukvarjali pri speleogenezi jamskih rovov skladno s hidrogeološkimi zakonitostmi.

3.1. Pregled raziskav obravnavane tematike v svetovni literaturi

3.1.1. Pregled raziskav vpliva tektonske zgradbe na oblikovanje kraških terenov

Oblikovanje jamskih rovov in kraških površinskih oblik v odvisnosti od tektonske zgradbe določenega terena pomeni krasoslovcem enega osnovnih izzivov, kar potrjujejo številne razprave in članki.

Maucci je leta 1953 primerjal smeri razpok s smerjo jamskih rovov na dveh med seboj ločenih terenih v severovzhodnem delu Italije. Ugotovil je, da so tektonske razmere na obeh terenih enake, medtem ko se smeri jamskih rovov razlikujejo.

Davies (1960) navaja štiri stopnje razvoja jam v nagubanih apnencih: (1) naključno raztapljanje v globini, (2) izpopolnitev in zrel razvoj raztopljenih odprtin, (3) odlaganje klastičnega materiala, (4) dviganje in erozija.

Kjer so jame razvite na krilih antiklinal ali sinklinal, imajo preprost tloris. Sestavljene so iz glavnega rova in nekaj podrejenih, vzporednih rovov. Na grebenu antiklinale, kjer so vpadni koti apnenca majhni je jama labirint sestavljen iz rovov v dveh navskrižnih sistemih (Davies, 1960).

3.0. PREVIOUS INVESTIGATIONS

In world literature as well as in Slovenian literature, many authors have emphasized the role of various geological elements (particularly tectonical elements and bedding) in the formation of cave passages and surface karst features. With regard to the use of aerial photographs for interpreting the geological structure of terrain, several very interesting investigations have already been carried out. The formation of cave cross-sections has usually been studied within the framework of the speleogenesis of cave passages in accordance with hydrogeological principles.

3.1. An Overview of Investigations of the Treated Subject in World Literature

3.1.1. An overview of investigations of the influence of tectonic structure on the formation of karst terrains

The formation of cave passages and surface karst features, being dependent upon the tectonic structure of a particular terrain, presents one of the main challenges to karstologists, which has been demonstrated by a great number of discussions and papers.

In 1953, Maucci compared the orientation of fissures with the orientation of cave passages in two separate terrains of NE Italy. He came to the conclusion that the two have the same tectonic conditions but different cave passage orientations.

Davies (1960) proposes four stages of cavern development in folded limestones: (1) random solution at depth, (2) integration and mature development of solution openings, (3) deposition of fill (clastic materials), (4) uplift and erosion.

Where caves are developed on the flanks of anticlines or synclines they are simple in plan, consisting of a major passage and a few subordinate parallel passages. At the crests of anticlines where dips are low the cave is a maze consisting of a series of passages developed

Ford (1965, 1968, 1971) in Renault (1967, 1968 a in b, 1970) sta, z delitvijo jam na vadozne, freatične, jame vodnega nivoja (plitve freatične jame in epifreatične), nerazvite (praznine ali večje dvorane) in prave arteške jame, jamskim rovom določila vlogo hidrološkega prevodnika.

Ek (1970 a, b) je v jami Remouchamps v Belgiji našel prelome, ki jih ni bilo mogoče slediti na površju. Proučeval je vplive plastnatosti, razpok in prelomov na kraško morfologijo. Raziskave so pokazale, da razpoke določajo položaj in obliko številnih jamskih rovov. Prelomi, ki jih je opazoval v jami, so radialni, največkrat transverzalni na smer plastnatosti. Močno vplivajo tudi na morfologijo jame, saj vsi ustrezajo podornim delom. Pri primerjanju geološke strukture nad jamo teh prelomov ni opazil.

Strukturno geologijo in hidrogeologijo so proučevali tudi pri Montpellierju v Franciji. Zajeli so ozemlje okrog 500 m^2 z 19 vrtinami globine od 30 do 100 m, s povprečjem 60 m. Na karbonatnih terenih so ugotovili dve tektonski fazi, ki so ju identificirali z makro in mikro strukturami. Prva faza je tlačna in je vezana na glavno pirenejsko-provansalsko fazo v zgornjem eocenu. Druga faza je natezna in oligocenske starosti. Najdaljše razpoke so kalcitizirane in zaprte. Odprtine, ugodne za zakrasevanje, se ravnajo po smeri, ki je posledica mehaničnega razpiranja (Drogue & Grillot, 1976).

V začetku razvoja jamskih rovov se v ravninah razpok pojavi freatični tok. Ford & Ewers (1978) imenujeta take rove "joint tubes" ali rove v razpokah. Pri razvoju jame vzdolž razpok je znotraj razpoke ali na njenem koncu lahko starejša praznina. V takem primeru se ta del jame razvije po najkrajši poti, s tem da vključi predhodno votlino.

Zgodnji pogoji nastanka jam so določeni strukturno in litološko. Jamski sistemi so zgrajeni iz mnogih posameznih delov. Posamezni odseki so lahko usmerjeni po plastnatosti, razpokah, prelomih ali križanjih razpok. V mnogih primerih so deli, kjer prevladuje plastnatost, jasno ločeni od delov, kjer prevladujejo razpoke. Večji jamski sistemi so nastali s postopnim napredovanjem in povečanjem začetnih kanalov (Ford & Ewers, 1978).

Raztapljanje kamnin, kar vodi v razvoj krasa, je pod naravnimi pogoji zelo počasno: 10^4 do 10^5 let za jamski sistem dolžine okrog 1 km. Zaradi kompleksne povezave med razpokami, plastnatostjo, pretokom podzemeljske vode in kinetiko raztapljanja, so kraške votline in poti drenaže težko določljive (Soderberg, 1979).

V hidrogeologiji razpokanih kamnin so raziskovanja usmerjena v določevanje strukture vodonosnikov. Zato je analiza razpokanosti postala eden glavnih elementov študije hidrogeologije teh okolij (Razack, 1980-81).

S hidrogeologijo krasa se je ukvarjal tudi Mangin (1986). Po njegovem mnenju klasični podatki vodonosnika, kot parametri pretoka, ne zadostujejo. Potrebno

in two intersecting systems (Davies, 1960).

By classifying caves into vadose, phreatic, water-table caves (shallow phreatic and epi-phreatic caves), non-integrated caves (vugs or larger rooms), and true artesian caves, Ford (1965, 1968, 1971) and Renault (1967, 1968 a and b, 1970) determined that cave passages have the role of a hydrological conduit.

In the Belgian cave Remouchamps, Ek (1970 a, b) discovered some faults which could not be seen on the surface. He studied the influence of bedding, fissures and faults on karst morphology. His investigations led to the conclusion that fissures determine the position and shape of a great number of cave passages. The faults which he observed in the cave are radial and in most cases transversal to the strike of the bedding. They greatly affect the morphology of the cave since they all correspond to the breakdown sections. By comparing the geological structure above the cave, the faults could not be observed on the surface.

Structural geology and hydrogeology were studied also near Montpellier in France. Nineteen boreholes of 30 to 100 m depth, with an average depth of 60 m, were drilled into an area of about 500 km^2. In the carbonate terrains two tectonic phases which were identified by macro- and micro-structures were determined. The first phase is a compression phase and is bound to the main Pyrenean-Provençal phase of the Upper Eocene. The second one, the extension phase, is of Oligocene age. The longest fissures are filled with calcite and closed. The openings favourable to karsti-fi-cation follow the direction, which is a consequence of mechanical widening (Drogue & Grillot, 1976).

At an early stage of cave passage development, phreatic flow occurs in joint planes. Ford & Ewers (1978) call such passages joint tubes. Cave development along the joint requires that there be an earlier void within the joint or at its end. In this case, the cave segment will follow the shortest route by including the earlier developed cavity.

Early conditions of cave development are determined structurally and lithologically. Cave systems are built of many individual segments which may be guided by bedding planes, joints, faults, or intersections of such fissures. In many cases, segments guided by bedding planes are clearly separate from joint-guided segments. Larger cave systems have developed by the progressive integration and enlargement of initial channels (Ford & Ewers, 1978).

Under normal conditions solution of rocks, leading to the evolution of karst, is a very slow process: it takes 10^4 to 10^5 years for a cave system of about 1 km length. Due to the complex relationship between fissures, bedding, groundwater flow and solution kinetics, it is difficult to determine karst caverns and drainage paths (Soderberg, 1979).

In the hydrogeology of fractured rocks, research is directed towards determining the structure of aquifers.

se je poglobiti v geometrijo vodonosnika ter v obstoječe poudarjene nezveznosti.

Kritiko metode statistične korelacije med smermi razpok, merjenimi na površju, in smermi rovov je podal Choppy (1988). Po njegovih ugotovitvah razpokanost ni merilo za določevanje smeri rovov. Podzemeljska odtekanja so v splošnem določena z regionalnimi in ne lokalnimi faktorji. Pri tem je potrebno upoštevati strukturne faktorje kot npr. osi sinklinal ter reliefne faktorje. Razpoke so torej uporabne pri meritvah, kjer dovoljujejo odtekanju, da se pridruži podzemeljskemu toku ali izviru. Prihodnje raziskave bi morale temeljiti na preverjanju in proučevanju teh zakonitosti (Choppy, 1988).

Palmer (1991) je proučeval podatke 425 ameriških jam s skupno dolžino rovov 2.315 km. Pri tem je podal razdelitev jam na posamezne tipe. Skupni podatki kažejo, da je 57% jamskih rovov razvitih po plastnatosti, 42% po razpokah in 1% po medzrnskih porah.

Statistika je pokazala, da so strižni prelomi in razpoke najugodnejše praznine za razvoj jam in endokraške hidrologije (Lauritzen, 1989, 1991). Na vhodih kraških jam lahko analiziramo razpoke, ki so bile nekoč najpomembnejše poti podzemeljske vode vodonosnika (Lauritzen, 1991).

Prevodnost večine karbonatnih vodonosnikov je posledica mreže odprtih kanalov, ki so se razvili z raztapljanjem kamnine vzdolž sistemov razpok in ravnin lezik. Stopnja rasti kanala je odvisna od koncentracije raztopine v tekočini, premera kanala in hitrosti toka. Raziskave, ki jih je opravljal Lauritzen (1992), prikazujejo začetne učinke raztapljanja vzdolž ploskev plasti in razpok ter so primerljive z rezultati laboratorijskih poskusov.

For that reason, the analysis of fracturing has become one of the main elements of the hydrogeological study of aquifer environments (Razack, 1980-81).

The hydrogeology of karst was also dealt with by Mangin (1986). In his opinion, classical data on aquifers, such as flow parameters, are insufficient. It is necessary to be deeply involved in the geometry of aquifers and in the existing distinct discontinuities.

Choppy (1988) made some critical comments upon the method of statistical correlation between the orientation of fractures measured on the surface and the orientation of passages. He came to the conclusion that fracturing is no criterion for determining passage orientations. Underground drainage is generally determined by regional and not local factors. Here it is necessary to take into account also some structural factors, such as the axes of synclines, and relief factors. In measurement, fractures are of use when they allow drainage waters to join underground streams or water sources. Any future investigations should be based on checking and studying these principles (Choppy, 1988).

Palmer (1991) closely examined the data on 425 American caves, having a total passage length of 2,315 km. He classified the caves by dividing them into individual types. The joint data indicates that 57% of the cave passages are developed along bedding, 42% along fissures, and 1% along intergranular pores.

Statistics have shown that shear faults and fissures are the most favourable voids for the development of caves and endokarst hydrology (Lauritzen, 1989, 1991). At the entrances to karst caves we may analyse fissures which once were the most important groundwater paths in aquifers (Lauritzen, 1991).

Conductivity of the major part of carbonate aquifers is a consequence of the system of open channels which have been formed by the solution of rock along the systems of fissures and bedding planes. The rate of channel growth depends on the concentration of solution in a fluid, the diameter of the channel and the velocity of flow. The investigations carried out by Lauritzen (1992) demonstrate the initial effects of solution along bedding planes and along fissures, and may be compared with the results of his laboratory experiments.

3.1.2. Pregled raziskav vpliva plastnatosti na oblikovanje jamskih rovov

V primeru jame Remouchamps plastnatost ne vpliva samo na smer rovov ampak tudi na njihovo obliko (Ek, 1970 a, b).

Ford (1971) imenuje »dip tubes« najzgodnejše jamske rove, razvite vzdolž vpadnice lezik. Rovi so v tlorisu ravni ali nekoliko sinusoidni in freatičnih presekov. Sledijo vpadu plasti ali pa odstopajo do približno

3.1.2. An overview of investigations of the influence of bedding on the formation of cave passages

In the case of the Remouchamps cave, bedding does not affect only the orientation of the passages but also their shape (Ek, 1970 a, b).

Ford (1971) considers dip tubes to be the earliest cave segments to develop along the dip of bedding planes. In ground plan, these are straight or slightly sinuous features with phreatic cross-sections. Dip tubes

15^0. Različna topnost posameznih plasti lahko določa, katere ploskve plasti so ugodnejše za razvoj rovov (Ford & Ewers, 1978).

Naklon 2-5^0 naj bi bil ločnica med vodoravnimi in strmimi plastmi. Kjer vpadajo plasti strmo, lahko vodijo vodo v velike globine (Ford & Ewers, 1978).

Freatični tipi jam so posebno pogosti v strmih, jame nivoja podtalnice predvsem v vodoravnih plasteh ali plasteh z majhnim vpadom (Ford & Ewers, 1978).

are propagated down the true dip of the strata or within approximately 15^0 of it. The different solubility of individual beds may determine which bedding planes are more favourable to the development of passages (Ford & Ewers, 1978).

The range 2^0 to 5^0 of dip separates strata which may be considered flat-lying from those that are steeply dipping. Steeply dipping strata tend to carry groun-dwater to great depth (Ford & Ewers, 1978).

Phreatic types of caves are particularly common in steeply dipping strata. Water-table caves are particularly common in flat-lying or gently dipping strata (Ford & Ewers, 1978).

3.1.3. Pregled raziskav o uporabnosti letalskih posnetkov pri interpretaciji geološke zgradbe kraških terenov

Danes ni geološkega kartiranja brez pomožne uporabe letalskih in satelitskih posnetkov. Zelo so uporabni tudi pri interpretaciji geološke zgradbe kraških terenov.

Pri proučevanju strukturne geologije in hidrogeologije v okolici Montpellierja v Franciji so s proučevanjem karte površinskih razpok, določenih z letalskih posnetkov in diagramom-polrozeto razpok (n=240) ugotovili, da so glavne smeri razpok enake, vendar se pomembnost razpokanosti spreminja s smerjo, ko se spremeni merilo opazovanj (Drogue & Grillot, 1976)

Da bi povečali učinkovitost interpretacije letalskih posnetkov, so razvili tudi različne računalniške programe za analizo dobljenih rezultatov. Interpolacija analiz razpokanosti na površju je bila primerna za ugotovitev značilnosti globoke geometrije vodonosnika. Uporabljali so program RAFRAC, ki upošteva orientacijo, dolžino in prostorsko razporeditev razpok. Proučevali so ozemlje v Causse du Larzac v Franciji, ki zajema približno 13 km^2. Pri določanju razpok na posameznih merilih (1:23.500, 1:15.000, 1:7.000, 1:4.000), so sodelovali štirje raziskovalci, kar so uporabili za statistično povprečje. Izkazalo se je, da je merilo 1:15.000 najprimernejše. Upoštevali so intenzivnost razpok, dolžino in razdaljo med razpokami. Ugotovili so zelo močno povezanost med naštetimi parametri, ki so izraz faktorja intenzitete (število in dolžina razpok) in faktorja položaja (razdalja med razpokami). Naredili so tudi diagrame razpok, in sicer v štirih smereh sever-jug, vzhod-zahod, severozahod-jugovzhod in severovzhod-jugozahod. Ugotovili so, da je geometrija vodonosnika kot zakonitost prilagojena določeni združbi razpok, ki so jasno opredeljene. V prihodnjih raziskavah bi morali dodati genetski in dinamični aspekt razpokanosti, da bi tako bolj kompletno razumeli razpokane masive (Razack, 1980-81).

Masson (1985) je z interpretacijo letalskih posnetkov masiva Parmélan v Franciji določil razpoke na

3.1.3. An overview of investigations of the use of aerial photographs for interpreting the geological structure of karst terrains

At the present time there is no geological mapping without the additional use of aerial photography and satellite imagery which are very useful for interpreting the geological structure of karst terrains.

By studying the structural geology and hydro-geology of the surrounding area of Montpellier in France, it was established by analysing the map of the surface fissures which had been determined by aerial photographs and a half-rose diagram of fissures (n = 240) that the dominant fissure orientations are the same, but the significance of fracturing varies with orientation by changing the scale of observation (Drogue & Grillot, 1976).

In order to increase the efficiency of aerophoto interpretation, the French developed various computer programs so as to analyse the obtained results. Interpolation of the analyses of fracturing on the surface was appropriate for determining the properties of aquifer deep geometry. The RAFRAC program, taking into account orientation, length and spatial distribution of fissures, was used. In Causse du Larzac, France, a terrain having a surface area of about 13 km^2 was studied. Four researchers took part in determining fissures at individual scales (1:23,500, 1:15,000, 1:7,000, 1:4,000). The results obtained were used for a statistical average of fissures. It turned out that the 1:15,000 scale was the most appropriate one. The researchers took into account the intensity of the fissures as well as the length and distance between them. They established a very strong relationship between the given parameters reflecting the factor of intensity (the number and length of the fissures) and the factor of position (the distance between the fissures). They also produced diagrams of the fissures in four directions: N-S, E-W, NW-SE, and NE-SW. They came to the conclusion that aquifer geometry as a rule is adapted to a particular group of fissures which are clearly defined. In any subsequent investigations also

9 km^2 površine nad jamskimi prostori. V tem masivu je znanih več kot 45 km rovov. Za statistično študijo parametrov zakrasevanja in razpokanosti v različnih merilih je uporabljal letalske posnetke. V njegovi razpravi je prikazana tudi distribucija pogostosti razpok in pogostosti smeri zakrasevanja glede na dolžino razpok. Zakrasevanje je najbolj razvito v sistemu najpogostejših smeri prelomov in razpok. Pri tem so najbolj ustrezni natezni prelomi, ki so vezani na gubanje masiva (Masson, 1985).

genetic and dynamic aspects of fracturing should be added in order to gain a better understanding of fractured massifs (Razack, 1980-81).

By interpreting aerial photographs of the Parmélan massif in France, Masson (1985) determined fissures above cave rooms within a surface area of 9 km^2. In the massif, over 45 km of passages have been discovered. For his statistical study of karstification parameters and fracturing at different scales Masson used aerial photographs. His discussion presents also the distribution of fissure frequency and that of the frequency of karstification orientation with regard to the length of the fissures. Karstification is best developed in a system of the most frequent directions of faults and fissures. In this case, the most appropriate are extension faults which are associated with the folding of the massif (Masson, 1985).

3.1.4. Pregled raziskav o oblikovanosti prečnih jamskih profilov

Od francoskih znanstvenikov je oblike prečnih profilov obravnaval Renault (1958). Med drugim poudarja, da geološka struktura, še posebno razpokanost, usmerja vodni tok in hkrati določa nekatere značilne oblike prečnih profilov (Renault, 1958, 36).

Oblike jamskih rovov so lahko ključ za razumevanje njihovega razvoja. Lange (1960, 77) meni, da so jame rezultat procesov erozije in odlaganja materiala, ki vplivajo na njihove prostorske meje.

Vpliv plastnatosti na obliko prečnih profilov je odvisen od vpadnega kota plasti. Pri vpadnem kotu 20^0 in manj sta strop in dno prečnega profila oblikovana po plastnatosti. Pri vpadnem kotu 20^0 do skoraj 90^0 je vpliv plastnatosti na obliko prečnih profilov zelo majhen (Davies, 1960, 11).

Maire (1980) loči oblike prečnih profilov glede na singenetske in paragenetske rove ter rove s prosto gladino.

Zoz (1982) je v geomorfološki študiji proučil genetski razvoj jame “Grotta di Vedronza (FR 71)” v severovzhodni Italiji. Glavne geološke strukture tega področja imajo osi orientirane v smeri zahod severozahod - vzhod jugovzhod. Poleg osnovnih geoloških podatkov je Zoz (1982) obdelal tudi 19 prečnih profilov v jami in jih klasificiral glede na obliko. V prečnih profilih je podal osnovne geološke strukturne podatke. Nekateri prečni profili imajo značilno obliko stožca in parabole. Potek jamskih rovov se je večinoma oblikoval po glavnih disjunktivnih strukturah. V začetku se je jama oblikovala vzdolž plastnatosti in razpokanosti (Zoz, 1982).

Tudi White (1988) je v svoje raziskave vključil oblikovanost in pogoje nastanka nekaterih prečnih jamskih profilov. Zaradi velike hitrosti toka in neplastnatega

3.1.4. An overview of investigations of the formation of cave cross-sections

Among French scientists, the shapes of cross-sections have been dealt with by Renault (1958). He points out that the structure of rock, particularly its fracturing, directs the flow of water and at the same time determines some characteristic shapes of cross-sections (Renault, 1958, 36).

The shapes of cave passages may be a key to understanding their development. Lange (1960, 77) is of the opinion that caves are the result of erosive and depositional processes acting on the cave boundaries.

The influence of bedding on the shape of cross-sections varies with the dip of beds. In dips of 20^0 or less the ceiling and bottom of cross-sections reflect bedding planes. Beds with dips from 20^0 to nearly 90^0 generally have little influence on the shape of cross-sections (Davies, 1960, 11).

Maire (1980) distinguishes the shapes of cross-sections with regard to syngenetic and paragenetic passages and passages with a free water table.

In his geomorphologic research, Zoz (1982) studied genetic development of the cave Grotta di Vedronza (FR 71), situated in NE Italy. The axes of the main geological structures of the terrain are oriented WNW-ESE. Besides the basic geological data, Zoz (1982) also made 19 cross-sections of the cave and classified them with regard to shape. In them he presented the basic geological structural data. Some of the cross-sections are characteristically cone-shaped or have the form of a parabola. The orientation of the cave passages has in most cases followed the main disjunctive structures. In the beginning, the cave was formed along the bedding and fracturing (Zoz, 1982).

In his investigations, White (1988) included the formation and conditions for the development of some apnenca nastajajo hidravlične oblike, medtem ko nizke hitrosti in neenakomerna plastnatost povzročajo rove z nepravilno oblikovanimi prečnimi profili. Sestavljeni rovi, ki so različnega razvoja ali nastanka, imajo lahko obliko črke T (White, 1988).

Ford & Williams (1989) menita, da mnogo rovov predstavlja sestavljene oblike, ki najprej kažejo sledove freatične in kasneje vadozne erozije. Oblika, ki nastaja, ko se rov poveča, je odvisna od pasivnih spremenljivk (litologije in strukture) in aktivnih spremenljivk (hitrosti toka, potenciala raztapljanja, tipa in izobilja klastičnega tovora). Po mnenju avtorjev se lahko zaradi izotropne geološke zgradbe, s počasnim prenosom snovi, enostavna razpoka poveča do velikih dimenzij. Variante freatičnih prečnih profilov so številne (Ford & Williams, 1989).

Oblika vadoznih rovov je povezana z vrezovanjem z ali brez širjenja. Oblike ključavnic kažejo, da so v njih reke prehajale iz freatične v vadozno cono. Trapezoidni prečni profil stabilne širine nastane kot kombinacija vrezovanja in podorov. Kjer so gradienti kanala strmi in je kamnina trda, se lahko razvijejo tokovne kotlice. Glavni razlog vseh podorov je mehanični razpad znotraj plasti, med plastmi ali med razpokanimi bloki (Ford & Williams, 1989).

Iz morfologije rovov je mogoče ugotoviti ali so nastajali v vadoznem ali freatičnem okolju. Rove vadoznega tipa oblikuje gravitacijski tok. Tipični vadozni rov je sestavljen iz poševnega kanjona ali cevi in je presekan z vertikalnimi stopnjami. Freatični rovi se razvijejo vzdolž poti največje hidravlične učinkovitosti. Nastajajo okrogli ali lečasti prečni profili. Nekatere freatične jame so tudi nepravilnih oblik (Palmer, 1991).

cave cross-sections. As a consequence of high velocities of water flow and thick non-bedded limestone there form hydraulic passage shapes while low velocities and nonuniform bedding result in the formation of conduits with irregularly shaped cross-sections. Composite passages of different development or origin may have a T cross-section (White, 1988).

Ford & Williams (1989) are of the opinion that many passages are compound forms, displaying first the traces of phreatic erosion and then the traces of vadose erosion. The form that develops as the passage enlarges depends on passive variables (lithology and structure) and active variables (flow velocity, solution potential, type and abundance of clastic load). According to these authors, a simple fissure may enlarge to great size due to isotropic geological structure with slow mass transfer. The variety of phreatic cross-sections is enormous (Ford & Williams, 1989).

The form of vadose passages is that of entrenchment, with or without widening. Keyhole shapes suggest that rivers in the passages have switched from the phreatic to the vadose zone. By a mixture of undercutting and breakdown a trapezoid cross-section of stable width is achieved. Where channel gradients are steep and the rock is hard, stream potholes may develop. The cause of all breakdown is mechanical failure within or between rock beds or joint-bounded blocks (Ford & Williams, 1989).

From the morphology of passages it is possible to establish whether these have been formed in vadose or phreatic environments. The passages of vadose type are formed freely under gravity by free flow. A typical vadose passage is composed of an inclined canyon or a tube and is cut by vertical sections. Phreatic passages are developed along the paths of highest hydraulic efficiency. There form circular or lens-shaped cross-sections. Some phreatic caves are also irregular in form (Palmer, 1991).

3.2. Pregled raziskav obravnavane tematike v slovenski literaturi

3.2.1. Pregled raziskav vpliva tektonske zgradbe na oblikovanje jamskih rovov

Odvisnost nastanka in oblikovanja jamskih rovov od prelomov in razpok v sistemu Postojnskih jam, pa tudi na širšem področju jugozahodne Slovenije je predvsem raziskoval Gospodarič (1963, 1964, 1965, 1969 a in b, 1976).

Gospodarič je temeljito preiskoval geološko

3.2. An Overview of Investigations of the Treated Subject in Slovenian Literature

3.2.1. An overview of investigations of the influence of tectonic structure on the formation of cave passages

The dependence of the origin and formation of cave passages on the faults and fissures of the Postojnska jama cave system, including the wider area of SW Slovenia, has been researched in particular by Gospodarič (1963, 1964, 1965, 1969 a and b, 1976).

Gospodarič thoroughly studied the geological zgradbo sistema Postojnskih jam in leta 1965 predstavil geološko karto v merilu 1:2.000, ki pa nikoli ni bila publicirana v tem merilu in je ostala le v obliki elaborata.

V osemdesetih letih je Čar (1982, 1983) klasificiral tektonsko pretrte cone na razpoklinske, porušene in zdrobljene. Pri tem je, z metodo podrobnega tektonsko-litološkega kartiranja površja v merilu 1:5.000, povezal jamske rove Planinske, Črne in Pivke jame z ugotovljenimi tektonsko pretrtimi conami na površju in ugotovil določeno skladnost (Čar, 1982, 1983; Čar & Gospodarič, 1984).

Metodo podrobnega tektonsko-litološkega kartiranja površja smo prenesli tudi v jamske rove Predjame, in sicer v merilu 1:1.000. Določitev tektonsko pretrtih con na razpoklinske, porušene in zdrobljene je bila v jamskih rovih še lažja kot na površju, skladnost podatkov iz površja v jamo, na razdalji okrog 100 m, pa zadovoljivo primerljiva (Šebela, 1991).

Podorne dvorane v Vzhodnem rovu Predjame, ki so razvite v debelo plastnatem do masivnem zgornje krednem apnencu, kažejo očitno navezanost na potek tektonsko pretrtih con (Šebela & Čar, 1991).

Na primeru turistično urejenega predela Postojnske jame in rova Podzemeljske Pivke je bilo na podlagi prečnih profilov ugotovljeno, da se je 41,2 % prečnih profilov oblikovalo v tektonsko pretrtih conah (Šebela, 1994 b).

structure of the Postojnska jama cave system and in 1965 presented a geological map at a scale of 1:2,000 which has never been published at that scale.

In the 1980s, Čar (1982, 1983) divided tectonically fractured zones into fissured, broken and crushed. By using the method of detailed tectonic-lithological mapping of the surface at a scale of 1:5,000, he connected the cave passages of Planinska jama, Črna jama and Pivka jama with the already determined tectonically fractured zones on the surface and established that there is some some degree of accordance (Čar, 1982, 1983; Čar & Gospodarič, 1984).

The method of detailed tectonic-lithological mapping of the surface was subsequently used also in the cave passages of Predjama at a scale of 1:1,000. The division of tectonically fractured zones into fissured, broken and crushed was even easier in the cave passages than on the surface. The conformity between the data collected on the surface and those collected in the cave, at a distance of about 100 m, was adequately comparable (Šebela, 1991).

In a cave section of Predjama, Vzhodni rov, the collapse chambers developed in thick-bedded to massive Upper Cretaceous limestone indicate apparent attachment to the orientation of the tectonically fractured zones in the cave (Šebela & Čar, 1991).

On the basis of the cross-sections in the tourist part of Postojnska jama and those of the cave section Podzemeljska Pivka it was established that 41.2% of the cross-sections have been developed in tectonically fractured zones (Šebela, 1994 b).

3.2.2. Pregled raziskav vpliva plastnatosti na oblikovanje jamskih rovov

Na pomen oblikovanja rovov sistema Postojnskih jam vzdolž plastnatosti je opozoril že Gospodarič (1965, 1976). Njegove raziskave kažejo, da je v Malih jamah, Koncertni dvorani, Zgornjem in Spodnjem Tartarusu ter Stari jami 30 % rovov delno vzporednih s plastnatostjo. Na številnih lezikah je bilo možno določiti tektonske raze, ki kažejo na medplastne zdrse nastale pri formiranju Postojnske antiklinale.

Z vplivom plastnatosti v razvoju jamskih rovov so se ukvarjali tudi drugi (Gams, 1961; Šušteršič, 1979 b).

Velika gora, ki je največja podorna dvorana v sistemu Postojnskih jam, se je oblikovala po geoloških strukturnih elementih. Z zadnjimi tektonskimi premikanji ob prelomni coni ter z odpadanjem podornih blokov po lezikah, poudarjenih z medplastnimi zdrsi, se je podorna dvorana večala do današnjih razsežnosti (Šebela, 1995 b).

3.2.2. An overview of investigations of the influence of bedding on the formation of cave passages

The significance of the formation of passages in the Postojnska jama cave system along the bedding was mentioned by Gospodarič (1965, 1976). His investigations indicate that in the cave sections Male jame, Koncertna dvorana, Zgornji Tartarus, Spodnji Tartarus, and Stara jama 30% of the passages are partly parallel to the bedding. On numerous beds it was possible to determine tectonic striae which give an indication of the interbedded movements which occurred during the formation of the Postojna anticline.

Several other researchers (Gams, 1961; Šušteršič, 1979 b) have also been concerned with the influence of bedding on the development of cave passages.

Velika gora, the largest collapse chamber of the Postojnska jama cave, was formed along structural geological elements. As a consequence of the last tectonic movements along the fault zone and the collapse of breakdown blocks along the bedding planes, being

Knez (1996) je proučeval nastanek začetnih kanalov v udornici Veliki dolini v Škocjanskih jamah. Jamski rovi, njihovi fragmenti in drugi sledovi podzemskega zakrasevanja se tu ne pojavljajo poljubno razmetani v stenah, ampak so očitno zbrani vzdolž majhnega števila t.i. nosilnih lezik. S stališča litologije Knez (1996) ni dobil tehtne razlage za selektivno zakrasevanje, pač pa se je pokazalo, da se je začetje odvijalo ob medplastnih zdrsih, ki so nujno povzročili razmik plasti.

distinct due to interbedded movements, the collapse chamber has been enlarged to the present dimensions (Šebela, 1995 b).

In the collapse doline Velika dolina at the Škocjanske jame caves, Knez (1996) studied the origin and development of initial channels. The cave passages, their fragments, and other traces of underground karstification do not occur randomly scattered in the walls but are evidently grouped along a small number of the so-called formative bedding planes. From a lithological point of view, Knez (1996) did not obtain any reasonable explanation for selective karstification; it turned out that inception had taken place along interbedded movements which apparently caused the widening between the beds.

3.2.3. Pregled raziskav o uporabnosti letalskih posnetkov pri interpretaciji geološke zgradbe kraških terenov

Za določevanje geoloških strukturnih linij uporabljamo v Sloveniji predvsem letalske posnetke v merilu 1:30.000 in 1:17.500. Na površju nad Predjamo sem uporabila posnetke v merilu 1:5.000, s katerimi sem dobila zelo natančne položaje tektonsko pretrtih con. Tako so bili rezultati podrobnega tektonsko-litološkega kartiranja površja v merilu 1:5.000 lažje primerljivi (Šebela, 1991).

3.2.3. An overview of investigations of the use of aerial photographs for interpreting the geological structure of karst terrains

For determining structural geological lines in Slovenia, particularly aerial photographs at scales of 1:30,000 and 1:17,500 have been used. For determining highly detailed positions of the tectonically fractured zones on the surface above the Predjama cave, I used aerial photographs at a scale of 1:5,000. In this way, the results of the detailed tectonic-lithological mapping of the surface at a scale of 1:5,000 were much more readily comparable (Šebela, 1991).

3.2.4. Pregled raziskav o oblikovanosti prečnih jamskih profilov

Oblike prečnih profilov so zelo pogosto izrisane predvsem v jamskih načrtih. Geološki podatki v prečnih profilih pa so prikazani le tu in tam.

Prečni profil je med poglavitnimi značilnostmi kraških jam in ena izmed osnov za študij speleogeneze (Gams, 1961,47). Rov je v zgodnji razvojni fazi močno špranjast in ima torej v eno smer razvlečen prečni profil. V smeri razpok, lezik, pretrtih skladov, korozijsko manj odpornih mest se rov hitreje veča in širi (Gams, 1961,48).

Korozijski vzdolžni profil v kratkih odsekih menjava razsežnost in obliko. Erozijski rov ima bolj zaokrožen prečni profil in v vzdolžni smeri obrušene stene (Gams, 1961,50).

Krogu podobni prečni profili so omejeni na neskladovite apnence. Če se rov razširi do lezike, dobiva sodast prečni profil. Daljša os poteka v smeri skladov (Gams, 1961,52).

Gospodarič (1965) je pri geoloških raziskavah sistema Postojnskih jam prikazal tudi geološke razmere v vzdolžnih in okrog 24 prečnih profilih.

Prečni profil v obliki ključavnice kaže tri primere

3.2.4. An overview of investigations of the formation of cave cross-sections

In general, cave maps illustrate the shapes of cross-sections and only occasionally present geological data of the cross-sections.

The cross-section is one of the major features of karst caves and one of the fundamentals for studying speleogenesis (Gams, 1961, 47). At its early development stage, a passage is in the form of a distinct fissure. Its cross-section is thus elongated in one direction. The passage grows and widens faster in the direction of fissures, bedding planes, fractured beds, and solutionally less resistant parts (Gams, 1961, 48).

A corrosional longitudinal section varies in size and shape in very short segments. The cross-section of an erosional passage is more rounded and the walls are eroded in the longitudinal direction (Gams, 1961, 50).

Circular cross-sections are confined to massive limestones. Passage enlargement extendig as far as a bedding plane results in a cross-section having a barrel-like shape. The longer axis runs in the direction of the beds (Gams, 1961, 52).

During his geological study of the Postojnska jama cave system, Gospodarič (1965) illustrated geooblikovanja: primarno korozijo, bočno (stransko) erozijo in talno korozijo (Šušteršič, 1979 b).

V Pisanem rovu Postojnske jame sem (Šebela, 1992) prikazala geološke razmere v 10 prečnih profilih. Pri tem so prečni profili ovrednoteni glede na oblikovanje po tektonsko pretrtih conah in plastnatosti.

logical conditions in longitudinal sections and in about 24 cross-sections.

A keyhole-shaped cross-section illustrates three instances of shaping: primary solution, lateral erosion, and ground corrosion (Šušteršič, 1979 b).

In 10 cross-sections, I illustrated geological conditions of the passage Pisani rov in Postojnska jama (Šebela, 1992). The cross-sections are evaluated with regard to the formation along the tectonically fractured zones and bedding.

3.3. Pregled geoloških raziskav

3.3.1. Pregled stratigrafskih in litoloških raziskav širše okolice sistema Postojnskih jam

Najstarejše geološke podatke o okolici Postojne je zbral Stur (1858). Ločil je apnence Postojnskega krasa od fliša na jugu in dolomita na severu in severovzhodu. Po prečnem profilu terena, ki ga je objavil, lahko sklepamo, da naj bi okrog 3 km severozahodno od Postojne ležali apnenci na numulitnih peščenjakih.

Leto kasneje (1859) je Stache omenil numulite v vezivu breč pod flišem pri železniški postaji v Postojni.

Kossmat (1897, 1905, 1909, 1913) je med Planinskim poljem in Pivško kotlino razdelil apnence na zgornje in spodnje kredne. Po njegovih raziskavah sta Nanos in Hrušica narinjena na fliš Pivške kadunje in na kredne sklade Postojnskega krasa. Limanowski (1910) je pojmoval Nanos in Hrušico kot precej daleč narinjeno poleglo gubo. Po Winklerju (1923) pa ima narinjena gruda Nanosa in Hrušice obliko tektonske polkrpe.

V letu 1960 je Pleničar opisal stratigrafski razvoj krednih kamnin na Notranjskem. Zgornjekredne kamnine so v okolici Postojne razvite v grebenskem in medgrebenskem faciesu. Med plastmi grebenskih rudistnih apnencev, nastopajo apnenci brez rudistov z vložki rožencev. Drobci slednjih so pretežno iz subkristalnega kremena, v katerem so majhni skupki kalcedona.

Pleničar (1961, 58) meni, da so prehodni rovi sistema Postojnskih jam večinoma vzporedni s plastmi, kjer jih prečkajo, postanejo suhi rovi neprehodni, v vodnih rovih pa se pojavijo sifoni.

Pri študiji geologije Postojnskih vrat je Pleničar (1961) pregledal tudi geološke razmere površja vse do Planinske jame. Mnenja je, da bi v neraziskanih delih Podzemeljske Pivke, ki potekajo pravokotno na smer plasti, lahko naleteli na potek prehodnih cenomanijsko-turonijskih plasti, ki so izredno bogate s školjkami iz rodov *Chondrodonta* in *Neithea* ter s školjkami iz

3.3. An Overview of Geological Investigations

3.3.1. An overview of stratigraphic and lithological investigations of the wider vicinity of the Postojnska jama cave system

The oldest geological data on the surrounding area of Postojna was collected by Stur (1858). He distinguished the limestones of the Postojna karst from the flysch to the S and the dolomite to the N and NE. On the basis of his published cross-section of the terrain it may be concluded that about 3 km NW of Postojna, the limestones are underlain by nummulitic sandstones.

A year later (1859), Stache mentioned that near the railway station of Postojna, nummulites can be found in the matrix of the breccias which are overlain by flysch.

Kossmat (1897, 1905, 1909, 1913) divided the limestones from the area between the Planinsko polje and the Pivka basin into Upper and Lower Cretaceous. According to his investigations, Nanos and Hrušica are overthrust onto the flysch of the Pivka basin and onto the Cretaceous beds of the Postojna karst. Limanowski (1910) considered Nanos and Hrušica to be a fairly far overthrust overturned fold. According to Winkler (1923), the thrust sheet of Nanos and Hrušica is in the form of a tectonic half nappe.

In 1960, Pleničar described stratigraphic development of the Cretaceous rocks of the Notranjska region. The Upper Cretaceous rocks from the surrounding area of Postojna are developed in reef and inter-reef facies. Between the beds of reef rudist limestones there occur limestones with chert inliers without any rudists. Fragments of the chert inliers are predominantly composed of subcrystal quartz containing small inclusions of chalcedony.

Pleničar (1961, 58) is of the opinion that the passable passages of the Postojnska jama cave system are mostly parallel to the beds. At the points of intersection, the dry passages become impassable, with sumps družine *Caprinae*. Na površju najdemo takšne apnence nekoliko zahodno od Ravbarkomande, na Jelenšku (Pleničar, 1961).

Z geološkimi raziskavami sistema Postojnskih jam in Pivške kotline se je doslej največ ukvarjal Gospodarič. Leta 1963 je podrobno opisal Pisani rov, ki je z litološkega pogleda zelo zanimiv. Poleg silificiranih so tu tudi dolomitizirani apnenci. Ker so plastnati in jih preprezajo dolge razpoke, je voda v njih izdelala prav take prostore kot drugod. Apnence z roženci najdemo tudi v Čarobnem vrtu, Lepih jamah, Ruskem rovu, Umetnem rovu, Martelovi dvorani, na površju pa okrog Jeršanovih dolin. Vse te lokacije kažejo povezavo plasti z roženci s potekom temena Postojnske antiklinale, ki je za razvoj rovov posebnega pomena (Gospodarič, 1963).

Pri nadaljnem geološkem preučevanju Postojnskega krasa in njegove okolice je Gospodarič (1963, 1964, 1965) natančneje kartiral litostratigrafske člene na površju in v podzemlju, zgradbo Postojnske antiklinale ter prelome in razpoke, ki jo križajo.

Po osnovni geološki karti, list Postojna (Buser, Grad & Pleničar, 1967), prištevamo apnence, ki gradijo sistem Postojnskih jam in površje nad njim zgornji kredi, in sicer turoniju in senoniju $K_2^{2,3}$. Debelina apnenca dosežе tudi 1.000 m. Gre za siv rudistni apnenec s slabo določljivo radiolitno favno in neznačilno mikrofavno.

Blizu ponora Pivke v sistem Postojnskih jam so našli lepo ohranjen primerek hipurita vrste *Hippurites giordanii*, ki je vodilni za maastricht, to je za zgornji del senonija (Pleničar, 1970).

Z obširnimi raziskavami je Gospodarič svoje temeljne rezultate in sklepe proučevanja jam in jamskih sedimentov združil v doktorskem delu. V njem obravnava razvoj jam med Pivško kotlino in Planinskim poljem v kvartarju (Gospodarič, 1976). Tako je bilo v preiskanem podzemlju sistema Postojnskih jam ugotovljeno več petrografsko, stratigrafsko in izvorno različnih naplavin. Naplavine so sestavljene iz paleogenskih kamnin ter istodobnih in preloženih kvartarnih sedimentov Pivške kotline, a tudi iz apnenca, v katerem poteka jamski sistem. Posebno je zanimiva primerjava paleocenskega in zgornjekrednega apnenca z roženci s prodniki rožencev v naplavini. Gospodarič (1976) je ločil prod pisanega in belega roženca, ki ju najdemo tudi v sistemu Postojnskih jam. Prod pisanega roženca je ena najstarejših naplavin v Pivški kotlini. Ti prodniki so večinoma iz roženca in metamorfnih kamnin, ki jih v širšem območju Pivške kotline in jugozahodne Sloveni- je ni. Prod belega roženca ima poreklo v paleocenskem apnencu Pivške kotline, kar je bilo potrjeno z mikroskopsko preiskavo zbruskov rožencev in prodnikov iz rožencev (Gospodarič, 1976).

S korelacijo sosednjih in bolj oddaljenih stratigrafskih zaporedij jamskih sedimentov so uspeli razvrstiti razvojne stopnje sistema Postojnskih jam na 10 glavnih stopenj v obdobju od srednjega kvartarja do danes (Gospodarič, 1976).

appearing in the water passages.

During his geological study of the Postojnska vrata, Pleničar (1961) examined also geological conditions of the surface as far as the Planinska jama cave. In his opinion, in the unexplored underground section of Podzemeljska Pivka, which is perpendicular to the strike of the beds, it would be possible to follow the direction of passable Cenomanian-Turonian beds which are extremely rich in shells of the genera *Chondrodonta* and *Neithea* as well as in shells of the family Caprinae. On the surface, such limestones may be found some distance to the W of Ravbarkomanda, i.e. in the area of Jelenšek (Pleničar, 1961).

The greatest extent of involvement in the geological research of the Postojnska jama cave system and the Pivka basin has been achieved by Gospodarič. In 1963, he gave a detailed description of the passage Pisani rov, which is very interesting from a lithological point of view. Besides silicified limestones there also occur dolomitized ones. Since they are bedded and interwoven with long fissures, water within the limestones has formed the same chambers as elsewhere in the system. Limestones with cherts can be found also in other sections of the system, such as Čarobni vrt, Lepe jame, Ruski rov, Umetni rov, Martelova dvorana, and on the surface around the dolines Jeršanove doline. All these locations indicate the relationship between the beds containing cherts and the direction of the crest of the Postojna anticline, which is of special significance for the development of the passages (Gospodarič, 1963).

During his subsequent geological study of the Postojna karst and its surrounding area, Gospodarič (1963, 1964, 1965) produced detailed maps of the lithostratigraphic units of both the Postojna karst surface and underground as well as maps of the Postojna anticline structure together with the faults and fissures intersecting the anticline.

According to the Basic Geological Map, Postojna Sheet (Buser, Grad & Pleničar, 1967), the limestones which make up the Postojnska jama cave system as well as the surface above may be attributed to the Upper Cretaceous, i.e. the Turonian and Senonian $K_2^{2,3}$. The limestone thickness reaches as much as 1,000 m. In this case, we deal with grey rudist limestone with barely determinable radiolitic fauna and noncharacte-ristic microfauna.

Near the sink of the Pivka entering the cave system of Postojnska jama, a well preserved fossil specimen of the species *Hippurites giordanii*, the principal fossil during the Maastrichtian, i.e. the top stage of the Senonian, has been discovered (Pleničar, 1970).

Gospodarič used the basic results and conclusions of his extensive research on caves and cave sediments in his doctoral dissertation, in which he deals with the development of the caves between the Pivka basin and Planinsko polje during the Quaternary (Gospodarič, 1976). In the researched underground section of the

Gospodarič je 1976 natančno raziskal tudi stratigrafske razmere v sistemu Postojnskih jam. Jamski rovi so razviti v zgornje krednem in sicer turonijskem K_2^2 in senonijskem K_2^3 apnencu. Najnižji litološki člen v turonijskih skladih predstavlja apnenec, ki vsebuje leče, gomolje in plasti rožencev. Horizont apnenca z roženci je debel najmanj 60 m. Nad apnencem z roženci je neplastnat turonijski apnenec debeline okrog 100 m. Temu sledi še plastnat apnenec, tako da je debelina turonijskih plasti 300 m. Turonijski apnenci prehajajo v senonijske brez izrazite meje. Senonijsko starost apnencev je Gospodarič (1976) določil predvsem zaradi številnih foraminifer vrste *Keramosphaerina tergestina* Stache. Senonijske plasti so v zahodnem in jugozahodnem delu Postojnskega jamskega sistema. V spodnjem delu so debelo plastnati, v zgornjem pa nekoliko tanjše plastnati apnenci. Debelina senonijskega apnenca je najmanj 500 m, njene prave debeline pa ni mogoče ugotoviti, saj so bile kamnine, preden jih je pokril eocenski fliš, delno erodirane (Gospodarič, 1976). V poglavju 7.1. sem na sliki 2 prikazala primerjavo litološkega stolpca sistema Postojnskih jam kot ga je določil Gospodarič (1976) z novejšimi raziskavami (Jurkovšek et al., 1996; Šribar, 1995; Rižnar, 1997).

V začetku osemdesetih let je Čar (1981, 1982, 1983) podrobno tektonsko-litološko kartiral površinske kraške terene nad Pivko in Planinsko jamo. Na Magdaleni gori je določil turonijske svetlo sive do bele različke organogenega apnenca, ki prehajajo na številnih mestih v lumakelo. Po zrnavosti so obravnavane kamnine kalkareniti s prehodi v kalkrudite (Čar, 1983).

Nad turonijskimi kamninami leži siv ali svetlo siv debelo plastnat apnenec z bolj ali manj enakomerno razporejenimi preseki rudistnih školjk (Čar, 1981, 1982). Poleg radiolitov opazujemo v apnencih še preseke hipuritov in sabinij ter številne ostanke foraminifer in različnih alg. Genetsko sta oba različka zgornje krednih kamnin del plitvovodne biostrome z obrobnimi organogenimi brečami (Čar, 1983).

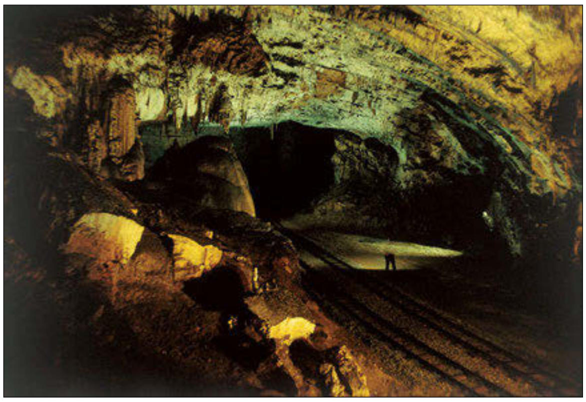
Ker predstavljajo turonijski apnenci z roženci, v monotonem apnencu sistema Postojnskih jam, litološko zanimiv člen, so bili pregledani mikroskopsko in z metodo rentgenske difrakcije. Pri tem ločimo leče

Postojnska jama cave system, Gospodarič identified deposits according to their varied petrography, stratigraphy and origin. The deposits consist of Palaeogene rocks, the Palaeogene and transported Quaternary sediments of the Pivka basin, as well as of the limestone in which the cave system is located. It is particularly interesting to compare Palaeocene and Upper Cretaceous limestones containing cherts with chert pebbles in the deposit. Gospodarič (1976) distinguished between the gravel of coloured chert and that of white chert. Both sorts of chert may be found also in the cave system of Postojnska jama. The gravel of coloured chert is one of the oldest deposits in the Pivka basin. The pebbles mostly consist of chert and metamorphic rocks which do not occur in the wider area of the Pivka basin and SW Slovenia. The origin of the gravel of white chert is the Palaeocene limestone of the Pivka basin, which was proved by microscopic examination of thin sections of the cherts and a study of the chert pebbles (Gospodarič, 1976).

By correlating the adjacent and more distant stratigraphic sequences of the cave deposits, the development stages of the Postojnska jama cave system have been divided into 10 main groups, ranging from the Middle Quaternary to the present (Gospodarič, 1976).

In 1976, Gospodarič made a close study of stratigraphic conditions within the Postojnska jama cave system. The cave passages are developed in Upper Cretaceous, i.e. Turonian K_2^2 and Senonian K_2^3, limestone. The lowest lithological unit of the Turonian beds is represented by the limestone containing lenses, nodules and layers of chert. The horizon of the limestone with cherts is at least 60 m thick. The limestone with cherts is overlain by a non-bedded Turonian limestone of about 100 m thickness, which is followed by a bedded limestone. The total thickness of the Turonian beds attains 300 m. The Turonian limestones pass into the Senonian limestones without any distinct boundary. Gospodarič (1976) determined the Senonian age of the limestones particularly on the basis of numerous foraminifers of the species *Keramosphaerina tergestina* Stache. The Senonian beds occur in the W and the SW part of the Postojnska jama cave system. In the lower part of the system, the limestones are thickly bedded, in the upper part the limestones are slightly thinner. The thickness of the Senonian limestone is at least 500 m. It has been impossible to determine its true thickness, since the rocks had been partly eroded before they were covered by Eocene flysch (Gospodarič, 1976). In Chapter 7.1., Figure 2, I make a comparison of the lithologic column of the Postojnska jama cave system, determined by Gospodarič (1976), with the latest investigations (Jurkovšek et al., 1996; Šribar, 1995; Rižnar, 1997).

In the early 1980s, Čar (1981, 1982, 1983) carried out detailed tectonic-lithological mapping of the karst surface between Pivka jama and Planinska jama. On the elevation Magdalena gora, he determined Turonian light grey to white varieties of organogenic limestone.



rožencev in kalcitizirane leče rožencev. V kalcitiziranih lečah rožencev je kremen nadomeščen s kalcitom. Gre za poznodiagenetsko nadomeščanje kremena s kalcitom (Šebela, 1989).

Ob severnem in vzhodnem robu Postojnske flišne kadunje, so našli konglomerat, ki vsebuje prodnike lipiške (zg. senonij), liburnijske (zg.K-Pc), slivske (Pc) formacije ter ponekod tudi alveolinsko-numulitnega apnenca (zg.Pc) z numuliti v vezivu. Na tem področju so bili torej odloženi tako Pc kot E karbonatni sedimenti (Jurkovšek et al., 1989).

Rovi sistema Postojnskih jam so zgrajeni iz zg. krednih apnencev (verjetno od cenomanija, turonija do senonija). Med cenomanijem in turonijem je prehodni sloj. Hondrodontni horizont uvrščamo v zg. cenomanij in vsaj sp. turonij. Za profil Z od Postojne (Šribar, 1995) je dokazano, da gre za plitvovodno sedimentacijo, ki je obstajala do sr. kampana (sr. senonij), ko je tudi tu nastopila emerzija. V zg. delu cenomanija se je začela paleogeografska diferenciacija terena. Prišlo je do dviganja južnega dela, to je tektonske enote Koprskega reverznega preloma. Tektonsko dviganje v smeri od juga proti severu se je nadaljevalo čez cel senonij. V zg. santonu do kampanu je bil večji del karbonatne platforme že dvignjen razen npr. Nanosa. V sr. mastrichtu je nastopila plitvovodna sedimentacija, razen v okolici Postojne, kjer je še trajala emerzija (Šribar, 1995).

Rižnar (1997) je geološko karto okolice Postojne prikazal v merilu 1:10.000 ter pri tem razdelil zgornjekredne sedimentne kamnine na posamezne litološke člene.

Hondrodontni horizont označuje približno mejo med srednjim in zgornjim cenomanijem (Rižnar, 1997). Apnenec z roženci ocenjuje Rižnar (1997) kot zgornje cenomanijski. Nad pelagičnimi mikriti se javljajo svetlejši mikriti v katerih najdemo drobir rudistnih školjk in hondrodont. Lumakela hondrodont je najlepše vidna v useku ceste od Risovca proti Pivki jami. Rižnar (1997) uvršča ta horizont v zgornji cenomanij.

At several sites the varieties pass into lumachelle. With regard to their grain size, the treated rocks are calcarenites with transitions to calcirudites (Čar, 1983).

The Turonian rocks are overlain by a grey or light grey thick-bedded limestone with more or less uniformly distributed sections of rudist shells (Čar, 1981, 1982). In the limestones, *Radiolites* sp., sections of *Hippurites* and *Sabinia* as well as numerous remains of foraminifers and various algae may be observed. Genetically, both varieties of the Upper Cretaceous rocks are part of a shallow-water biostrome with marginal organogenic breccias (Čar, 1983).

Within the monotonous limestone of the Postojnska jama cave system, the Turonian limestones with cherts represent a lithologically interesting unit. For that reason the limestones have been examined microscopically and by x-ray diffraction. We may distinguish between chert lenses and calcified lenses of cherts where quartz is replaced by calcite. In this case we may speak about late diagenetic replacement of quartz by calcite (Šebela, 1989).

At the N and the E margin of the flysch basin of Postojna, conglomerate has been encountered. It contains pebbles of the Lipica Formation (Upper Senonian), Liburnian Formation (Upper K-Pc), and Slivje Formation (Pc). In places the conglomerate contains pebbles of alveolinid-nummulitid limestone (Upper Pc) with nummulites in the matrix. In the area we may encounter both Pc and E carbonate deposits (Jurkovšek et al., 1989).

The passages of the Postojnska jama cave system consist of Upper Cretaceous limestones (probably ranging from the Cenomanian and Turonian to the Senonian). Between the Cenomanian and Turonian there is a transitional layer. The *Chondrodonta* horizon may be attributed to the Upper Cenomanian and at least the Lower Turonian. The profile W of Postojna (Šribar, 1995) gives evidence of shallow-water sedimentation which existed to the Middle Campanian (Middle Senonian) when emersion took place in this area as well. In the upper part of the Cenomanian palaeogeographical differentiation of the terrain began. There was uplift of the S part, i.e. the tectonic unit of the Koper reverse fault. The tectonic uplifting from S to N continued all through the Senonian. In the period of Upper Santonian to Campanian, the major part of the carbonate platform was already uplifted, except for Nanos. In the Middle Maastrichtian, shallow-water sedimentation took place, except for the surrounding area of Postojna where emersion was still in progress (Šribar, 1995).

Rižnar (1997) presented his geological map of the surrounding area of Postojna at a scale of 1:10,000. On the map he divided the Upper Cretaceous sedimentary rocks into individual lithological units.

The *Chondrodonta* horizon marks an approximate boundary between the Middle and Upper Cenomanian (Rižnar, 1997). The limestone with cherts is estimated by Rižnar (1997) to be of Upper Cenomanian age. Above the pelagic micrites there occur lighter micrites with crushed fragments of rudist shells and chondrodonts. The most distinct *Chondro-donta* lumachelle may be observed in a road cutting between Risovec and Pivka jama. The horizon is attributed by Rižnar (1997) to the Upper Cenomanian.

3.3.2. Pregled tektonskih raziskav

Že leta 1858 je Stur opozoril na povezavo med špranjami in prelomi ter oblikami jam v sistemu Postojnskih jam.

Starejši raziskovalci, med drugimi Kossmat (1897, 1905, 1909), Limanowski (1910) in Winkler (1923), so podali osnovne razlage tektonske zgradbe jugozahodne Slovenije, pri čemer je bila vključena tudi okolica Postojne.

Na osnovni geološki karti, list Postojna, je meja med zgornje krednimi apnenci in eocenskim flišem pri Postojni, označena kot erozijska meja (Buser, Grad & Pleničar, 1967).

Za severozahodne Dinaride, katerim prištevamo ozemlje nad Postojnskim jamskim sistemom, je značilna prelomna tektonika. Prevladujejo horizontalni premiki blokov. Ti prelomi sekajo strukture alpskega tipa Pirenejske oziroma morda celo Laramijske orogeneze. Še danes so aktivni, kar kažejo potresi. Uvrščamo jih v strižne prelome Dinarskih in prečno Dinarskih smeri (Gospodarič, 1969 b).

Velika gubanja in narivanja prištevamo Pirenejski fazi. Nastali so narivi Visokega krasa. Iz tega obdobja so tudi prelomi in narivi od severozahoda proti jugovzhodu. Močnejše dviganje ob prelomih, ki je povzročilo grudasto razčlenitev ozemlja, je domnevano s konca pliocena (Pleničar, 1970).

V tektonskem smislu je v tolmaču h geološki karti za list Postojna ozemlje sistema Postojnskih jam del tektonske enote Javorniško-snežniških grud, ki jo prištevamo k narivu Visokega krasa. Južneje je tektonska enota, ki jo imenujemo "fliš Postojnske in Pivške kadunje" (Pleničar, 1970). Pri tem je potrebno poudariti, da Placer (1981) flišno kotlino prišteva Snežniški narivni grudi.

S problemi tektonske zgradbe Postojnske kotline se je pri svojem delu večkrat srečal Gospodarič (1976). Ugotovil je, da Postojnska antiklinala tone proti severozahodu pod kotom $20-25^0$. Njena osna ravnina je nagnjena za $8-10^0$ proti jugozahodu. V jugozahodnem krilu je vpad plasti $30-60^0$ proti jugozahodu, v nasprotnem krilu pa $15-20^0$ proti severovzhodu. Na severovzhodni strani Magdalene gore se Postojnska antiklinala deli v dva kraka (Gospodarič, 1976).

Geološko zgradbo jugozahodne Slovenije je leta 1981 podrobneje opisal Placer. Tektonske razmere ozemlja med Postojno, Planino in Cerknico se odražajo v epirogenetskih premikanjih v kredi, v orogenetskih

3.3.2. An overview of tectonic investigations

As early as 1858, Stur pointed out the relationship between the fissures and faults in the Postojnska jama cave system on the one hand and the shapes of the caves on the other.

Older researchers, e.g. Kossmat (1897, 1905, 1909), Limanowski (1910) and Winkler (1923), gave some basic explanations of the tectonic structure of SW Slovenia, including the area surrounding Postojna.

On the Basic Geological Map, Postojna Sheet, the boundary between the Upper Cretaceous limestones and Eocene flysch near Postojna is marked as an erosion boundary (Buser, Grad & Pleničar, 1967).

Characteristic of the NW Dinarides, part of which is also the area above the Postojnska jama system, is fault tectonics with predominant horizontal displacements of blocks. The faults intersect the Alpine-type structures of the Pyrenean or probably even Laramian orogeny. At the present time the faults are still active, which is evidenced by earthquakes. They may be regarded as shear faults of the Dinaric and cross-Dinaric directions (Gospodarič, 1969 b).

Extensive processes of folding and overthrus-ting were part of the Pyrenean phase. It was then that the overthrusts of the High Karst occured. In that period there also occurred the faults and thrusts trending from the NW towards the SE. Intense uplifting along the faults which resulted in the territory being dissected into tectonic blocks, may be attributed to the end of the Pliocene (Pleničar, 1970).

Tectonically, the Geology of the Basic Geological Map, Postojna Sheet, presents the area of the Postojnska jama cave system as part of the tectonic unit of the Javorniki-Snežnik sheets. This unit may be attributed to the overthrust of the High Karst. To the S there is another tectonic unit called the "flysch of the Postojna and Pivka basins" (Pleničar, 1970). Here it should be pointed out that Placer (1981) attributes the flysch basin to the Snežnik thrust sheet.

Several times during his work, Gospodarič (1976) encountered problems concerning the tectonic structure of the Postojna basin. In his opinion, the Postojna anticline has been sinking towards the NW at an angle of $20-25^0$. Its axis plane is inclined by $8-10^0$ towards the SW. In the SW flank, the beds dip in a SW direction at $30-60^0$, in the opposite flank they dip NE at $15-20^0$. On the NE side of Magdalena gora, the narivnih in nagubanih deformacijah po eocenu ter prelomnih deformacijah iz neogena in kvartarja, kar se sklada s tektonskim razvojem zahodne Slovenije. Predjamski prelom, ki je eden večjih regionalnih prelomov, poteka severozahodno od Postojne, nato zavije vzdolž severovzhodnega dela Pivške kadunje, mimo Postojne in dalje proti vzhodu (Placer, 1981).

Konec eocena ali v oligocenu je Alpsko-Dinarski prostor zajelo obsežno narivanje. Plasti so se najprej nagubale, nato pa pretrgale. V miocenu in pliocenu je narivanje spremljalo gubanje (Placer, 1982).

Placer (1982) loči staroterciarno tektoniko in neotektoniko. Pod neotektoniko, h kateri šteje tudi Idrijski in Predjamski prelom, razume (Placer, 1981) strme prelome v smeri severozahod-jugovzhod, ki se ločijo od narivnih deformacij.

Pri podrobnem tektonsko-litološkem kartiranju kraških terenov je Čar (1982) ločil tektonsko pretrte cone na razpoklinske, porušene in zdrobljene. V terciarni tektoniki pa je določil dva tipa deformacij: starejše narivanje in mlajše subvertikalno prelamljanje (Čar, 1982).

Teme Postojnske antiklinale je močno pretrto z razpoklinskim sistemom vzporednim z osno ravnino. Te deformacije so nastale sočasno z gubanjem. Po kasnejši radialni tektoniki je bilo teme antiklinale dodatno pretrto. V njem je izrazita morfološka depresija, ki se vleče na jugozahodni strani Magdalene gore in se proti zahodu izgubi, kjer izgine tudi izrazitost antiklinalnega temena (Čar, 1983).

Prvotno so bile osi gub bolj ali manj horizontalne. Današnje tonjenje je posledica regionalnega dviganja jugovzhodnega dela Slovenije, ki je odraz dviganja Dinaridov in hkrati erozije (Placer, 1981). Odmik Postojnskega jamskega sistema proti jugozahodu je nedvomno posledica omenjenega dviganja (Čar, 1983).

Jamski prostori sistema Postojnskih jam ne sledijo Dinarskim smerem. Ob Dinarskih conah so nastali le krajši jamski odseki. Dinarske cone so posledica tlačnih napetosti, zaradi katerih so nastale zaprte razpoke. Sekundarne pretrte cone, ki so nastale zaradi nateznih sil v blokih med močnejšimi Dinarskimi prelomi, so široke, dobro odprte razpoklinske cone. Prav ob teh razpoklinskih conah smeri sever-severovzhod in severovzhod-jugozahod je nastala večina rovov sistema Postojnskih jam. Zvezne rove med sistemom Postojnskih jam in Planinsko jamo lahko pričakujemo v smeri osi Studenške sinklinale (Čar, 1983).

Čar in Gospodarič (1984) sta na ozemlju med Postojno, Planino in Cerknico določila generacije prelomnih con in strukturno geometrijo snežniške narivne grude med Idrijskim in Predjamskim prelomom. Ugotovljene so štiri generacije deformacij iz neogena in domnevno kvartarja. Tektonske razmere obravnavanega terena delimo na:

- starejša premikanja
- narivne strukture in gube

Postojna anticline is divided into two branches (Gospodarič, 1976).

The geological structure of SW Slovenia was described in more detail by Placer in 1981. The tectonic conditions of the territory between Postojna, Planina and Cerknica are reflected in epirogenetic movements during the Cretaceous, orogenetic thrust and fold deformations after the Eocene, and fault deformations during the Neogene and Quaternary, which accords with the tectonic development of W Slovenia. The Predjama fault, which is one of the most significant regional faults, runs NW of Postojna, turns along the NE part of the Pivka basin, passes Postojna and proceeds to the NE (Placer, 1981).

At the end of the Eocene or in the Oligocene, the Alpine-Dinaric region was subjected to intense over-thrusting. The beds were first folded and subsequently were broken. During the Miocene and Pliocene, the overthrusting was accompanied by folding (Placer, 1982).

Placer (1982) distinguishes between Old Tertiary tectonics and neotectonics. Neotectonics, part of which are also the Idrija and Predjama faults, is regarded by Placer (1981) as steep NW-SE trending faults which are separate from the thrust deformations.

During his detailed tectonic-lithological mapping of karst terrains, Čar (1982) divided tectonically fractured zones into fissured, broken and crushed. For Tertiary tectonics he determined two types of deformation: older thrusting and younger subvertical faulting (Čar, 1982).

The crest of the Postojna anticline is highly fractured with a fractured system which is parallel to the axis plane. These deformations were formed contemporaneously with the folding. After subsequent radial tectonics, the anticline crest was additionally fractured. In the crest there is a distinct morphological depression which runs on the SW side of Magdalena gora and gradually disappears towards the W together with the anticline crest (Čar, 1983).

At first the axes of the folds were more or less horizontal. Present sinking is a consequence of the regional uplifting of SE Slovenia, which is a reflection of the uplifting of the Dinarides and of erosion (Placer, 1981). The orientation of the Postojnska jama cave system towards the SW is undoubtedly a consequence of the previously-mentioned uplifting (Čar, 1983).

The chambers and passages of the Postojnska jama cave system do not follow the Dinaric trends. Along the Dinaric zones, only short cave sections have been formed. The Dinaric zones are a consequence of compression which resulted in the development of closed fissures. The secondarily fractured zones of the cave system which were formed due to extension within the blocks between stronger Dinaric faults, are wide, open fissured zones. Right along these fractured zones, trending NNE and NE-SW, were formed most of the passages and chambers in the Postojnska jama cave

- prelomne deformacije.

Kredni skladi kažejo, da se je sedimentacija odvijala pod vplivom epirogenetskih premikanj. Kratkotrajni subaeralni pogoji se odražajo v teksturah dolomitnih in apnenčevih skladov ter v nadplimskih brečah in konglomeratih. To je vidno v kamninah srednjega dela spodnje krede in na prehodu spodnje v zgornjo kredo. To ustreza starejšim premikanjem (Čar & Gospodarič, 1984).

Iz prelomnih deformacij sklepamo na 4 obdobja disjunktivnega premikanja, ki verjetno pripadajo isti tektonski fazi. V prvem obdobju so nastale in bile aktivne prelomne cone smeri severovzhod-jugozahod, to so prelomi 1.generacije, ki jih Dinarski prelomi sekajo. Kaže, da se je 1.generacija prelomov razvila iz prvotnih razpok v skladih in bila kasneje udeležena v vseh nadaljnih deformacijah. Prelomi 2. generacije imajo smer severozahod-jugovzhod. Gre za navpične in strme zmike, ki jih spremljajo dobro razvite zdrobljene, porušene in razpoklinske cone v smereh sever-jug in sever severovzhod-jug jugozahod. Najslabše definirani so premiki 3. generacije, ki so nastali bodisi sočasno s premiki 2. generacije, bodisi pozneje. Ponovno je bila reaktivirana prelomna cona smeri severovzhod-jugozahod skozi Postojnska vrata. K 4. generaciji štejemo prelomno območje Idrijskega preloma z vsemi spremljajočimi pretrtimi conami. Te sekajo vse starejše prelomne faze in so deloma še aktivne. Večinoma gre za zmični značaj. Te prelome spremljajo zdrobljene, porušene in razpoklinske cone smeri sever-jug ter izrazite pretrte cone v prečno Dinarski smeri med Rakovim Škocjanom in obrobjem Cerkniškega polja (Čar & Gospodarič, 1984).

Prelomi 1. generacije severovzhod-jugozahod so bili aktivni pri vseh tektonskih premikanjih, lahko celo prav do holocena. V smereh sklepnih delov Rakovega in Pivškega rokava v Planinski jami, se verjetno tudi odraža vpliv regeneriranih prelomov 1. generacije smeri severovzhod-jugozahod, ki ga slutimo tudi v legah udornic okrog Vodnega dola in doline Risovec ter v poteku vodnih rovov Črne in Pivke jame. Povsod tod gre za aktivne vodne rove, ki so usmerjeni pravokotno na nagubane sklade (Čar & Gospodarič, 1984).

V letu 1996 je Placer predstavil svoje raziskave o geološki zgradbi Soviča. Potek notranje prelomne cone Predjamskega preloma se kaže okrog 100 m južneje od kontakta zgornjekredni apnenec-eocenski fliš, pri Postojni pa povsem čez središče mesta. Pri regionalno dokazanem premiku ob Predjamskem prelomu na območju Hrušice, ki je desni zmik, se je severovzhodno krilo preloma v Postojni nasproti jugozahodnemu premaknilo v desno nekoliko poševno navzgor. Velikosti premika ni bilo mogoče ugotoviti (Placer, 1996).

Strukturna geometrija Soviča je identična geometriji Nanosa. Narivanje se je dogajalo nekako na meji med eocenom in oligocenom. Dolžina narivanja Soviške narivne grude je okoli 600 m. Narivanje je potekalo od severovzhoda proti jugozahodu pravokotno na osi gub

system. Between this system and the Planinska jama cave, interconnecting passages may be expected in the direction of the axis of the Studeno syncline (Čar, 1983).

Within the area between Postojna, Planina and Cerknica, Čar and Gospodarič (1984) determined generations of fault zones and the structural geometry of the Snežnik thrust sheet between the Idrija and Predjama faults. They established four generations of deformations from the Neogene and supposedly the Quaternary. The tectonic conditions of the treated terrain are divided into:

- older movements,
- thrust structures and folds,
- fault deformations.

The Cretaceous beds indicate that sedimentation was affected by epirogenetic movements. Short-lived subaerial conditions are reflected in the textures of the dolomite and limestone beds as well as in overtidal breccias and conglomerates, evidenced by the rocks from the middle part of the Lower Cretaceous and by those at the transition from the Lower to the Upper Cretaceous. This accords with the older movements (Čar & Gospodarič, 1984).

From the fault deformations, four periods of disjunctive movement may be concluded. The periods might be attributed to the same tectonic phase. In the first period the active fault zones of the NE-SW direction were formed. These are the faults of the first generation and are intersected by the Dinaric faults. It seems that the first generation of the faults developed from the primary fissures in beds and was subsequently active in all of the following deformations. The faults of the second generation run in the NW-SE direction. These are vertical and steep strike-slip faults which are accompanied by well developed crushed, broken and fissured zones in the directions N-S and NNE-SSW. The least defined are the movements of the third generation, which were formed either contemporaneously with the movements of the second generation or afterwards. The fault zone of the NE-SW direction was reactivated through the Postojnska vrata gap. To the fourth generation we may attribute the fault area of the Idrija fault with all the accompanying fractured zones which intersect all of the older fault phases and are partly still active. In most cases, they are of strike-slip character. These faults are accompanied by the crushed, broken and fissured zones of the N-S direction as well as by the distinct fractured zones of the cross-Dinaric direction between Rakov Škocjan and the margin of the polje of Cerknica (Čar & Gospodarič, 1984).

The faults of the first generation trending NE-SW were active in all the tectonic movements, probably even up to the Holocene. The directions of the final sections of the Rak branch and the Pivka branch in Planinska jama may reflect the influence of the regenerated faults of the first generation trending NE-SW. The influence is thought to be present also in collapse dolines around

(Placer, 1996).

Strukturno zgradbo okolice Postojne je proučeval tudi Rižnar (1997). Prečno Dinarski prelomi so najstarejši in večkrat naknadno reaktivirani. Najstarejši je verjetno Postojnski prelom, ki je bil verjetno aktiviran že v zgornjem cenomaniju. Prelom med sovičem in Kaculom je najbrž prvič aktiviran v paleocenu. Nekoliko mlajše so večje gube (Studenška sinklinala in Postojnska antiklinala). Po starosti sledijo prevrnjene in pretrgane oziroma narinjene gube Soviča in ozemlja severno in severozahodno od Postojne. Najmlajši so Dinarski prelomi in med njimi aktivirani in reaktivirani prečno Dinarski prelomi (Rižnar, 1997).

Vodni dol and in those around the blind valley Risovec, as well as in the orientation of the water channels in Črna jama and Pivka jama. In all these cases, we deal with active water channels which are perpendicular to the folded beds (Čar & Gospodarič, 1984).

In 1996, Placer presented his investigations of the geological structure of Sovič. About 100 m to the S of the contact, the orientation of the inner fault zone of the Predjama fault is demonstrated by Upper Cretaceous limestone-Eocene flysch, and in the case of Postojna the orientation is right through the centre of the town. Near the regionally proved movement along the Predjama fault in the area of Hrušica, which is a dextral movement, the NE flank of the fault at Postojna moved opposite the SW flank to the right and was slightly inclined upwards. It has been impossible to establish the extent of the movement (Placer, 1996).

The structural geometry of Sovič is identical to the geometry of Nanos. Thrusting took place somewhere on the boundary between the Eocene and Oligocene. The thrusting length of the Sovič thrust sheet is about 600 m. The thrusting took place from the NE towards the SW and was perpendicular to the axes of the folds (Placer, 1996).

The structure of Postojna and its surrounding area has been studied also by Rižnar (1997). Of the greatest age are the cross-Dinaric faults, which were often subsequently reactivated. The oldest one is presumably the Postojna fault, which was probably already active in the Upper Cenomanian. The fault between Sovič and Kacul was probably first activated in the Palaeocene. Slightly younger are larger faults (the Studeno syncline and the Postojna anticline). Younger again are the overturned and disconnected or thrust folds of Sovič and those from the areas N and NW of Postojna. Youngest of all are the Dinaric faults together with the activated and reactivated cross-Dinaric faults (Rižnar, 1997).

4

4.0. SPELEOGRAFSKI OPIS SISTEMA POSTOJNSKIH JAM

4.0. SPELEOGRAPHIC DESCRIPTION OF THE POSTOJNSKA JAMA CAVE SYSTEM

Podpisi obiskovalcev Postojnske jame izvirajo že iz 13.stoletja. Leta 1748 je dunajski matematik Nagel naredil prvi načrt jame. 14.aprila 1818 je Luka Čeč odkril nove dele Postojnske jame, tako da v letu 1998 poteka 180 let od odkritja novih delov. Leta 1985 je bil rekorden obisk Postojnske jame in sicer več kot 900.000 obiskovalcev. Po osamosvojitvi Slovenije leta 1991 se je obisk, zaradi bližine vojne v bivši Jugoslaviji, močno zmanjšal, v letu 1997 je jamo obiskalo okrog 400.000 turistov.

Dolžina sistema Postojnskih jam je po podatkih Katastra jam IZRK ZRC SAZU 19.555 m (slika 1, priloga 1), kar predstavlja najdaljši jamski sistem v Sloveniji.

Po načelu zveznosti je izmerjena dolžina rovov nekoliko daljša, in sicer 20.766 m, pri čemer merijo:

- Podzemeljska Pivka 3.128 m
- Postojnska jama 10.399 m
- Otoška jama 713 m
- Magdalena jama 1.427 m
- Črna jama 3.225 m
- Pivka jama 1.874 m.

Globina sistema Postojnskih jam je 115 m. Nadmorska višina ponora je 511 m, nadmorska višina ploščadi pred jamo je 529,5 m, kar sem, po italijanskih načrtih iz let 1933-34 (Kataster jam IZRK ZRC SAZU), vzela za osnovo prečnih in vzdolžnih profilov.

Odkrivanje glavnih rovov sistema Postojnskih jam po letu 1818 je bilo že večkrat zelo podrobno opisano (npr. Gospodarič, 1968 a).

Po naravni poti so prehodne in povezane Postojnska jama, Otoška jama, Magdalena jama in Podzemeljska Pivka, prav tako pa tudi Pivka in Črna jama.

Nekateri odseki v sistemu Postojnskih jam so še vedno neprehodni ter se začno in končajo s sifoni ponikalnice Pivke, ki so delno preplavani (Krivic & Praprotnik, 1973).

Tak je odsek med Magdaleno jamo in Pivka jamo v razdalji okrog 180 m, ki še ni povsem preplavan, medtem ko je odsek med Perkovim rovom in Vilharjevim rovom Črne jame danes že znan. Med Pivko jamo in Pivškim rokavom Planinske jame v razdalji 2.200 m je še vedno neznani splet jamskih rovov (Kataster jam IZRK ZRC SAZU).

The first inscriptions made by visitors to the Postojnska jama cave date back to the 13th century. In 1748, the Viennese mathematician Nagel made the first manuscript plan of the cave. On 14th April 1818, Luka Čeč discovered extensive new parts of the cave. In 1998, it was 180 years since these discovery of these new sections. The year 1985 was a record-breaking year with regard to the number of tourists visiting Postojnska jama, i.e. over 900,000 visitors. Since the declaration of Slovenia's independence in 1991, public viewing has greatly descreased as a consequence of the war in the vicinity, in former Yugoslavia. In 1997, the cave was visited by about 400,000 tourists.

According to the data of the IZRK ZRC SAZU Caves Cadastre, the length of the entire cave system is 19,555 m, which makes it the longest cave system in Slovenia.

By following the principle of continuity, the total measured length of the passages and chambers is a little bit longer, i.e. 20,766 m. Within the cave system, the lengths of the individual sections are as follows:

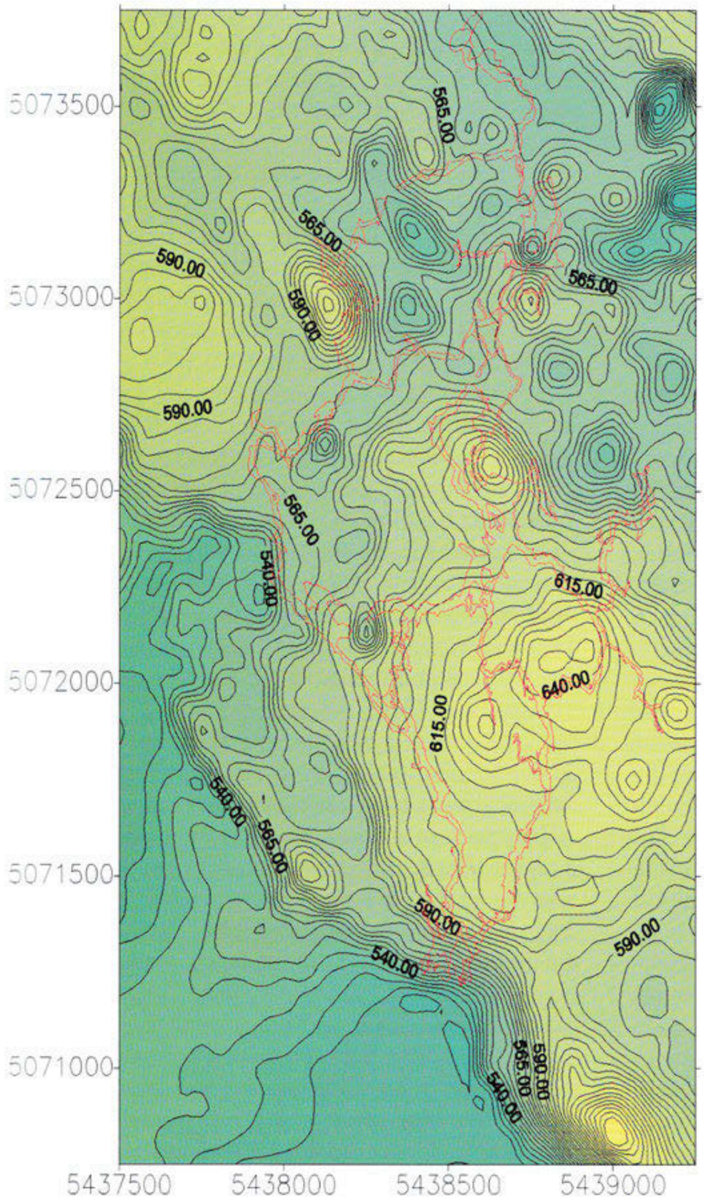
- Podzemeljska Pivka: 3,128 m,
- Postojnska jama: 10,399 m,
- Otoška jama: 713 m,
- Magdalena jama: 1,427 m,
- Črna jama: 3,225 m,
- Pivka jama: 1,874 m.

The vertical extent of the system is 115 m. The altitude of the river Pivka where it enters the cave is 511 m and that of the platform in front of the cave entrance 529.5 m, which I adopted from Italian cave plans made in the years 1933-34 (IZRK ZRC SAZU Caves Cadastre) as a basis of cross-sections and longitudinal sections.

The discovery of the main sections within the Postojnska jama cave system since 1818 has often been described in detail (e.g. Gospodarič, 1968 a).

All the major sections within the cave system are naturally connected and passable: Postojnska jama, Otoška jama, Magdalena jama, Podzemeljska Pivka, Pivka jama, and Črna jama.

In the system, however, there are still some sections which are impassable; they start and end in sumps created by the sinking river Pivka. These sumps



Slika 1. Morfologija površja nad sistemom Postojnskih jam in tloris jamskih rovov (izohipse so v metrih). **Rumeno**: vzpetina, **temno zeleno**: morfološka depresija, **rdeče**: tloris jamskih rovov.

Figure 1. Surface morphology over the Postojnska jama cave system and the cave passage ground plan (contour lines are in metres). **Yellow**: hill, **dark green**: morphological depression, **red**: cave passages ground plan.

Rove med navedenimi jamami prekinjajo podori, večinoma pa so zapolnjeni z različnimi sedimenti, ki jih še niso uspeli odkopati ali prebiti. Najkrajša prekinjena zveza suhih rovov, dolga le 10 m, je med Lepimi jamami Postojnske jame in Prečnim rovom Perkovega rova Črne jame (Gospodarič, 1976).

Podzemeljska Pivka ima vse značilnosti aktivnega vodnega rova. Današnja voda poglablja skalno dno, s stropa pa se lomijo podorni bloki (Gospodarič, 1976).

Pred Martelovim podorom izginja Pivka v 8,5 m globok sifon in se onkraj podora zopet pojavi v Kraigherjevi dvorani. V neposredni bližini Martelovega podora, 25 m nad Podzemeljsko Pivko, je potrebno omeniti jamo Koliševko, ostanek nekdanjega vodnega kanala (Michler & Hribar, 1959, 168). Dva različna horizonta podzemeljskih prostorov sta vsaj navidezno povezana z mlajšo udornico Koliševko in Martelovim podorom. Zanimivo je, da je to zvezo prav dobro skiciral

have been partly explored (Krivic & Praprotnik, 1973).

Between the caves Magdalena jama and Pivka jama there is a 180 m long impassable section which has not been completely dived. On the other hand, in the Črna jama cave, the section between the passages Perkov rov and Vilharjev rov is already known. In the 2,200 m long section between the Pivka jama cave and the Pivka branch of the Planinska jama cave, there is still an unknown system of cave passages (IZRK ZRC SAZU Caves Cadastre).

Passages between the above-mentioned caves are interrupted by breakdowns; in most cases they are filled with various deposits which have not yet been dug through or penetrated. The shortest blocked connection between dry passages, only 10 m long, is between the section Lepe jame in Postojnska jama and the passage Prečni rov, which is part of the passage Perkov rov in Črna jama (Gospodarič, 1976).

Podzemeljska Pivka has all characteristics of an active water passage. The present river water is deepening the rock bottom, and breakdown blocks fall from the ceiling onto the floor (Gospodarič, 1976).

Just before reaching the breakdown chamber Martelov podor, the Pivka river dissapears into a 8.5 m deep sump and reappears beyond the breakdown in the chamber Kraigherjeva dvorana. In close proximity to the Martelov podor, 25 m above Podzemeljska Pivka, there is a collapse doline called Koliševka, which is the remaining part of a former water channel (Michler & Hribar, 1959, 168). Two different underground horizons are at least apparently connected with the younger Koliševka collapse doline and the Martelov podor. It is interesting to note that this connection was pretty well sketched already by Martel (1894, 448) more than a hundred years ago.

The sinking river Pivka flows from the Kraigherjeva dvorana chamber in Postonjska jama into the passage Zvezni rov in Magdalena jama. At middle and high water levels, the river floods into the passages že Martel (1894, 448).

Iz Kraigherjeve dvorane teče Pivka v Zvezni rov Magdalene jame, ob srednjem in visokem vodostaju pa tudi v Perkov rov ter naprej v Vilharjev rov in Krožni rov v Črni jami (Gospodarič, 1976).

Zvezo med suhimi in vodnimi rovi so podrobneje pregledali v Otoški jami (Gospodarič, 1976). O nekdanji povezavi Otoške jame z Zgornjim Tartarusom Postojnske jame, ki jo danes prekinja udornica Stara apnenica, je pisal že Martel (1894, 448).

Genetsko se Otoška jama nadaljuje v Zgornjem Tartarusu dosegljivem iz Postojnske jame (Gospodarič, 1976).

V Podzemeljsko Pivko so bili sedimenti naplavljeni skozi ponor ob današnjem jamskem vhodu pri Postojnski jami. Ponornica je tekla proti severozahodu, v obratni smeri kot starejša ponornica v Otoški jami, ki je ponikala v slepi dolini Risovec in tekla proti vzhodu oziroma jugovzhodu (Gospodarič, 1976).

Udori so mogli nastati šele tedaj, ko je aktivna ponikalnica s spremenljivo gladino in erozijsko močjo spodjedala skalno dno više ležečega rova in odnašala tamkajšne naplavine, ki jih je v ponikalnico nanašala tudi prenikajoča voda. Tam, kjer rov Podzemeljske Pivke ni križal starejših rovov ali potekal pod njimi, udori in medsebojne zveze niso mogle nastati, npr. v turističnem delu Postojnske jame. Tudi tam, kjer je razdalja med obema horizontoma večja, npr. med jamo Koliševko in Martelovim podorom, ali pa tam, kjer ponornica ni bila več sposobna erodirati in sproti odnašati grušča nastajajočih podorov ter starejših naplavin (npr. v Črni jami), je zveza le delno vzpostavljena (Gospodarič, 1976).

Slabe (1995) je v svojih raziskavah obravnaval speleogenezo sistema Postojnskih jam. Pri tem omenja, da so se najstarejši vodni tokovi v zalitih conah pretakali z jugovzhoda proti severu in severozahodu in tudi skozi predhodnico Pivke jame. V tem času ali nekoliko kasneje se je voda pretakala tudi iz Otoške jame proti vzhodu in severovzhodu. Ponorov je bilo verjetno več. Mlajši epifreatični vodni tokovi, ki so se pretakali od juga proti severu, so oblikovali Staro jamo. Zgornji Tartarus se je reaktiviral, ko se je voda od jugozahoda, verjetno iz predhodnice rovov današnje Podzemeljske Pivke, hitro pretakala proti severu.

Perkov rov, Vilharjev rov and Krožni rov in Črna jama (Gospodarič, 1976).

The connection between the dry and water passages has been examined in more detail in Otoška jama (Gospodarič, 1976). The former connection between Otoška jama and the cave section Zgornji Tartarus in Postojnska jama was discussed already by Martel (1894, 448). At present, this connection is interrupted by the collapse doline Stara apnenica.

Genetically, the continuation of Otoška jama is in Zgornji Tartarus, which can be reached from Postojnska jama (Gospodarič, 1976).

In the past, deposits were carried into Podze-meljska Pivka through the river sink near the present cave entrance to the Postojnska jama cave. The river flowed towards the NW, i.e. in the opposite direction compared with the direction of flow of the older sinking river in Otoška jama, which sank in the blind valley Risovec and flowed in the E or the SE direction (Gospodarič, 1976).

Roof collapses did not take place before the active sinking river, with its variable water level and erosional power, had eaten away the rocky bottom of a higher passage and had carried away the deposits that had been partly introduced into the river by percolating waters. Collapses and interconnections could not be formed at places where Podzemeljska Pivka did not intersect older passages or run below them, e.g. in the tourist section of Postojnska jama. Connections between the passages are only partly established at places where the distance between the two horizons is greater, e.g. between the Koliševka cave and the breakdown section Martelov podor, or at places where the sinking river was no longer capable of eroding and simultaneously carrying away the rubble of the forming breakdowns and older deposits (e.g. in Črna jama) (Gospodarič, 1976).

In his studies, Slabe (1995) deals with the speleogenesis of the Postojnska jama cave system. Here he mentions that within the phreatic zone the oldest streams ran from the SE towards the N and NW as well as through the predecessor of Pivka jama. At that time or a little later, the water from Otoška jama flowed towards the E and NE. Presumably there were several sinks. Younger epi-phreatic streams passing from the S towards the N formed the cave section Stara jama. Zgornji Tartarus was reactivated when the water from the SW, probably from the predecessor of the the present Podzemeljska Pivka, flowed towards the N at very high flow rates.

5.0. HIDROGRAFSKE RAZMERE PIVŠKE KOTLINE

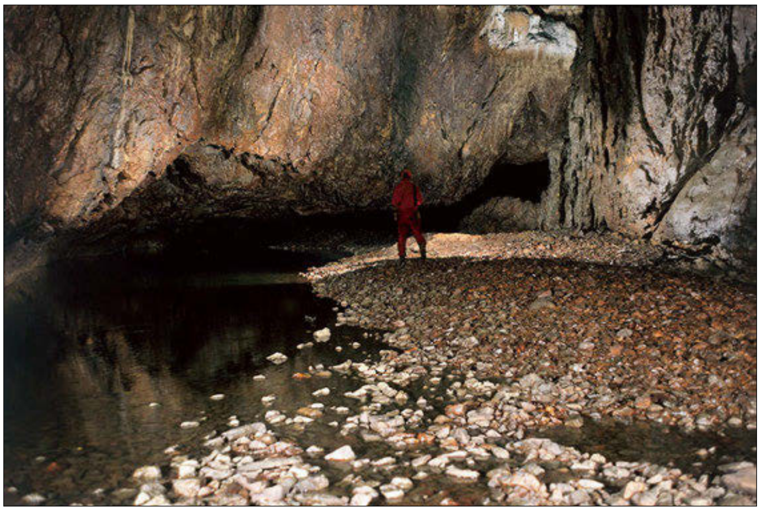
Reka Pivka, ki priteče s flišnega povirja Pivške kotline in teče skozi sistem Postojnskih jam (slika 1, priloga 1), izginja v odtočnem sifonu v Pivki jami ter se po okrog 2 km pojavi v Pivškem rokavu Planinske jame. Na severnem obrobju Planinskega polja ponika kot reka Unica, ki prihaja na dan v izvirih Ljubljanice. Tako pripada črnomorskemu porečju (Gospodarič & Habič, 1976). Povprečni letni pretok Pivke je 5,26 m^3/s, v Postojni pa pade letno povprečno 1.644 mm padavin.

Barvanja v letu 1988 (Habič, 1989) so pokazala bifurkacijo Pivke, kar pomeni, da se le-ta odvodnjava tudi proti izvirom Vipave in tako pripada Jadranskemu in Črnomorskemu porečju. Vzroki za podzemeljsko raztekanje so različni, poleg geološke zgradbe in razpokanosti kamnin ima pomembno vlogo mlada tektonika in pomikanje blokov, podiranje in zasipanje rovov ter splošni razvoj vodnih poti v širšem območju (Habič, 1989). Poleg podzemeljske pa obstaja tudi površinska bifurkacija, saj se ob višjih vodostajih del javorniških voda preliva v površinsko Pivko, ki skupaj z Nanoščico napaja postojnsko podzemlje in po tej poti tudi izvire Unice (Habič, 1989, 238).

5.0. HYDROGRAPHIC CONDITIONS OF THE PIVKA BASIN

The Pivka river, which flows from the flysch catchment area of the Pivka basin and runs through the Postojnska jama system (Figure 1, Annex 1), disappears into the sump of Pivka jama and after about 2 km reappears in the Pivka branch of Planinska jama. At the N margin of the polje of Planina, the river sinks under the name of Unica and reappears at the sources of the Ljubljanica. Thus the Pivka is part of the Black Sea drainage basin (Gospodarič & Habič, 1976). The average discharge of the Pivka is 5.26 m^3/s. At Postojna the average annual precipitation is 1,644 mm.

Dye-tracing experiments in 1988 (Habič, 1989) provided evidence of the bifurcation of the Pivka, for the river also drains towards the sources of the Vipava and thus forms part of both the Adriatic and the Black Sea drainage basins. There are various reasons for underground bifurcation; besides geological structure and fracturing of rocks, important roles are played by neotectonics and movements of blocks, breakdowns and the filling of passages, as well as general development of the water routes in the wider area (Habič, 1989). Besides the underground bifurcation we may encounter also surface bifurcation. When the water table is high, part of the Javorniki waters flow into the surface Pivka which, together with the Nanoščica, feeds the Postojna underground and in this way also the sources of the Unica (Habič, 1989, 238).



6.0. METODE DELA

Glavna metoda mojega dela v jami in na površju je podrobno tektonsko-litološko kartiranje. To metodo je na kraških površinskih terenih uvedel Čar (1982, 1983), na primeru Predjame (Šebela, 1991) pa sem jo prvič preizkusila v jamskih rovih v merilu 1:1.000. Izkazalo se je, da je zaradi boljše preglednosti kartiranje v jami še lažje kot na površju. Jamske prostore je kartiral tudi Gospodarič (1965,1976), ki je poudaril predvsem prelomne ploskve in razpoke, a jih ni združeval v tektonsko pretrte cone.

Pri podrobnem tektonsko-litološkem kartiranju ozemlja nad Predjamo (Šebela, 1991), se je pri kartiranju v merilu 1:5.000 pokazalo, da je tako merilo za primerjavo z jamo, ki je bila kartirana v merilu 1:1.000 (Šebela, 1991), premalo natančno. Pri kartiranju površja nad sistemom Postojnskih jam sem se zato odločila za merilo 1:2.500.

V rovih sistema Postojnskih jam sem podrobno tektonsko-litološko kartirala v merilu 1:500, končni prikaz podatkov je bil izdelan v merilu 1:2.000 (priloga 1).

Upoštevala sem tudi delitev prelomne cone na notranjo in zunanjo (Placer, 1982) ter splošne zakonitosti tektonike pri določevanju smeri in premikov ob prelomnih ploskvah (De Sitter, 1956; McClay, 1992; Ramsay & Huber, 1987 a in b).

Pri delu na površju sem uporabljala letalske posnetke v merilu 1:5.000 (priloga 5). Metodo sem uspešno uporabila že pri kartiranju nad Predjamo (Šebela, 1991, 1995 a).

Geološke in speleološke podatke iz jamskih rovov sem prikazala s prečnimi profili na različnih razdaljah, in sicer od 10 do 50 m. Na podlagi značilne oblike prečnega profila in tektonsko-litoloških razmer v jamskih rovih sem uvedla klasifikacijo oblike jamskih rovov v odvisnosti od geoloških razmer, kjer je bilo le mogoče (priloga 4).

Dobljene geološke podatke površja sem primerjala z jamskimi in obratno, za kar sem uporabila vzdolžne profile (priloga 1). Vertikalna razdalja od površja do jamskih rovov je 20-110 m.

Geološke podatke sem prikazala tudi statistično. Pogostosti geoloških elementov plasti apnenca na površju in v jamskih rovih sem izrisala na Schmidtovi mreži.

6.0. METHODS OF WORK

The principal method used in my work in the cave and on the surface is detailed tectonic-lithological mapping. This method was introduced in karst surface terrains by Čar (1982, 1983). I used the method in cave passages and chambers for the first time, more specifically in the Predjama cave (Šebela, 1991) at a scale of 1:1,000. It turned out that because of better visibility mapping in the cave is even easier than on the surface. Cave passages and chambers were also mapped by Gospodarič (1965, 1976), who put emphasis particularly on fault planes and fissures which he did not include in tectonically fractured zones.

During my detailed tectonic-lithological mapping of the area above Predjama (Šebela, 1991), it turned out while mapping at a scale of 1:5,000 that such a scale is not large enough for making an accurate comparison with the cave which had been mapped at a scale of 1:1,000 (Šebela, 1991). For mapping the surface above the Postojnska jama cave system, I therefore decided to use the 1:2,500 scale.

In the passages and chambers of the Postojnska jama cave system, I carried out detailed tectonic-lithological mapping at a scale of 1:500, the final presentation of the data being at a scale of 1:2,000 (Annex 1).

I took into account also the division of the fault zone into the inner zone and outer zone (Placer, 1982), as well as the general principles of tectonics in determining the directions and movements along fault planes (De Sitter, 1956; McClay, 1992; Ramsay & Huber, 1987 a and b).

During my work on the surface, I used aerial photographs at a scale of 1:5,000 (Annex 5). I had already used this method successfully during the mapping above the Predjama cave (Šebela, 1991, 1995 a).

Using cross-sections, I demonstrated geological and speleological data about the cave passages and chambers at various distances apart, i.e. from 10 m to 50 m. Whenever possible, I introduced the classification of cave passage shapes dependent on geological conditions on the basis of the characteristic shapes of the cross-sections and tectonic-lithological conditions in the cave passages and chambers (Annex 4).

By means of longitudinal sections, I compared

Primerjavo pogostosti smeri razpoklinskih, porušenih, zdrobljenih ter vseh pretrtih con skupaj na površju in v jami sem prikazala z rozetami.

the geological data obtained about the surface with those about the cave, and conversely (Annex 1). The vertical distance between the surface and the cave passages is 20 m to 110 m.

Geological data were illustrated also statistically. On Schmidt's net, I presented the frequencies of geological elements of the limestone beds on the surface and those in the cave passages. By constructing rose diagrams, I made a comparison between the frequencies of orientation of the fissured, broken, crushed and all the fractured zones on the surface and in the cave.

7.0. TEKTONSKO-LITOLOŠKO KARTIRANJE SISTEMA POSTOJNSKIH JAM

7.1. Litološko kartiranje

Osnovni podatki litološkega kartiranja jamskih rovov so prikazani na prilogah 1 in 2. Litološki stolpec kamnin v sistemu Postojnskih jam, za katerega sem naredila tudi primerjavo z litološkim stolpcem Gospodariča (1965), je prikazan na sliki 2. Pri določitvi različnih litoloških značilnosti kamnin v sistemu Postojnskih jam sem se opirala na raziskave Šribarja (1995), ki je ob cesti med slepo dolino Risovca in Magdaleno goro raziskal profil debeline 760 m ter na rezultate Rižnarja (1997), ki je geološko kartiral okolico Postojne.

Rovi sistema Postojnskih jam so razviti v 825 m debelem litološkem stolpcu zgornje krednega apnenca (slika 2). Ker so rovi razviti v obeh krilih Postojnske antiklinale, prehajamo po podzemeljskem toku reke Pivke iz senonijskih apnencev v turonijske in zgornje cenomanijske.

Ponorni vhod v sistem Postojnskih jam (slika 3 in slika 4) se je oblikoval v lezikah poudarjenih z medplastnimi zdrsi (slika 4). Skrajni južni in skrajni severni del znanih rovov je razvit v debelo plastnatem, sivo rjavem apnencu (slika 2). Po starosti pripada senoniju K_2^3.

V notranjosti jame, in sicer v Rovu podpisov (slika 6), dvorani Veliki dom in Biospeleološki postaji (priloga 1 in 2), vpada debelo plastnat (1,5 do 2 m) apnenec od 30 do 50^0 proti jugozahodu.

Do Kongresne dvorane (priloga 1 in 2, slika 2) gradi jamske stene zelo debelo plastnat apnenec, senonijske starosti K_2^3. Debelina horizonta je 225 m. Med Biospeleološko postajo (priloga 1) in Kongresno dvorano so značilni podori, ki na vzhodnih straneh jamskih prostorov ustvarjajo podorne nasipe. Podori so se oblikovali po tektonsko pretrtih conah, pa tudi po lezikah, kar je prikazano v prečnih profilih 10-10*, 11-11* in 12-12* (priloga 1).

Kristalni rov (priloga 1 in 2) je oblikovan v debelo plastnatem, rjavo sivem apnencu. Ponekod so ostanki rudistov tako številni, da je moč govoriti o lumakeli. Smer vpada plasti je proti severozahodu 320-340^0, vpadni kot pa 30-50^0. Debelina formacije je 225

7.0. TECTONIC-LITHOLOGICAL MAPPING OF THE POSTOJNSKA JAMA CAVE SYSTEM

7.1. Lithological Mapping

The basic data for the lithological mapping of the cave passages are presented in Annexes 1 and 2. The lithological column in the Postonjska jama cave system which I compared with the lithological column of Gospodarič (1965), is presented in Figure 2. By defining different lithological characteristics in the cave system I relied on the researches of Šribar (1995), who investigated a 760 m thick profile along the road between the Risovec blind valley and Magdalena gora, and on the results of Rižnar (1997), who mapped the surroundings of Postojna geologically.

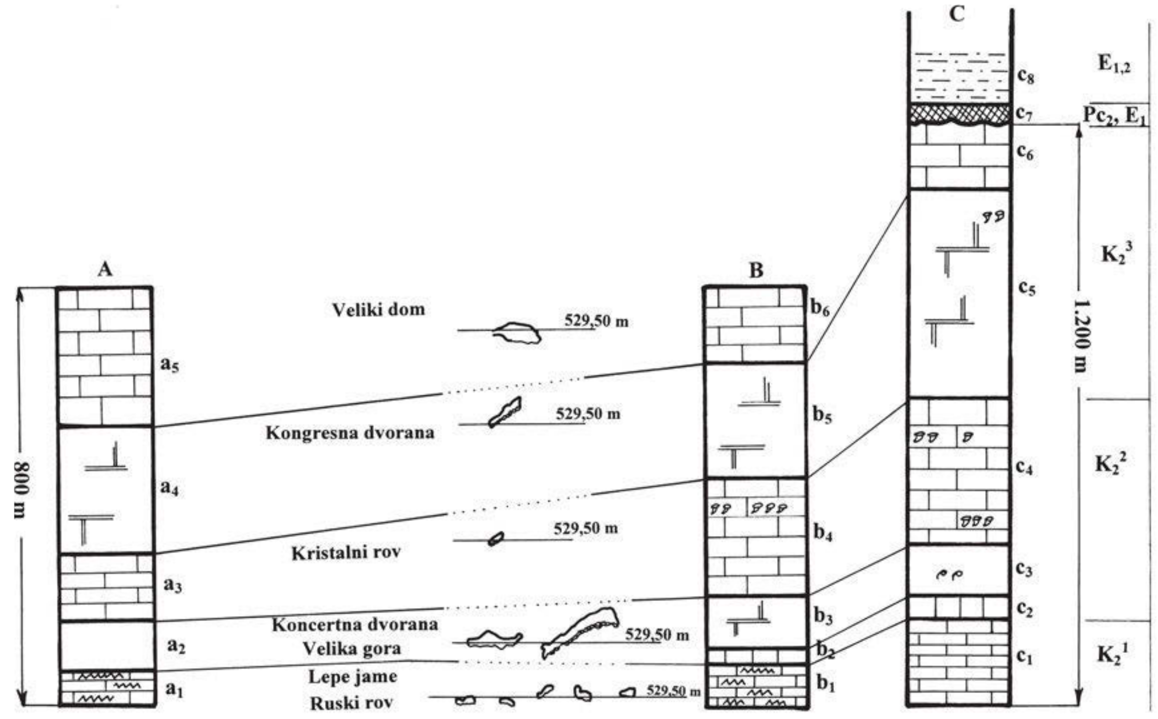
The Postojnska jama cave system passages are developed in the Upper Cretaceous limestone 825 m thick (Figure 2). As the passages are developed in both flanks of the Postojna anticline, we pass along the underground Pivka river from Senonian into Turonian and Upper Cenomanian limestone.

The river entrance into the cave (Figure 3 and 4) was formed along bedding planes deformed by interbedded movements (Figure 4). The most S and most N parts of the known passages are developed in thick-bedded grey-brown limestone (Figure 2) belonging to Senonian K_2^3.

In the cave interior, for example in Rov podpisov (Figure 6), Veliki dom chamber and Biospeleološka postaja (Annexes 1 and 2), the thick-bedded limestone (1.5-2 m) dips from 30 to 50^o towards the SW.

As far as Kongresna dvorana (Annexes 1 and 2, Figure 2) the cave walls are built of a very thick-bedded limestone of Senonian age K_2^3. The horizon thickness is 225 m. Between Biospeleološka postaja (Annex 1) and Kongresna dvorana there are characteristic collapses which create collapse cone on the E sides of the cave chamber. The collapses were formed along tectonically fractured zones, and also along bedding planes, as presented in cross-sections 10-10*, 11-11* and 12-12* (Annex 1).

Kristalni rov (Annexes 1 and 2) is formed in thick-bedded brown-grey coloured limestone. In places the rudist remains are so numerous that one can talk



Slika 2. Primerjava litoloških stolpcev in položaj nekaterih prečnih profilov glede na litološki stolpec.
A: litološki stolpec sistema Postojnskih jam (po Gospodariču, 1965, 1976). **a**$_1$ apnenec z roženci (60 m in več), **a**$_2$ neplastnat apnenec (100 m), **a**$_3$ plastnat apnenec (130 m), **a**$_4$ debelo plastnat apnenec (250 m), **a**$_5$ plastnat apnenec.
B: litološki stolpec sistema Postojnskih jam. **b**$_1$ tanko plastnat (siv) apnenec z roženci (100 m), **b**$_2$ debelo plastnat apnenec (35 m), **b**$_3$ zelo debelo plastnat (bel) apnenec (99 m), **b**$_4$ debelo plastnat (sivo rjav) apnenec z rudisti (225 m), **b**$_5$ zelo debelo plastnat apnenec (225 m), **b**$_6$ debelo plastnat (sivo rjav) apnenec (141 m)
C: litološki stolpec površja nad sistemom Postojnskih jam. **c**$_1$ tanko plastnat apnenec (siv do temno siv, 165 m), **c**$_2$ debelo plastnat apnenec (50 m) **c**$_3$ zelo debelo plastnat (svetlo rjav) apnenec (do 35 m), **c**$_4$ zelo debelo plastnat (bel) apnenec s hondrodontnim horizontom (do 110 m), **c**$_5$ debelo plastnat (rjavo siv) apnenec z rudisti (290 m), **c**$_6$ zelo debelo plastnat (rjavo siv) apnenec z rudisti (420 m), **c**$_7$ debelo plastnat apnenec (130 m), **c**$_8$ bazalni konglomerat (1-2 m), **c**$_9$ fliš.

Figure 2. Comparison of lithological columns and the position of some cross-sections position in the lithological column.
A: Postojnska jama cave system lithological column (according to Gospodarič, 1965, 1976). **a**$_1$ limestone with cherts (60 m and more), **a**$_2$ nonbedded limestone (100 m), **a**$_3$ bedded limestone (130 m), **a**$_4$ thick-bedded limestone (250 m), **a**$_5$ bedded limestone.
B: Postojnska jama cave system lithological column. **b**$_1$ thin-bedded (grey) limestone with cherts (100 m), **b**$_2$ thick-bedded limestone (35 m), **b**$_3$ very thick-bedded (white) limestone (99 m), **b**$_4$ thick bedded (grey-brown) limestone with rudists (225 m), **b**$_5$ very thick-bedded limestone (225 m), **b**$_6$ thick-bedded (grey-brown) limestone (141 m).
C: surface lithological column over the Postojnska jama cave system. **c**$_1$ hin-bedded limestone (grey to dark grey, 165 m), **c**$_2$ thick-bedded limestone (50 m), **c**$_3$ very thick-bedded (light brown) limestone (up to 35 m), **c**$_4$ very thick-bedded (white) limestone with *Chondrodonta* horizon (up to 110 m), **c**$_5$ thick-bedded (brown-grey) limestone with rudists (290 m), **c**$_6$ very thick-bedded (brown-grey) limestone with rudists (420 m), **c**$_7$ thick-bedded limestone (130 m), **c**$_8$ basal conglomerate (1-2 m), **c**$_9$ flysch.

m (b$_4$ na sliki 2). Gospodarič (1965) je apnence uvrščal v turonij (slika 2).

Pred odcepom rova za Male jame plasti sprva vpadajo proti zahodu (260/20), po odcepu pa proti jugozahodu. Na levi strani rova pred Malimi jamami

about lumakelle. The bedding plane dip strike is towards NW (320-340°), and the dip angle is 30-50°. The formation thickness is 225 m (b$_4$ in Figure 2). Gospodarič (1965) classified the limestone as Turonian (Figure 2).

Before the passage turning towards Male jame the bedding planes dip first towards W (260/20), and afterwards turn towards SW. On the left side of the passage, in front of Male jame, there are syncline flexible bedding planes an almost E-W direction. The general direction of the syncline flexible bedding planes is transverse to the Postojna anticline direction, and thus represents a secondary deformation in the folding development.

The coures of the NE part of Male jame is a serpentine winding passage with very explicit stratification (Figure 7). The thick-bedded limestone (0.5-1 m) dips

Slika 3. Vhod v sistem Postojnskih jam (foto S. Šebela).
Figure 3. Entrance to the Postojnska jama cave system (photo S. Šebela).

Slika 4. Danes neaktivni in aktivni vhodi v sistem Postojnskih jam so razviti v lateralno istih plasteh (foto S. Šebela).
Figure 4. The present inactive and active entrances to the Postojnska jama cave system are developed in the same bed (photo S. Šebela).

so sinklinalno upognjene plasti v smeri skoraj vzhod-zahod. Generalna smer sinklinalno upognjenih plasti je prečna na potek Postojnske antiklinale, tako da predstavlja sekundarne deformacije glede na razvoj gubanja.

Predel jame severovzhodno od Malih jam je vijugast rov z zelo izrazito stratifikacijo (slika 7). Debelo plastnat apnenec (0,5-1m) vpada proti jugozahodu 240/30-40. Jamski rov deloma sledi lezikam od katerih so nekatere poudarjene z medplastnimi zdrsi (slika 8). Del rova pa poteka prečno na smer lezik (slika 7). Med slednjimi so se ponekod oblikovale stropne in stenske kotlice.

V Rovu brez imena gradi jamske stene zelo debelo plastnat bel in redkeje siv apnenec (slika 2). Gospodarič (1976) je te apnence uvrščal v turonij. Po Šribarju (1995) pripadajo plasti že zg. cenomaniju do srednje turoniju, po Rižnarju (1997) pa zg.cenomaniju. Oba sta svoje ugotovitve povzemala po razdelitvi krednih karbonatnih kamnin na geološki karti jugozahodne Slovenije (Jurkovšek et al., 1996)

Pisani rov so s sedimentološkega in litološkega stališča že večkrat raziskovali (Gospodarič, 1963; Šebela, 1989; 1992). Po Gospodariču (1963) je osrednji del Pisanega rova razvit v silificiranih in dolomitiziranih apnencih.

Južni del Pisanega rova se je oblikoval v debelo plastnatem apnencu z vpadom 10-20^0 proti jugozahodu. V osrednjem delu rova so na vzhodni steni dvorane an-

towards the SW 240/30-40. The cave passage partially follows the bedding planes where some of them are tectonicaly deformed by interbedded movements (Figure 8). A part of the passage is transverse to the bedding plane direction (Figure 7). In places ceiling and wall potholes were formed among the latter.

In Rov brez imena the cave walls are formed of a very thick-bedded white and rarely grey limestone (Figure 2). Gospodarič (1976) classified this limestone as Turonian. Šribar (1995) placed these bedding planes in the Upper Cenomanian to Middle Turonian, and Rižnar (1997) in the Upper Cenomanian. Both of them summarised their findings according to the distribution of Cretaceous carbonate rocks on the SW Slovenia geological map (Jurkovšek et al., 1996).

Pisani rov has already been researched many times from sedimentological and lithological points of view (Gospodarič, 1963; Šebela, 1989; 1992). Gospodarič (1963) claims that the central part of Pisani rov is developed in the silicified and dolomitised limestone.

The S part of Pisani rov was formed in a thick-bedded limestone with a dip of 10-20^o towards the SW. On the E wall of the central part of the passage there are anticline flexible bedding planes which are already completely horizontal in the vertical distance of three metres towards the chamber ceiling. As to the axis course of the Postojna anticline (Annexes 1 and 2) we may assume that in Pisani rov, Čarobni vrt, Ruski

Slika 5. Poplava pred sistemom Postojnskih jam (oktober 1992, foto J. Hajna).
Figure 5. Flood in front of the Postojnska jama cave system (October 1992, photo J. Hajna).

tiklinalno upognjene plasti, ki se na vertikalni razdalji treh metrov proti stropu dvorane že povsem izravnajo. Glede na potek osi Postojnske antiklinale (priloga 1 in 2), lahko v Pisanem rovu, Čarobnem vrtu, Ruskem rovu in Skalnem rovu (v Magdaleni jami) sklepamo na antiklinalo, katere os je od osi Postojnske antiklinale odmaknjena za 25^0 proti jugovzhodu. Elementi vpada severnega krila antiklinalno upognjenih plasti v Pisanem rovu so 20/20 in južnega krila 200/15. V nadaljevanju rova proti severu vpada apnenec proti zahodu, in sicer v osrednjem delu za 5^0 in v severnem $5\text{-}30^0$. Strop najsevernejšega dela Pisanega rova se je oblikoval po plastnatosti.

V predelu jame od južnega vhoda v Pisani rov do vznožja Velike gore vpadajo zgornje kredni apnenci proti jugozahodu. Apnenec je tanko do debelo plastnat (0,1 do 1 m). Tudi do 20 m širok jamski rov je oblikovan po leziki.

V Čarobnem vrtu opazujemo teme antiklinale, katere osna ravnina poteka v Dinarski smeri (priloga 1 in 2). V obeh krilih vpadajo plasti za $5\text{-}20^0$ proti jugozahodu oziroma severovzhodu.

Velika gora je največja podorna dvorana v sistemu Postojnskih jam. Oblikovala se je v debelo plastnatem (0,5 do 1,5 m) apnencu (slika 9) z vpadnim kotom $40\text{-}50^0$ proti jugozahodu. Po Gospodariču (1976) gre za turonijsko starost, po Rižnarju (1997) pa za zg. cenomanij.

rov and Skalni rov (in Magdalena jama) there is an anticline whose axis is declined by 25^o towards the SE of the Postojna anticline axis. In Pisani rov the N flank flexible bedding plane dip elements are 20/20, and the on the S flank 200/15. In the further passage section to the N the limestone dips towards the W, in the central part at 5^o, and in the N from $5\text{-}30^o$. The ceiling of the most N part of Pisani rov was formed along bedding.

In the cave section from the S entrance into Pisani rov, and to the foot of Velika gora, the Upper Cretaceous limestone dips SW. The limestone varies from thin to thick- bedded (0.1-1 m). Even up to 20 m wide passage is formed along the bedding plane.

In Čarobni vrt we see the anticline crest where the axis plane runs in the Dinaric direction (Annexes 1 and 2). On both flanks the bedding planes dip for $5\text{-}20^o$ to SW and NE respectively.

Velika gora is the biggest collapse chamber in the Postojnska jama cave system. It was formed in the thick-bedded (0.5-1.5 m) limestone (Figure 9) with a dip angle of $40\text{-}50^o$ towards the SW. According to Gospodarič (1976) it is of the Turonian age, as to Rižnar (1997) it is Upper Cenomanian.

The Velika gora collapse was formed in a strongly expressed Dinaric fault zone and along bedding planes (Figure 9). Interbedded movements in the SW flank of the anticline which runs through Čarobni vrt had an important role in forming the chamber.

Slika 6. Rov podpisov, lezika poudarjena z medplastnim zdrsom (foto S. Šebela).
Figure 6. Rov podpisov, bedding plane emphasised by an interbedded movement (photo S. Šebela).

Slika 7. Del rova poteka vzporedno s slemenitvijo plasti, del pa prečno na slemenitev; predel meandrov (foto J. Hajna).
Figure 7. A part of the passage runs parallel to the bedding plane direction, and a part transversally to the direction; meander region (photo J. Hajna).

Podor na Veliki gori se je oblikoval v močno izraženi Dinarski prelomni coni ter po lezikah (slika 9). Tudi medplastni zdrsi v jugozahodnem krilu antiklinale, ki poteka skozi Čarobni vrt, so imeli pomembno vlogo pri oblikovanju dvorane.

Lepe jame in Ruski rov ležijo v tanko plastnatih sivih apnencih z roženci (slika 2 in slika 10). Gre za tankoplastnate apnence s polami, lečami in plastmi

Lepe jame and Ruski rov lie in a thin-bedded grey limestone with cherts (Figure 2 and Figure 10). There is a thin-bedded limestone with layers, lenses and nodules of cherts. By microscopic examination of the cherts I found in certain cases a late diagenetic replacement of quartz by calcite (Šebela, 1989).

In the W part of Lepe jame there are elements of a bedding plane dipping 210-230/30-50. Between Lepe

Slika 8. Lezika poudarjena z medplastnim zdrsom (foto J. Hajna).
Figure 8. Bedding plane emphasised by an interbedded movement (photo J. Hajna).

rožencev. Z mikroskopsko preiskavo rožencev sem v določenih primerih ugotovila pozno diagenetsko nadomeščanje kremena s kalcitom (Šebela, 1989).

V zahodnem delu Lepih jam so elementi vpada plasti 210-230/30-50. Med Lepimi jamami in Ruskim rovom opazujemo neizrazito sinklinalno upognjene plasti (priloga 1 in 2). Rov je nastal v tanko plastnatem sivem do črnem apnencu z roženci.

Rov Lepih jam in Ruskega rova se je nekoč verjetno nadaljeval proti danes znanim rovom Vilharjevega rova. Apnence z roženci najdemo tudi v Partizanskem rovu, Krožnem in Skalnem rovu Magdalene jame, Martelovi dvorani ter južnem delu Črne jame, to je v rovu, ki vodi do Vilharjevega rova. Apnenec z roženci (slika 2, b_1) predstavlja nastarejše v jamskih rovih dostopne plasti zgornje kredne starosti.

V podorni dvorani Ruskega rova (priloga 1) je antiklinala izrazito oblikovana. Čeprav teme antiklinale ni posebno ostro, pa je nagib kril dovolj izrazit. V temenu antiklinale so močno poudarjeni medplastni zdrsi, ki se v bližnjem umetnem Partizanskem rovu pojavijo še večkrat, predvsem zaradi bližine Postojnske antiklinale (priloga 1 in 2).

Koncertna dvorana je oblikovana v zelo debelo plastnatem apnencu, katerega skupna debelina v litološkem stolpcu obsega 99 m (b_3 na sliki 2). Bel apnenec je po Gospodariču (1976) turonijske starosti. Podorna dvorana je nastala v prelomni coni št. 5 in po lezikah poudarjenih z medplastnimi zdrsi.

Del Zgornjega in Spodnji Tartarus sta oblikovana že v senonijskem apnencu. Plasti vpadajo proti jugozahodu. Ponekod, predvsem v Spodnjem Tartarusu

jame and Ruski rov we see gentle syncline flexible bedding planes (Annexes 1 and 2). The passage was formed in a thin-bedded grey to black limestone with cherts.

At one term the Lepe jame and Ruski rov passage probably continued on towards the passages of Vilharjev rov. We can also find limestone with cherts in Partizanski rov, Krožni and Skalni rov of Magdalena jama, in Martelova dvorana and in the S part of Črna jama, that is in the passage which leads to Vilharjev rov. The limestone with cherts (Figure 2, b_1) represents the oldest accessible Upper Cretaceous beds in the cave passages.

In the Ruski rov collapse chamber (Annex 1) the anticline is explicitly formed. Although the anticline crest is not especially sharp, the inclination of the flanks is explicit enough. The interbedded movements are strongly emphasised in the anticline crest, and they appear even several times in the near artificial Partizanski rov, mainly due to the Postojna anticline vicinity (Annexes 1 and 2).

Koncertna dvorana is formed in a very thick-bedded limestone where the common thickness in the lithological column comprises 99 m (b_3 in Figure 2). According to Gospodarič (1976) the white limestone is of Turonian age. The collapsed chamber was formed in the fault zone No. 5, and along bedding planes deformed by interbedded movements.

A part of Zgornji and Spodnji Tartarus were formed in the Senonian limestone. The bedding planes dip towards SW. In some places, mainly in Spodnji Tartarus, the bedding planes are deformed by interbedded movements. The bedding thickness where there are also some rudist remains is from 0.5 m to 1 m.

Slika 9. Na Veliki gori vpada apnenec proti jugozahodu (pogled proti severozahodu) (foto J. Hajna).

Figure 9. At Velika gora the limestone dips towards SW (view looking NW) (photo J. Hajna).

so lezike poudarjene z medplastnimi zdrsi. Debelina plasti, v katerih so tudi rudistni ostanki, je 0,5 m do 1 m.

Ruski rov je z umetnim Partizanskim rovom povezan s Črno jamo. V južnem delu umetnega rova so apnenci z roženci najprej upognjeni v blago sinklinalo, nato pa proti severu prehajamo v teme Postojnske antiklinale.

Rovi Črne jame so zgrajeni iz debelejše plastnatega apnenca (0,5-1 m). V pritočnem sifonu podzemeljske Pivke, to je že v Pivka jami so rovi razviti v zelo debelo plastnatem svetlo sivem do belem apnencu, ki vsebuje veliko rudistnih ostankov.

Med Črno in Pivko jamo vpad plasti proti severovzhodu in severozahodu kaže na potek antiklinalno upognjenih plasti v smeri skoraj sever-jug, oziroma SSV-JJZ.

V Pivki jami je južno od vhodne udornice blaga sinklinala v smeri severovzhod-jugozahod.

V Podzemeljski Pivki, južno od Martelove dvorane, pa vse do ponornega vhoda reke Pivke v sistem Postojnskih jam (priloga 1) vpadajo debelo plastnati apnenci proti jugozahodu za $40-60^0$. Vseskozi lahko opazujemo plasti poudarjene z medplastnimi zdrsi. Rov Podzemeljske Pivke prehaja jugozahodno od Martelovega podora iz turonijskih apnencev v senonijske.

Pogostost in razporeditev polov plasti v rovih sistema Postojnskih jam prikazuje slika 11. Podatki 131 meritev kažejo položaj osi Postojnske antiklinale v smeri severozahod-jugovzhod. Opazimo pa tudi potek še ene antiklinale v smeri skoraj sever-jug, oziroma SSZ-JJV. Slednjo sem določila med Črno in Pivko jamo (priloga 1 in 2).

Ruski rov is connected with Črna jama by the artificial tunnel Partizanski rov. In the S part of the tunnel there is limestone with cherts folded to a gentle syncline, and then to the N we reach the crest of the Postojna anticline.

The pasages of Črna jama are in a thicker-bedded limestone (0.5-1 m). In the upstream sump in Pivka jama the passages are developed in a very thick-bedded light grey to white limestone which contains a lot of rudist remains.

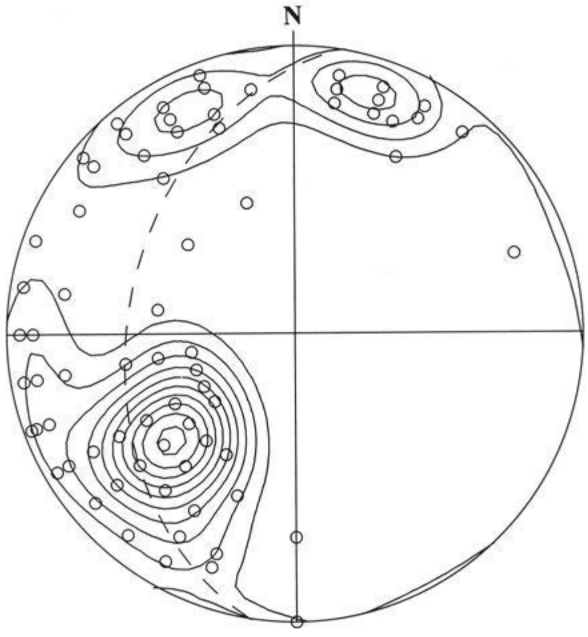
The bedding plane dip between Črna jama and Pivka jama towards NE and NW shows the anticline flexible bedding planes course change into directions of almost NS or NNE-SSW respectively.

On the S side of the E collapse doline of Pivka jama there is a gentle syncline in NE-SW direction.

In Podzemeljska Pivka S of Martelova dvorana and all the way along to the Pivka river entrance into the Postojnska jama cave system (Annex 1) the thick-bedded limestone dips towards SW for $40-60^{o}$. All the time we can observe the bedding planes deformed by interbedded movements. The Podzemeljska Pivka passage passes over from Turonian to Senonian limestone in the SW of Martelov podor.

The Postojnska jama cave system passages poles frequency of bedding planes is presented in Figure 11. 131 measurements show the Postojna anticline axis is in the NE-SW direction. We also see the course of another

Slika 10. Leče rožencev v Ruskem rovu (foto S. Šebela).
Figure 10. Chert lenses in Ruski rov (photo S. Šebela).



Slika 11. Poli plasti v sistemu Postojnskih jam, n=131.
Figure 11. Poles of the bedding planes in the Postojnska jama cave system, n=131.

Potrebno je poudariti, da je Gospodarič pri kartiranju sistema Postojnskih jam (1965) v merilu 1:2.000 v Lepih jamah, Ruskem rovu ter deloma tudi Pisanem rovu ugotovil več antiklinal in sinklinal, katerih osi so večinoma vzporedne osi Postojnske antiklinale, lahko pa tudi prečne nanjo. Po svojih opazovanjih lahko potrdim, da obstajajo, vendar so zelo neizrazite, tako da je pravilneje govoriti o antiklinalno in sinklinalno upognjenih plasteh. Menim, da gre kvečjemu za sekundarne gube (Dimitrijević, 1978, 208), ki pripadajo Postojnski antiklinali. V področju temena Postojnske antiklinale, kot tudi temena antiklinale, ki poteka od Skalnega rova (Magdalena jama) v Pisani rov, opazujemo večjo neurejenost smeri vpada plasti, kar nakazuje, da gre za večje število gub znotraj glavne gube - Postojnske antiklinale.

7.2. Tektonsko kartiranje

Z metodo podrobnega tektonsko-litološkega kartiranja (Čar, 1982, 1983) sem kartirala celotni dostopni del sistema Postojnskih jam, in sicer na terenu v merilu 1:500.

Za pomoč pri interpretaciji pomembnosti določene tektonsko pretrte cone v jami sem upoštevala tudi rezultate s površja (poglavje 8.3.).

V sistemu Postojnskih jam ločimo starejše deformacije gubanja, ki predstavljajo Postojnsko antiklinalo ter mlajše prelomne deformacije. Čar in Gospodarič (1984) sta prelomne deformacije med Postojnsko kotlino, Planinskim in Cerkniškim poljem razdelila v 4 generacije. Pri svojem delu sem upoštevala prav to delitev. Podroben opis genetske klasifikacije je v poglavju 3.3.2.

Reka Pivka ponika na n.m.v 511 m. Aktivni jamski vhod se je razvil v lezikah, ki so poudarjene z medplastnimi zdrsi (slika 3). Za turistični vhod v jamo

anticline in a direction almost N-S or NNW-SSE. The latter I determined between Črna jama and Pivka jama (Annexes 1 and 2).

It is necessary to stress that, by mapping the Postojnska jama cave system at a scale of 1:2,000 in Lepe jame, Ruski rov and in part of Pisani rov Gospodarič (1965) found more anticlines and synclines where the axes were mainly parallel to the Postojna anticline axis, but possibly also transverse to it. After my observations I can confirm that they exist, but they are very undetermined, thus it is more correct to talk about anticline and syncline flexible bedding planes. I think that the most there are secondary folds (Dimitrijević, 1978, 208) which belong to the Postojna anticline. In the Postojna anticline apex crest, as well as the anticline crest which goes from Skalni rov (Magdalena jama) to Pisani rov, we observe greater bedding plane dip and strike disorder, which indicates that there is a greater number of folds inside the main fold – the Postojna anticline.

7.2 Tectonic Mapping

By a detailed tectonic-lithological mapping method (Čar, 1982, 1983) I mapped the entire accessible Postojnska jama cave system section, at a scale of 1:500.

For the assistance in interpreting the importance of the specific cave tectonically fractured zone I paid regard also to the surface results (Chapter 8.3.).

In the cave system we differentiate older folding deformations which represent the Postojna anticline, and younger fault deformations. Čar and Gospodarič (1984) divided the fault deformations with the area between Postojna basin, Planina and Cerknica into 4 generations. In my work I used this division. A genetic classification detailed description is in the Chapter 3.3.2.

The Pivka river sinks at 511 m above sea level. An active cave entrance was developed in bedding planes which were deformed by interbedded movements (Figure 3). For the tourist entry into the cave the old passage filled up by cave sediments was dug through and enlarged. It lies at 529.50 m above sea level. There is also an artificial platform in front of the so prekopali in povečali star, z jamskimi sedimenti zapolnjen rov, ki danes leži v n.m.v. 529,50 m. Na tej višini je tudi umetna ploščad pred jamo. Omenjena n.m.v. je vzeta tudi za osnovo prečnih profilov na prilogi 1. Aktivni in neaktivni vhodi v jamo so razviti v lateralno istih plasteh, debeline okrog 6-7 m (slika 4), pri čemer je treba omeniti, da se niso oblikovali v isti leziki.

Ob ponoru Pivke je še posebno izrazit prelom z zdrobljeno cono 130/80 (št.10), ki je opazen kot strma prelomna stena (slika 12), ob kateri je prišlo do horizontalnih premikov. To potrjuje tudi morfološka zajeda na površju in podorni material ob prelomni ploskvi.

Po vhodu v jamo se prostor razširi v dvorano Veliki dom, skozi katero teče reka Pivka v rov Podzemeljske Pivke. Dvorana je razvita v zdrobljeni coni z elementi vpada 110/80 in predstavlja nadaljevanje cone št. 10 (priloga 1). Severni rob dvorane omejuje prelomna cona 50/80, ki proti vzhodu prehaja v cono 230/40.

Rov podpisov je v začetnem delu razvit v leziki, ki je poudarjena z medplastnimi zdrsi. V nadaljevanju rova so opazne porušene cone s smerjo vpada 110^0 in 100^0, ki predstavljajo vzporedne prelomne deformacije prelomni coni št. 10. Krajši rov severovzhodno od Rova podpisov je razvit v razpoklinski coni s smerjo vpada

cave at the same level. This level is taken also as the basis of cross-sections in Annex 1. Active and inactive entrances into the cave are developed in the laterally same bedding, about 6-7 m thick (Figure 4) where one should mention that they were not formed in the same bedding plane.

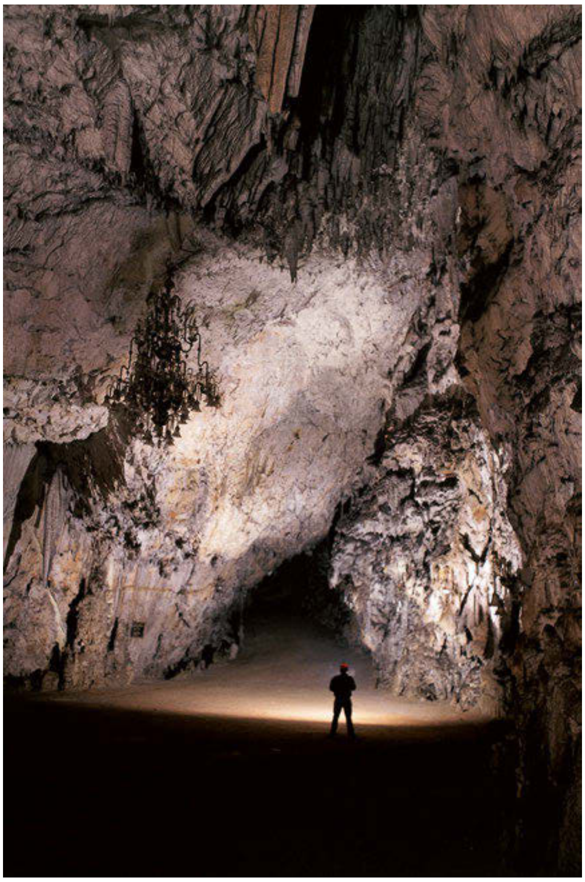
By the Pivka sink there is a particularly marked fault with a crushed zone 130/80 (No.10) which is noticed as a steep fault wall (Figure 12) along which horizontal movements occurred. This is likewise confirmed by a morphological notch on the surface, and by the collapse material by the fault plane.

Near the cave entrance the passage expands into the Veliki dom chamber through which the Pivka river flows to the Podzemeljska Pivka passage. The chamber is developed in the crushed zone with dip elements 110/80 and represents the continuity of No.10 zone (Annex 1). The N chamber side is bounded by the fault zone 50/80 which passes over to the zone 230/40 towards E.

In the initial part of Rov podpisov the passage is developed in a bedding plane which is deformed by interbedded movements. Further in along the passage one notices broken zones with the dip and strike 110^0 and 100^0 which represents parallel fault deformations

Slika 12. Prelomna ploskev, ki omejuje prelomno cono št. 10 (foto S. Šebela)

Figure 12. Fault plane which restrains fault zone No. 10 (photo S. Šebela).



Slika 13. Kongresna dvorana; zdrobljena cona 100/70-90 (pogled proti jugu) (foto J. Hajna).

Figure 13. Kongresna dvorana; crushed zone 100/70-90 (view looking S) (photo J. Hajna).

70^0 (priloga 1).

Severni del Biospeleološke postaje se je oblikoval v medplastnih zdrsih (priloga 1, prečni profil 8-8*). Prelomna cona 230/40 predstavlja najmočneje izražen zdrs.

Severno od Biospeleološke postaje je v stropu opazna prelomna cona 100-130^0 (priloga 1, prečni profil 9-9*).

V nadaljevanju proti severu se vije rov, v katerem se na vzhodni strani pojavijo podori in hkrati z njimi tudi razširitev jamskih prostorov. Iz rova Podzemeljske Pivke se skozi podorne dvorane nadaljuje močno izražena zdrobljena cona Dinarske smeri (230/60 in 50^0). Podori so se oblikovali v prelomnih conah. Podorni material se je s stropa luščil iz dveh zdrobljenih con, in sicer iz prevladujoče Dinarske in podrejene prečno Dinarske cone. Podorni nasipi tonejo od vzhoda proti zahodu. Enako vpada tudi zelo debelo plastnat apnenec (priloga 1, prečni profil 10-10* in 11-11*).

Zahodni del Kongresne dvorane se je oblikoval v močno izraženi zdrobljeni coni z elementi vpada 100/70-80 (slika 13). Nadaljevanje rova severovzhodno od Kongresne dvorane je razvito v zdrobljeni coni 120-130^0 (priloga 1, prečni profil 18-18*), in sicer vse do predela, kjer prevladujeta porušena cona s smerjo vpada 60^0 in zdrobljena cona s smerjo vpada 80-90^0.

to No.10 fault zone. The shorter passage in the NE of Rov podpisov is developed in the fissured zone with dip and strike 70^0 (Annex 1).

The N part of Biospeleološka postaja was formed in interbedded movements (Annex 1, cross-section 8-8*). The fault zone 230/40 represents the most strongly expressed movement.

To the N of Biospeleološka postaja a fault zone 100-130^0 is noticed in the ceiling (Annex 1, cross-section 9-9*).

Further to the N there is a passage with collapses in the E side, which makes it bigger. A strongly expressed crushed zone in the Dinaric direction (230/60 and 50^0) continues from the Podzemeljska Pivka passage through collapse chambers. The collapses are formed in the fault zones. The collapse material scaled off from the ceiling of two crushed zones, namely, of the prevailing Dinaric and inferior cross-Dinaric zones. Collapse cones dip from E to W. A very thick-bedded limestone dips also in the same manner (Annex 1, cross-section 10-10* and 11-11*).

The W part of Kongresna dvorana was formed in a strongly expressed crushed zone with dip elements 100/70-80 (Figure 13). The further passage NE of Kongresna dvorana is developed in the crushed zone 120-130^0 (Annex 1, cross-section 18-18*) all the way

Slika 14. Jamski rov se je razvil prečno na razpoklinsko cono 70/90 (foto J. Hajna).

Figure 14. Cave passage was developed transversally to the fissured zone 70/90 (photo J. Hajna).

V dvorani pred Kristalnim rovom je strop oblikovan v zdrobljeni coni, ki se razteza v smeri sever-jug. Na severu jo režejo porušene do razpoklinske cone Dinarske smeri 70^0 (priloga 1, prečni profil 24-24*). Sledimo jih lahko vse do južnega dela Malih jam.

Kristalni rov leži nižje kot glavni rov sistema Postojnskih jam (priloga 1, prečni profil 23-23*) in je freatično oblikovan. Rov spreminja smer in tako prehaja iz ene porušene cone v drugo. Kristalni rov je bil verjetno povezan z Ozkim rovom. Med obema je danes neprehoden predel dolg približno 70 m. Ozki rov je po obliki podoben Kristalnemu. Freatični rov se je oblikoval po plastnatosti in porušenih conah.

Predel sistema Postojnskih jam pri odcepu Malih jam je pogojen z vpadom in slemenitvijo debelo plastnatega apnenca. Na stropu rova opazujemo zdrobljeno cono 60-80/80, ki močno povija (priloga 1, prečni profil 28-28*). Sledimo ji lahko tudi v jugovzhodnem delu Malih jam, kjer spremeni smer v 50^0.

Glavni rov sistema Postojnskih jam severovzhodno od odcepa za Male jame na razdalji okrog 130 m večkrat zavije (priloga 1). Podobno vijuganje, čeprav manjših dimenzij, smo opazovali že v aktivnem Vzhodnem rovu Predjame (Šebela & Čar, 1991). Razpoklinske oziroma porušene cone imajo Dinarsko smer 60-80/60-90, tako da poteka rov večinoma prečno na smer tektonsko pretrtih con (slika 14). Debelo plastnat apnenec vpada proti jugozahodu pod kotom $30\text{-}50^0$. Jamski rov se je večinoma oblikoval prečno in le ponekod vzporedno s plastnatostjo. Zelo jasno so izraženi medplastni zdrsi (slika 8), ki prehajajo iz lezike v leziko. Medplastni zdrsi so deformirali plastnatost (slika 15).

Že Gospodarič (1965) je ta del sistema Postojnskih jam natančno preiskal. Ugotovil je, da smeri rova v stropu in na dnu ne sovpadajo. V višini današnjega stropa so se po njegovem mnenju pretakale manjše, v višini dna pa večje količine vode. Iz površja so prenašale mnogo proda in ilovic, saj so s tem materialom erodirale stene.

Rov brez imena leži nekoliko višje kot Stara jama. Konča se z zožitvijo rova in zapolnitvijo s sigo. Rov poteka v Dinarski smeri, in sicer v severnem delu po zdrobljeni do porušeni coni s smerjo vpada 40^0. Na razdalji okrog 85 m južno od vhoda v rov zasledimo izraziti prelomni ploskvi 310/60 in 310/40, ki rov prečkata. Ob stenah rova se je v eni od njiju razvil stranski freatični rov s stenskimi kotlicami (slika 16).

Po Šušteršiču (1991, 79) so manjši stranski rovi preostanki prvotne mreže zakraselih geoloških nezveznosti, ki so ob večanju današnjega glavnega rova v razvoju zaostali. Ker potekajo stranski rovi včasih tudi

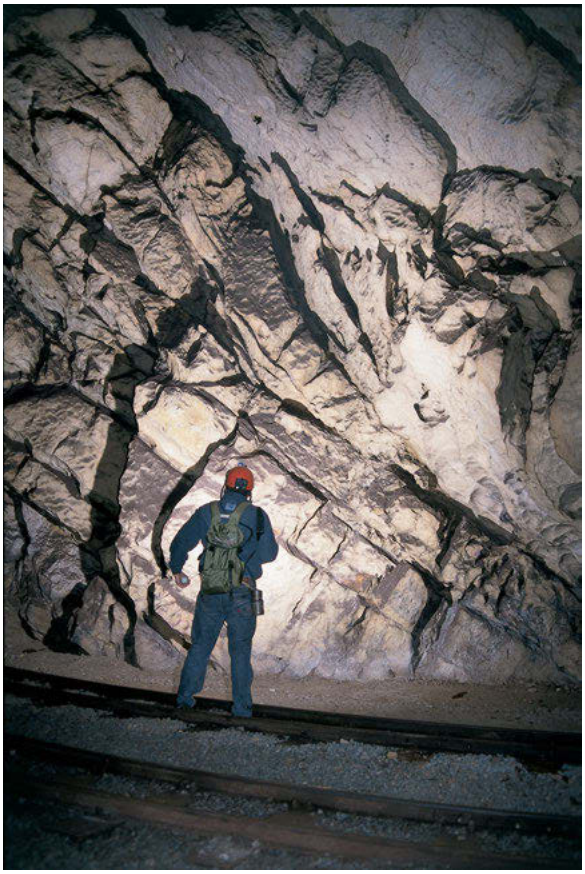
to the section where the broken zone with the dip and strike 60^0, and the crushed zone with the dip and strike $80\text{-}90^0$ prevail.

In the chamber in front of Kristalni rov the ceiling is formed in the crushed zone which extends in a N-S direction. In the N it is cut by broken to fissured zones of the Dinaric direction 70^0 (Annex 1, cross-section 24-24*). We can follow it all the way to the S part of Male jame.

Kristalni rov lies lower than the main passage of Postojnska jama cave system (Annex 1, cross-section 23-23*), and is phreatically formed. The passage varies in direction, and thus it passes over from one broken zone to another. Kristalni rov was probably connected with Ozki rov. Between both there is nowadays an impassable section about 70 m long. In form Ozki rov is similar to Kristalni rov. Phreatic passage was formed along the bedding and broken zones.

The part of the cave by the Male jame branch was dependent on dip and on strike of the thick-bedded limestone. On the passage ceiling we observe the crushed zone 60-80/80 which turns greatly (Annex 1, cross-section 28-28*). We can follow it also to the SE part of Male jame where it changes the strike to 50^0.

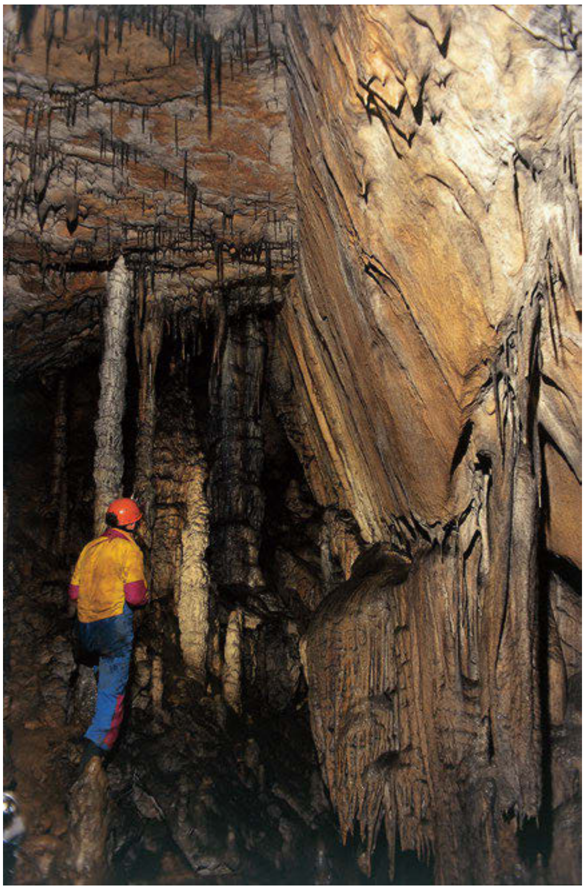
The Postojnska jama cave system main passage in the NE part of the branch for Male jame at the distance of 130 m turns several times (Annex 1). Similar winding, although on a smaller scale, we had already observed in the active Vzhodni rov of Predjama (Šebela



Slika 15. Medplastni zdrsi so deformirali plastnatost; predel meandrov (foto S. Šebela).

Figure 15. Interbedded movements deformed bedding; meander region (photo S. Šebela).

Slika 16. Ob prelomni ploskvi 310/60 se je oblikoval freatični rov (Rov brez imena) (foto J. Hajna).
Figure 16. Phreatic passage was formed along the fault plane 310/60 (Rov brez imena) (photo J. Hajna).



& Čar, 1991). Fissured or broken zones have the Dinaric direction 60-80/60-90 respectively, in the way that the passage goes mainly transverse to the tectonically fractured zones strike (Figure 14). The thick-bedded limestone dips to the SW at an angle of 30-50^{o}. The cave passage was mainly formed transversally, and only in some places parallel to the bedding. The interbedded movements are very clearly expressed (Figure 8), and they cross over from bedding plane to bedding plane. Interbedded movements deformed the bedding (Figure 15).

Gospodarič (1965) has already accurately studied this part of the Postonjska jama cave system. He found out that the passage strikes on the ceiling and floor did not coincide. In his opinion smaller quantities of water flowed at the present ceiling level, and greater quantities at the bottom level. The waters brought from the surface a lot of gravel and clay, and this material eroded the walls.

Rov brez imena lies a bit higher than Stara jama. It ends up by the passage narrowing and filling up by flowstone. The passage runs in the Dinaric direction,

Slika 17. Prelomna ploskev 320/80 v Rovu brez imena (foto F. Drole).
Figure 17. Fault plane 320/80 in Rov brez imena (photo F. Drole).

nad glavnimi, to potrjuje misel, da je z osredotočenjem vode v en sam velik kanal, dejansko prišlo do znižanja piezometra.

V nadaljevanju poteka Rov brez imena v močni zdrobljeni coni prečno Dinarske smeri (slika 17), ki jo je raziskal že Gospodarič (1965). Ob prelomni ploskvi 320/80 je prišlo do vertikalnega premikanja, kjer se je severozahodni blok spustil, jugovzhodni pa dvignil (priloga 1). V notranji prelomni coni, v kateri je apnenec pretrt do stopnje tektonske breče, se je oblikovala podorna dvorana. Zdrobljena cona prečno Dinarske smeri v Rovu brez imena je del širše prelomne cone.

V Pisanem rovu so prevladujoče smeri tektonsko pretrtih con sever-jug. Najsevernejši del je oblikovan v zdrobljeni coni smeri 80^0. Druga zdrobljena cona, katere smer vpada je 130^0 (slika 18), seka zgoraj omenjeno prelomno cono in jo tudi zamika. Strop jamskega rova severne dvorane Pisanega rova se je oblikoval v lezikah in prelomnih conah (slika 19 in slika 20).

Zdrobljena cona, ki je označena s št. 7 (priloga 1, prečni profil 43-43*), je v jamskih stenah manj izrazita kot na površju nad jamo, kar je v soglasju z vertikalnim spreminjanjem tektonskih con. Če nadaljujemo opisovanje tektonske zgradbe Pisanega rova proti jugu, se je južni stranski rov oblikoval v prečno Dinarski zdrobljeni coni 130-140^0 (slika 21).

Odsek med prečnima profiloma 40-40* in 42-42* (priloga 1), dolžine okrog 100 m, poteka v smeri vzhod-zahod. Najmočneje so izražene porušene cone smeri sever-jug, širine 2 do 3 metre. Južno od prečnega profila 40-40* (priloga 1) se je Pisani rov oblikoval v ja-

that is in the N part along the crushed to broken zones with the dip and strike 40^0. At a distance of about 85 m S of the passage entrance we notice two explicit fault planes 310/60 and 310/40, which traverse the passage. By the passage walls in one of them there developed a lateral phreatic passage with wall potholes (Figure 16).

According to Šušteršič (1991, 79) smaller lateral passages are the remains of the primary network of karst-like geological incongruities whose development was retarded by enlargement of the present main passage. Since lateral passages also sometimes go above the main ones, it confirms the belief that the water table was lowered by the water becoming concentrated into one big channel.

Rov brez imena continues in a strongly crushed zone of cross-Dinaric direction (Figure 17) which was already investigated by Gospodarič (1965). On the fault plane 320/80 there occured a vertical movement where the NW block sank, and the SE one was raised (Annex 1). In the inner fault zone in which the limestone was fractured to a tectonic breccia a collapse chamber was formed. The cross-Dinaric direction crushed zone in Rov brez imena is a part of a larger fault zone.

In Pisani rov the tectonically fractured zones prevailing directions are N-S. The most N part is formed in the crushed zone of the strike 80^0. Another crushed zone where the strike and dip is 130^0 (Figure 18); it crosses the above-mentioned fault zone, and also moves it. The Pisani rov N chamber cave passage ceiling was formed in bedding planes and fault zones (Figure 19 and Figure 20).

Slika 18. Pisani rov; prelomna cona s smerjo vpada 130^o (foto F. Drole).
Figure 18. Pisani rov; fault zone with the dip and strike 130^0 (photo F. Drole).

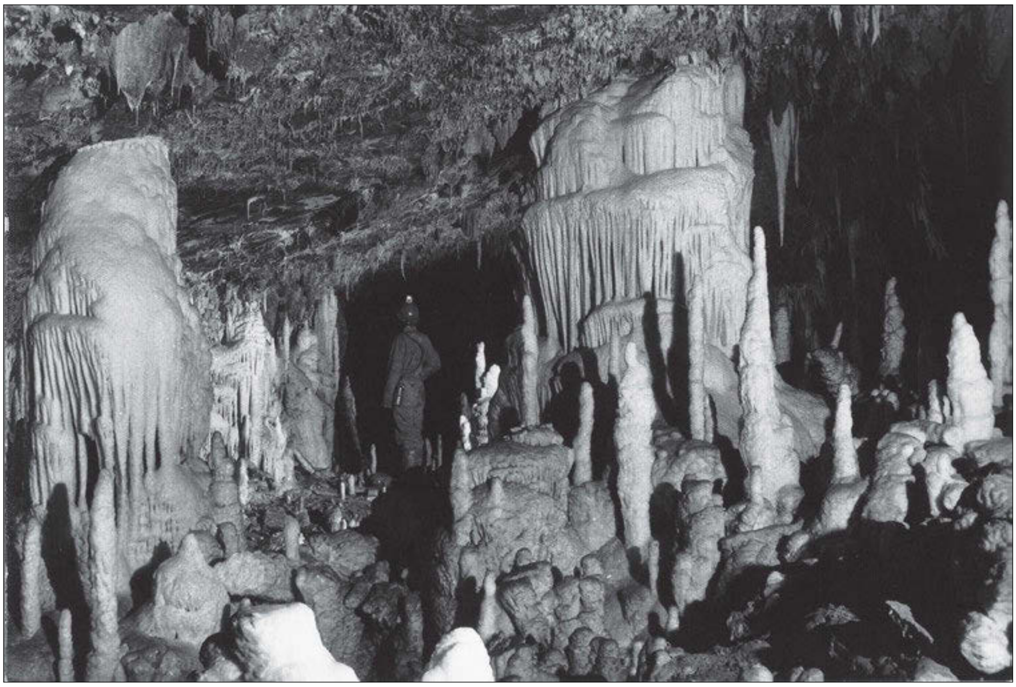
Slika 19. Strop dvorane se je oblikoval po plastnatosti in prelomni coni 80/90; Pisani rov (foto F. Drole).
Figure 19. The chamber ceiling was formed along the bedding and the fault zone 80/90; Pisani rov (photo F. Drole).

sno izraženi zdrobljeni coni v smeri sever-jug. Notranja prelomna cona, ki jo gradi tektonska breča je široka do 1 m in poteka po vzhodni strani rova. V zunanji prelomni coni so glavni prelomni ploskvi vzporedne prelomne ploskve ter spremljajoče porušene cone.

Največja podorna dvorana Pisanega rova je nastala v močni Dinarski zdrobljeni coni, ki poteka čez celo dvorano. Prelomna ploskev z elementi vpada 30/60 (slika 22) seka vse ostale tektonsko pretrte cone. Ob njej je prišlo do horizontalnih premikov, in sicer do levega zmika. Ista prelomna cona Dinarske smeri se nadaljuje tudi v Čarobnem vrtu, na Veliki gori, Lepih jamah in

The crushed zone marked by No.7 (Annex 1, cross-section 43-43*) is less expressive on the cave walls than on the surface above the cave, what is in conformity with tectonic zone vertical modifications. If we continue with the Pisani rov tectonic structure description towards S, the S side passage was formed into the cross-Dinaric crushed zone 130-140^0 (Figure 21).

The section between cross-sections 40-40* and 42-42* (Annex 1), about 100 m long, run in a E-W direction. The N-S directions broken zones from 2 to 3 metres wide are most strongly expressed. To the S of the cross-section 40-40* (Annex 1) Pisani rov was



Slika 20. Strop dvorane se je oblikoval po plastnatosti; Pisani rov (foto F. Drole).
Figure 20. The chamber ceiling was formed along the bedding; Pisani rov (photo F. Drole).

rovu Podzemeljske Pivke (priloga 1).

Južno od podorne dvorane je Pisani rov razvit v prelomni coni z elementi vpada 60-90^0. Tudi tu je osrednji del dvorane podoren. V južnem krilu antiklinalno upognjenih plasti so jasno izraženi medplastni zdrsi (slika 23), po katerih so se krušili večji bloki apnenca. Proti jugu prevladujejo porušene do razpoklinske cone Dinarskih smeri. Posebno izrazita je porušena cona s smerjo vpada 70^0 v vzhodnem stranskem rovčku.

Na vhodu v Pisani rov je najizrazitejša zdrobljena cona 10/60 (slika 24), ki seka prelomno cono 50-70^0, ob kateri je rov Stare jame usmerjen proti severu (priloga 1). Del Stare jame pred Veliko goro, se je oblikoval po lezikah (slika 25).

V Čarobnem vrtu so plasti nagubane v antiklinalo. Jugovzhodni del Čarobnega vrta je nastal delno po plastnatosti (slika 26) in delno v zdrobljeni coni z elementi vpada 20^0. Čarobni vrt leži glede na severni del podorne dvorane Velike gore okrog 30 metrov nižje.

Podorna dvorana Velika gora je v severnem delu omejena s prelomno ploskvijo 30-40/80-90 (slika 27), ki je del močno izražene Dinarsko usmerjene prelomne cone. Ta je večinoma vzporedna s Postojnsko antiklinalo, medtem ko drugo antiklinalo med Čarobnim vrtom in Pisanim rovom seka (priloga 1).

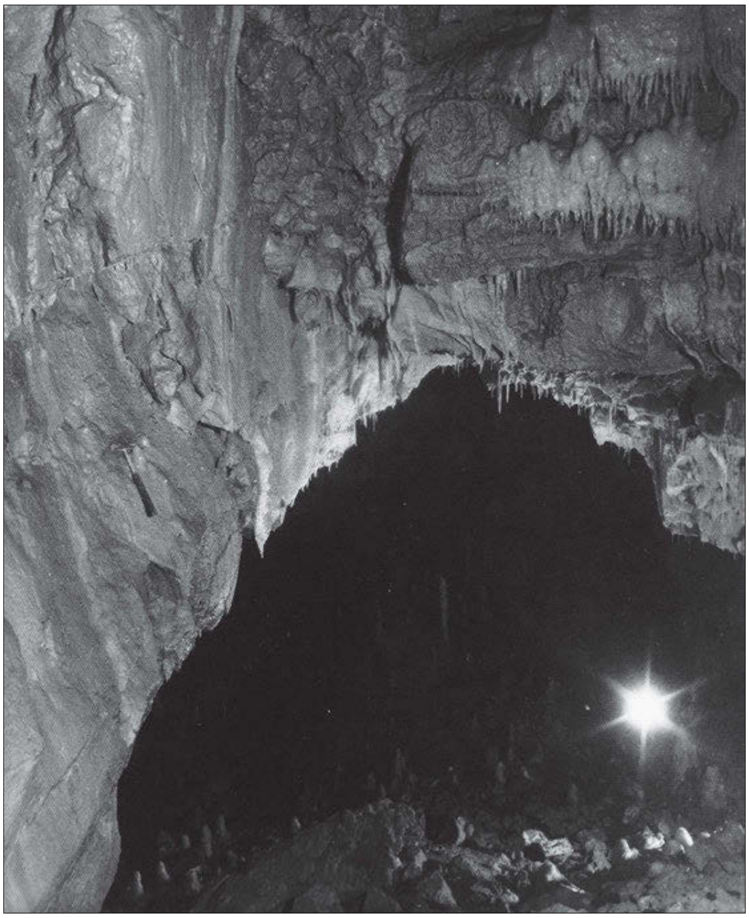
Ob zdrobljeni coni je v dvorani Velike gore prišlo do vertikalnih premikov. Glede na povitost plasti (slika 27), sklepamo, da se je južni blok, v katerem se je ob-

formed in a clearly expressed crushed zone in the N-S direction. The inner fault zone which is being built up by a tectonic breccia is up to 1 m wide, and goes along the E passage side. In the outer fault zone the main fault planes are parallel with the accompany broken zones.

The biggest Pisani rov collapse chamber was formed in a strong Dinaric crushed zone which goes over the whole chamber. The fault plane with dip elements 30/60 (Figure 22) crosses all the other tectonically fractured zones. There arose horizontal movements along it, that is to the left strike-slip. The same Dinaric direction fault zone continues also in Čarobni vrt, at Velika gora, in Lepe jame, and in the Podzemeljska Pivka passage (Annex 1).

To the S of the collapse chamber Pisani rov is developed in the fault zone with dip elements 60-90^0. The central part of the chamber is collapsed also here. In the S anticline flexible bedding planes flank the interbedded movements are clearly expressed (Figure 23), along which greater limestone blocks were being crumbled. The Dinaric directions broken to fissured zones prevail towards S. The broken zone with the dip strike 70^0 in the small E side passage is particularly expressive.

At the entrance of Pisani rov the crushed zone 10/60 is the most expressive (Figure 24), and it crosses the fault zone 50-70^0, along which there is the Stara jama passage oriented towards the N (Annex 1). A part of Stara jama in front of Velika gora was formed along



Slika 21. Zdrobljena cona 130-140/90 v Pisanem rovu (foto F. Drole).
Figure 21. Crushed zone 130-140/90 in Pisani rov (photo F. Drole).

Slika 22. V Pisanem rovu se je podorna dvorana oblikovala v prelomni coni 30/60 (pogled proti jugu) (foto J. Hajna).
Figure 22. In Pisani rov the collapse chamber was formed in the fault zone 30/60 (S view) (photo J. Hajna).

likovala podorna dvorana, spustil, severni pa dvignil. Ocenjena velikost vertikalnega premika je manj kot 3 m.

Čez celotno dvorano Velike gore so opazne vzporedne prelomne ploskve z elementi vpada 50^0 (priloga 1, prečni profil 51-51*). Podorni material se je krušil

bedding planes (Figure 25).

In Čarobni vrt the bedding planes are folded into the anticline. The Čarobni vrt SE part was partially formed inside bedding (Figure 26), and partially in the crushed zone with dip elements 20^0. Čarobni vrt lies about 30 metres lower than the NE part of the Velika gora collapse chamber.

In the N part the Velika gora collapse chamber is bounded by the fault plane 30-40/80-90 (Figure 27) which forms a part of a strongly expressed Dinaric direction fault zone. It is mainly parallel to the Postojna

Slika 23. Podorni bloki so se odlomili po lezikah poudarjenih z medplastnimi zdrsi (Pisani rov, pogled proti jugu) (foto F. Drole).
Figure 23. Collapse blocks broke off along bedding planes emphasised by interbedded movements (Pisani rov, S view) (photo F. Drole).

Slika 24. Prelomna cona 10/60 pri odcepu za Pisani rov (pogled proti jugu) (foto J. Hajna).
Figure 24. Fault zone 10/60 at the branch to Pisani rov (S view) (photo J. Hajna).

Slika 25. Jamski rov je oblikovan po plastnatosti (pogled proti jugu) (foto J. Hajna).
Figure 25. Cave passage is formed along the bedding (S view) (photo J. Hajna).

po prelomnih ploskvah 220-230/40-50, ki predstavljajo medplastne zdrse (slika 28). Velika gora se je na skrajnem severnem delu oblikovala po notranji prelomni coni, na južnem delu pa po zunanji prelomni coni. V slednji so Dinarske vzporedne prelomne ploskve ponekod prekinjene s prečno Dinarsko zdrobljeno cono smeri vpada 140-170^0. V osrednjem in južnem delu Velike gore je do 10 m široka prelomna cona v smeri sever-jug (slika 29). Glede na njen položaj med prelomno cono na severu Velike gore in prelomno cono št. 5 na severu Koncertne dvorane, je to ena od močneje izraženih veznih porušenih (slika 30) do zdrobljenih con.

Turistično najbolj znani del sistema Postojnskih jam so Lepe jame, ki so zanimive tudi z geološkega in speleološkega stališča. Rov je manjših dimenzij, bogato zasigan in zapolnjen z jamskimi sedimenti. V južnem delu Lepih jam so tektonsko pretrte cone manj vidne. Še najbolj je določljiva zdrobljena cona 60^0 in razpoklinska cona 100^0. Tik preden preidejo Lepe jame iz Dinarske smeri v prečno Dinarsko smer, je manjša podorna dvorana oblikovana po lezikah poudarjenih z medplastnimi zdrsi (priloga 1, prečni profil 56-56*) ter po zdrobljenih in porušenih conah.

Stranski rovček na severnem robu rova Lepih jam se je oblikoval v isti prelomni coni, ki smo jo spoznali že na Veliki gori. Še posebno jasno sta izraženi

Slika 26. Jamski rov je oblikovan po plastnatosti; Čarobni vrt (foto J. Hajna).
Figure 26. Cave passage is formed along the bedding; Čarobni vrt (photo J. Hajna).

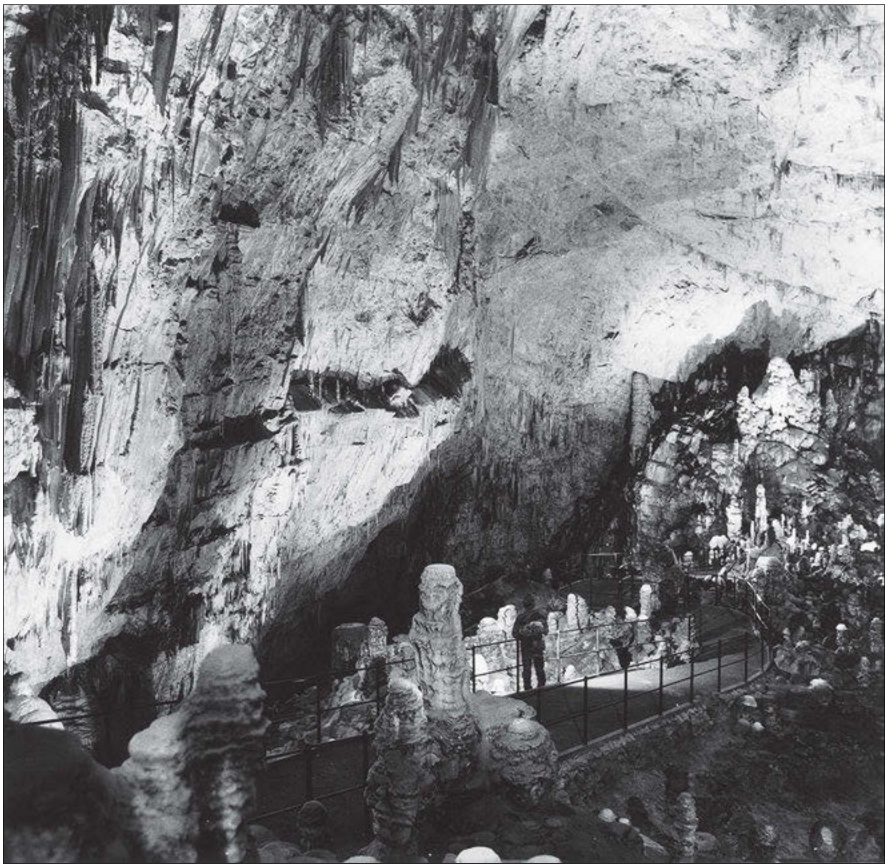
anticline, while it crosses another anticline between Čarobni vrt and Pisani rov (Annex 1).

In the Velika gora chamber there arose vertical movements along the crushed zone. As to bedding planes deformations (Figure 27) we assume that the S block, where the collapse chamber was formed, was lowered, and the N one raised up. The vertical movement is estimated to be less than 3 m.

Parallel fault planes with dip elements 50^0 are noticed in the entire Velika gora chamber (Annex 1, cross-section 51-51*). Collapsed material was crumbled along the fault planes 220-230/40-50 which represent interbedded movements (Figure 28). At its most N part Velika gora was formed in the inner fault zone, and at its S part in the outer fault zone. In the latter the Dinaric parallel fault planes are intersected by the cross-Dinaric crushed zone of the dip and strike 140-170^0. In the Velika gora central and S parts there is a fault zone up to 10 m wide in a N-S direction (Figure 29). With its position between the Velika gora fault zone in the N and the fault zone No. 5 in the N of Koncertna dvorana, this is one of more strongly expressed connective broken (Figure 30) to crushed zones.

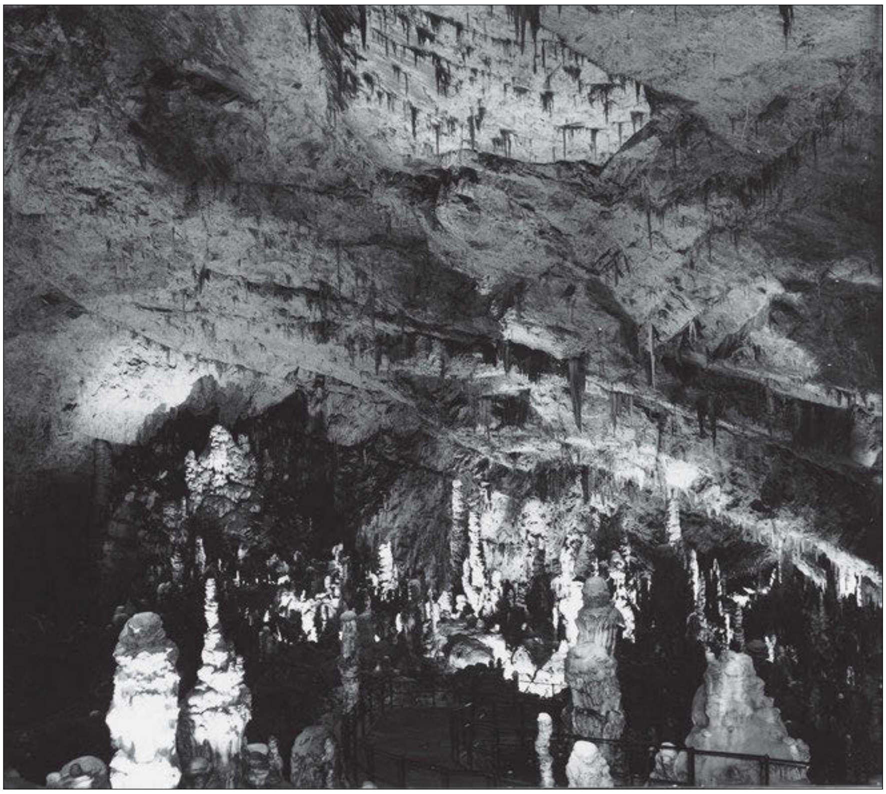
The Lepe jame passage are to the tourists best known part of the Postojnska jama cave system, and they are also interesting from the geological and speleological point of view. The passage is of smaller dimensions, rich with flowstone and filled up with cave sediments. In the S part of Lepe jame the tectonically fractured zones are less visible. The crushed zone 60^0 and the fissured zone 100^0 are the most definable. Just before the Lepe

Slika 27. Severovzhodni del dvorane Velike gore se je oblikoval v prelomni coni 30-40/80-90 (pogled proti jugovzhodu) (foto J. Hajna).
Figure 27. NE part of the Velika gora chamber was formed in the fault zone 30-40/80-90 (SE view) (photo J. Hajna).

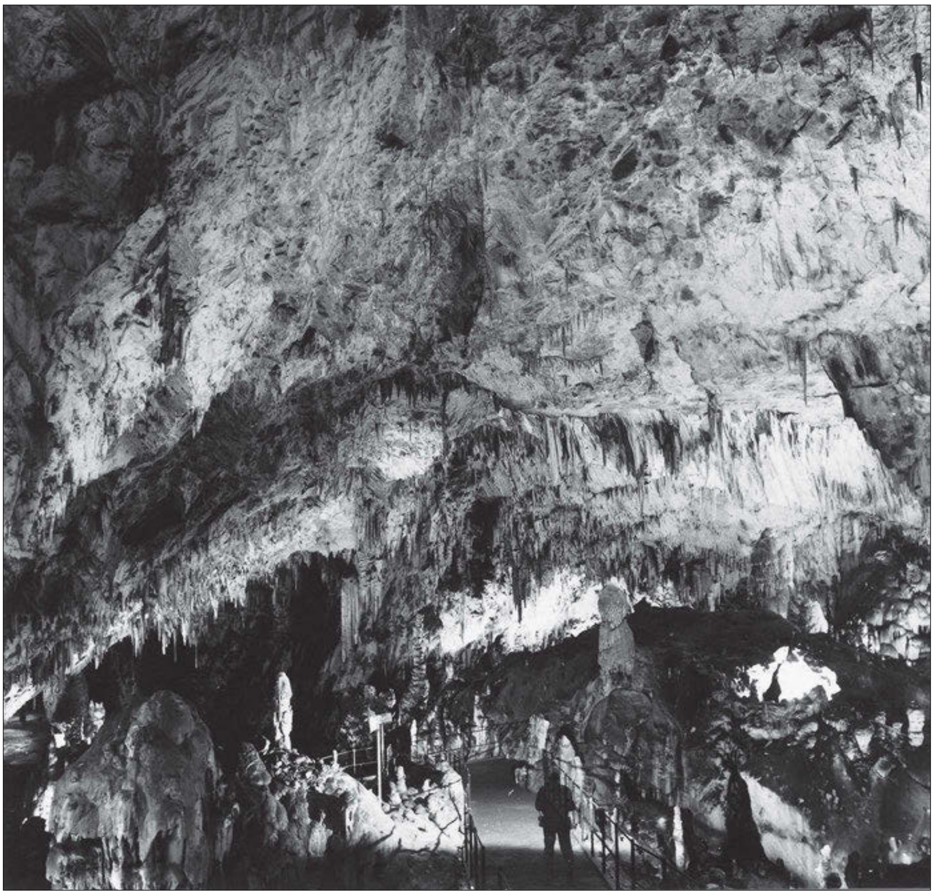


prelomni ploskvi 30/60 in 30/85 (slika 31), ki omejujeta notranjo prelomno cono. Širina le-te je od 0,5 do 1 m. Apnenec je pretrt do stopnje tektonske breče in gline. Ob severni prelomni ploskvi z elementi vpada 30/60

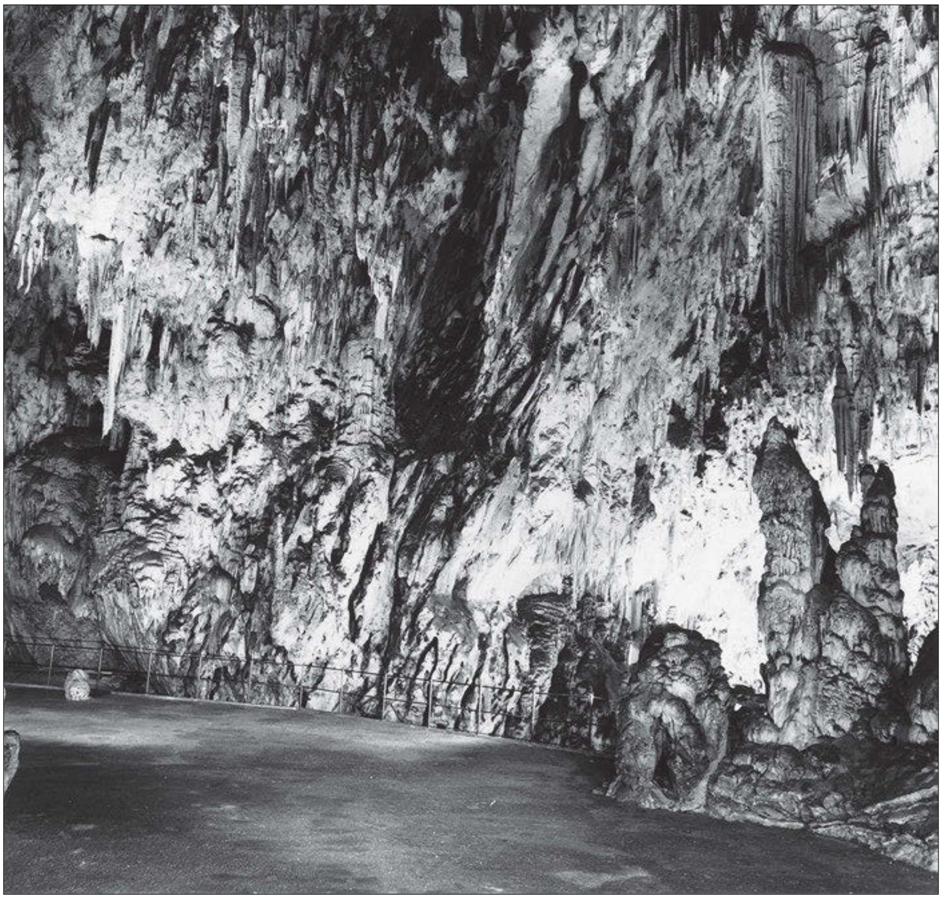
jame passage come from the Dinaric direction into the cross-Dinaric direction there is a smaller collapse chamber formed along bedding planes emphasised by interbedded movements (Annex 1, cross-section 56-



Slika 28. Velik del dvorane Velike gore se je oblikoval po lezikah, poudarjenih z medplastnimi zdrsi (foto J. Hajna).
Figure 28. Great part of the Velika gora chamber was formed along bedding planes emphasised by interbedded movements (photo J. Hajna).



Slika 29. Južni del dvorane Velike gore se je oblikoval v prelomni coni 90/90 (pogled proti jugozahodu) (foto J. Hajna).
Figure 29. S part of the Velika gora chamber was formed in the fault zone 90/90 (SW view) (photo J. Hajna).



Slika 30. Porušena cona 100-110/90 v južnem delu dvorane Velike gore, (foto J. Hajna).
Figure 30. Broken zone 100-110/90 in the S part of the Velika gora chamber (photo J. Hajna).

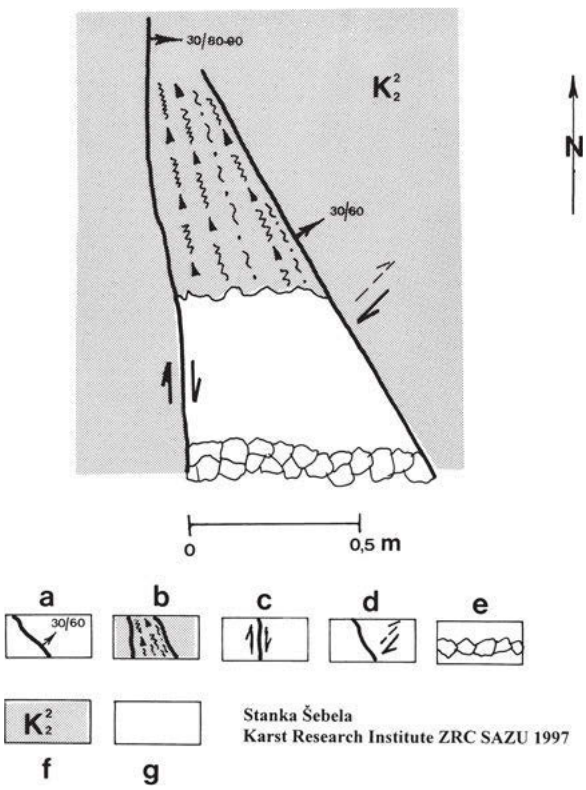
je prišlo do horizontalnih premikov in sicer do desnih zmikov. Ob južni prelomni ploskvi 30/85 pa opazimo vertikalni premik. Tektonske drse kažejo, da se je severni blok spustil, južni pa dvignil. Pri tem je potrebno poudariti, da so bili omenjeni premiki aktivni v različnih obdobjih iste tektonske faze.

Zanimivo je, da se v Lepih jamah ob opisani prelomni coni niso oblikovali večji jamski prostori tako kot npr. na Veliki gori. Menim, da je glavni vzrok v ožji notranji prelomni coni ter v manjši velikosti vertikalnega premika ob prelomu v Lepih jamah kot na Veliki gori.

V nadaljevanju Lepih jam proti severovzhodu je najpomembnejša prečno Dinarska prelomna cona 140-160/70-90 (priloga 1, prečni profil 57-57*, 58-58* in 59-59*), ob kateri se je oblikoval jamski rov. Porušene cone s smerjo vpada 50^0 potekajo prečno na smer rova.

Podorna dvorana pred krajšim umetnim tunelom do Ruskega rova je nastala v blago sinklinalno upognjenih plasteh. Zaradi manjšega (nekaj cm) horizontalnega premika ob zdrobljeni coni s smerjo vpada 55^0 (priloga 1, prečni profil 60-60*) so se tankoplastnati apnenci z roženci sinklinalno upognili. Podorni bloki, ki so zaprli nadaljevanje rova proti severu, so se luščili po plastnatosti.

V Ruskem rovu se je v temenu antiklinale oblikovala podorna dvorana (priloga 1, prečni profil 61-61*). Podorni material se je s stropa krušil po lezikah, ki so poudarjene z medplastnimi zdrsi. Severovzhodni del dvorane poteka po zdrobljeni coni 50^0, ki je vzporedna



56*), and along crushed and broken zones.

A small side passage in the Lepe jame N side was formed in the same fault zone which we met at Velika gora. The fault zones 30/60 and 30/85 (Figure 31) which bound the inner fault zone are particularly clearly expressed. The passage width is from 0.5 to 1 m. Limestone is fractured to the tectonic breccia and clay level. Along the N fault plane with dip elements 30/60 there appeared horizontal movements, that is to the right strike-slips. Along the S fault plane 30/85 we notice a vertical movement. Tectonic movements show that the N block sank, and the S one rose. It is necessary to emphasise here that the above mentioned movements were active in different periods of the same tectonic phase.

It is interesting that along the described fault zone in Lepe jame there were no really large cave rooms formed as for instance at Velika gora. I think that the main reason is in the narrower inner fault zone, and in smaller size of the vertical movement along the fault in Lepe jame than at Velika gora.

Further in Lepe jame towards the NE the most important is the cross-Dinaric fault zone 140-160/70-90 (Annex 1, cross-section 57-57*, 58-58* and 59-59*), along which a cave passage was formed. Broken zones with the dip and strike 50^0 go transversally to the passage direction.

The collapse chamber in front of the short artificial tunnel to Ruski rov was formed in gently syncline flexible bedding planes. Due to a smaller (some cm) horizontal movement along the crushed zone with the dip and strike 55^0 (Annex 1, cross-section 60-60*) the thin-bedding limestone with cherts were synclinally bent. The collapse blocks which closed further passage towards the N were scaled off from the bedding.

In Ruski rov a collapse chamber was formed in the anticline crest (Annex 1, cross-section 61-61*). The collapse material was crumbled from the ceiling along bedding planes which were emphasised by interbedded movements. The NE part of the chamber goes along the crushed zone 50^0 which is parallel to the anticline axis. In SW part of the chamber there are broken to fissured zones $70\text{-}80^0$. Anticline crest in that part of the cave is not broken with tectonic zones parallel to anticline axis. There are gently flexible bedding planes where the limestone collapse blocks were scaled off from the ceiling

Slika 31. Skica tektonskih razmer v Lepih jamah. **a** prelomna ploskev z geološkimi elementi, **b** zdrobljena cona s tektonsko brečo in glino, **c** vertikalni premik, **d** horizontalni premik, **e** podorni bloki, **f** apnenec, **g** jamski prostor.

Figure 31. Lepe jame tectonic conditions sketch. **a** fault plane with geological elements, **b** crushed zone with tectonic breccia and clay, **c** vertical movement, **d** horizontal movement, **e** collapse blocks, **f** limestone, **g** cave space.

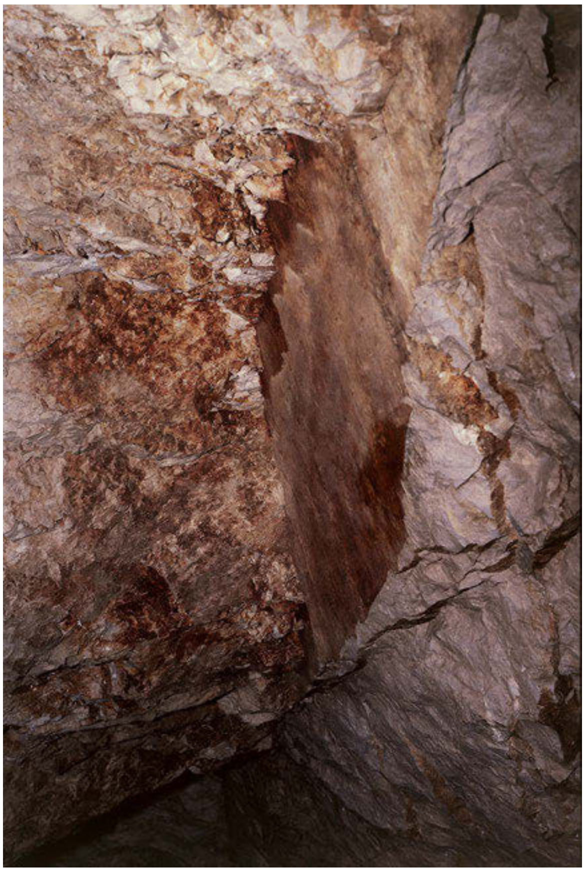
osi antiklinale. V jugozahodnem delu podorne dvorane sledimo porušeni do razpoklinski coni 70-80^0. Teme antiklinale v tem delu jame ni pretrto s tektonskimi conami vzporednimi osi antiklinale. Gre za blago vpognjene plasti, kjer so se podorni bloki apnenca luščili s stropa le zaradi medplastnih zmikov. Presek stropa dvorane (priloga 1, prečni profil 61-61*) je v temenu antiklinale oblikovan v obliki blage elipse.

Do vznožja Velike gore poteka Ruski rov prečno na prelomno con Dinarske smeri, ki je oblikovala Veliko goro. Prelomna cona je v Ruskem rovu bistveno manj izrazita kot na Veliki gori, saj je notranja prelomna cona široka le 0,5 m.

Severno od Koncertne dvorane prevladujejo porušene cone 60-70^0. Glede na močno, ponekod že kaotično pretrt apnenec predstavlja ta del jame vmesno tektonsko pretrto področje med prelomno cono št. 5 in prelomno cono na severnem robu Velike gore.

Severni del Koncertne dvorane se je oblikoval v Dinarsko usmerjeni zdrobljeni coni št. 5. Nastala je podorna dvorana, podorni bloki pa so se krušili tudi po lezikah poudarjenih z medplastnimi zdrsi. Zdrobljena cona št. 5 se nadaljuje tudi v predel Podzemeljske Pivke imenovan Martelov podor.

Vzhodno od Koncertne dvorane je manjši stranski rov razvit v prelomni coni št. 5. Le-ta se v tem delu močno zoži, tako da je širina notranje prelomne cone le nekaj cm (slika 32). Prelomna cona vpada proti severovzhodu za 30-40^0. Na močno zdrsani prelomni ploskvi



just because of the interbedded slides. The chamber ceiling cross-section (Annex 1, cross-section 61-61*) is formed as a gentle ellipse in the anticline crest.

To the foot of Velika gora, Ruski rov goes transversally to the Dinaric direction fault zone which formed Velika gora.The fault zone in Riski rov is in the main less expressive than at Velika gora, as the fault zone is only 0.5 m wide.

To the N of Koncertna dvorana broken zones 60-70^0 prevail. With a strong, already chaotically fractured limestone in places, this part of the cave represents an intermediate tectonically fractured area between the fault zone No. 5 and the fault zone on the Velika gora N side.

The Koncertna dvorana N part was formed in the Dinaric oriented crushed zone No. 5. The collapse chamber appeared, and the collapse blocks were also crumbled along bedding planes emphasised by interbedded movements. Crushed zone No. 5 continues also into the Podzemeljska Pivka region called Martelov podor.

In the E of Koncertna dvorana there is a small lateral passage developed in fault zone No. 5. It considerably narrows in this part, thus the inner fault zone width is only a few centimetres (Figure 32). The fault zone dips towards the N-E for 30-40^o. On the highly slipped fault plane there are abrasions which indicate vertical and horizontal movements. The last tectonic activity is represented by the vertical movement, where the SW block sank, and the NE one rose.

To the S of fault zone No. 5, Koncertna dvorana is developed in the crushed to broken zone with the dip and strike 110^0 in over least a 30 m width. The crossing from the bigger Koncertna dvorana to the smaller Zgornji Tartarus is formed along the bedding plane emphasised by the interbedded movement 210/60.

In the N part of Male jame fault zone No. 9 has a general E-W direction. It continues towards E into the cave tract in front of the entrance to Pisani rov. Up to the Ozki rov branch, Male jame passages are developed in the broken zone with the dip and strike 100^0 (Annex 1, cross-section 79-79*). To the E of Ozki rov the Male jame passage is traversed by broken and crushed zones.

Zgornji Tartarus goes transversally to the broken zones direction, but parallel to the bedding plane ridging, and congruently with the fault zone No. 9. In the W side, the collapse obstructed the passage to Otoška jama. Also Martel (1894) and later Gospodarič (1965, 1976) connected this disconnection

Slika 32. Prelomna ploskev 30/60 v stranskem rovčku pri železnici (foto J. Hajna).

Figure 32. Fault zone 30/60 in the small lateral passage near the railway (photo J. Hajna).

so raze, ki kažejo na vertikalne in horizontalne premike. Zadnjo tektonsko aktivnost predstavlja vertikalni premik, kjer se je jugozahodni blok spustil, severovzhodni pa dvignil.

Južno od prelomne cone št. 5 je Koncertna dvorana razvita v zdrobljeni do porušeni coni s smerjo vpada 110^0 v širini najmanj 30 m. Prehod iz večje Koncertne dvorane v manjši Zgornji Tartarus je oblikovan po leziki poudarjeni z medplastnim zdrsom 210/60.

V severnem delu Malih jam ima prelomna cona št. 9 splošno smer vzhod-zahod. Proti vzhodu se nadaljuje v predel jame pred vhodom v Pisani rov. Do odcepa za Ozki rov so Male jame razvite v porušeni coni s smerjo vpada 100^0 (priloga 1, prečni profil 79-79*). Vzhodno od Ozkega rova pa rov Malih jam prečkajo porušene in zdrobljene cone.

Zgornji Tartarus poteka prečno na smer porušenih con, vendar vzporedno s slemenitvijo plasti in skladno s prelomno cono št. 9. Na zahodni strani je podor prekinil nadaljevanje rova v Otoško jamo. Tudi Martel (1894) in kasneje Gospodarič (1965, 1976) sta prekinitev nekoč enotnega jamskega rova povezala z oblikovanjem udornice Stare apnenice na površju (poglavje 8.5.2.). Sprva je moral biti rov še nekaj časa prehoden, morda tudi na površje, kasneje pa se je zaradi kopičenja jamskih sedimentov ter grušča zapolnil, da ni bilo več zveze z Otoško jamo. Gospodarič (1965) meni, da je bila Stara apnenica prvotno brezno, in da je klima pospešila hitrejši mehanični razpad kamnin na površju.

Spodnji Tartarus je vezni rov med danes neak-

of once a unified cave passage with the formation of the Stara apnenica collapse doline on the surface (Chapter 8.5.2.). At first the passage must have been transitional for some time, perhaps also to the surface, but due to heaping up of cave sediments and gravel it was later filled up, thus there was no connection with Otoška jama. Gospodarič (1965) believes that Stara apnenica was a primary shaft, and that the climate accelerated faster mechanical dilapidation of rock on the surface.

Spodnji Tartarus is a linking passage among the now inactive and active passages of the Postojnska jama cave system. In the N passage tract the cross-Dinaric direction broken and crushed zones prevail. Further towards the S the cave passage traverses the Dinaric fault zones, and goes along the bedding planes and interbedded movements dip.

The Podzemeljska Pivka passage lies at a lower height above sea level than the now inactive main passage of the Postojnska jama cave system. But on the whole they both run parallel to the bedding plane direction.

In the S part of Podzemeljska Pivka (Figure 33) it is possible to follow the Dinaric direction broken to crushed zone (Annex 1, cross-section 94-94*)

Slika 33. Podzemeljska Pivka in medplastni zdrs (foto A. Mihevc).
Figure 33. Podzemeljska Pivka and interbedded movement (photo A. Mihevc).

tivnimi in aktivnimi rovi sistema Postojnskih jam. V severnem delu rova prevladujejo porušene do zdrobljene cone prečno Dinarske smeri. V nadaljevanju proti jugu jamski rov prečka Dinarske prelomne cone in poteka po vpadu plasti in medplastnih zdrsih.

Rov Podzemeljske Pivke leži v nižji n.m.v. kot danes neaktivni glavni rov sistema Postojnskih jam. V celoti pa oba potekata vzporedno s smerjo plasti.

V južnem delu Podzemeljske Pivke (slika 33) je moč slediti porušeni do zdrobljeni coni Dinarske smeri (priloga 1, prečni profil 94-94*), ki se bolj ali manj opazno vleče proti severozahodu vse do odcepa za Spodnji Tartarus. Nadaljuje se v močni prelomni coni 230/70, ki je označena s št. 4. V kombinaciji s plastnatostjo ima rov v tem delu jame lečasto obliko (priloga 1, prečni profil 89-89*). Izrazita cona se nadaljuje proti severozahodu in seka Otoško jamo, kjer ima geološke elemente 220/80.

Podzemeljska Pivka od Otoške do Magdalene jame poteka v generalno prečno Dinarski smeri v jamskem rovu pa so najbolj očitno vidne Dinarsko usmerjene prelomne cone in plastnatost.

Najstarejše so deformacije narivanja in gubanja. Teme Postojnske antiklinale sledimo od Martelove dvorane čez Perkov rov in Partizanski rov. Os antiklinale v jamskih rovih najlažje določimo glede na položaj njene osi na površju nad jamskimi rovi, kjer je teme Postojnske antiklinale najbolj očitno (poglavje 8.3.). V rovih sistema Postojnskih jam najdemo več antiklinalno in sinklinalno vpognjenih plasti, ki so v regionalnem smislu del Postojnske antiklinale. Smer Postojnske antiklinale je 110^0 proti vzhodu, smer antiklinale čez Ruski rov in Čarobni vrt je $135\text{-}140^0$ proti vzhodu (priloga 1). Slednjo lahko povežemo z antiklinalo v Skalnem rovu Magdalene jame, ki jo Postojnska antiklinala seka.

Poleg tega opazujemo v Martelovi dvorani tudi plasti apnenca blago sinklinalno in antiklinalno vpognjene, in sicer v prečno Dinarski smeri. Te gube dokazujejo, da so poleg glavnih pritiskov (SV-JZ), ki so oblikovali Postojnsko antiklinalo, obstajali tudi pritiski v smeri skoraj S-J in SZ-JV.

which is more or less clearly traced towards the NW, all the way to the Spodnji Tartarus branch. It continues in the strong fault zone 230/70 marked by No.4. In combination with bedding the passage in this part of the cave has a lenticular form (Annex 1, cross-section 89-89*). An expressive zone continues towards NW and crosses Otoška jama, where it has geological elements 220/80.

Podzemeljska Pivka runs from Otoška jama to Magdalena jama in the general cross- Dinaric direction, and in the cave passage the Dinaric direction fault zones and bedding are most clearly visible.

Overthrusting and folding deformations are the oldest. We follow the Postojna anticline crest from Martelova dvorana over to Perkov rov and Partizanski rov. The anticline axis in the cave passages can most easily be determined from the axis position on the surface above the cave passages, where the Postojna anticline crest is the most evident (Chapter 8.3.). In the cave passages we find more anticline and syncline flexible bedding planes which are a part of the Postojna anticline in the regional sense of the word. The Postojna anticline direction is 110^o towards the E, and the anticline direction over Ruski rov and Čarobni vrt is $135\text{-}140^o$ towards the E (Annex 1). The latter may be connected with the anticline in Skalni rov of Magdalena jama which is crossed by the Postojna anticline.

Besides, in Martelova dvorana we also observe

Slika 34. Pivka jama, podorna dvorana Veliki vdor (foto J. Hajna).
Figure 34. Pivka jama, Veliki vdor collapse chamber (photo J. Hajna).

Črna in Pivka jama sta razviti že v severovzhodnem krilu Postojnske antiklinale. Iz vhodne udornice v Črno jamo pridemo v podorno dvorano iz katere so dostopni Matevžev, Vilharjev rov in stranski rovi v severnem delu. Glavne tektonske cone potekajo v Dinarski in prečno Dinarski smeri. Podorni bloki pa so se s stropa luščili po plastnatosti.

Oba pritočna sifona Pivke jame sta oblikovana v tektonskih conah smeri 135/60 in 135/70 ob katerih opazujemo horizontalne premike. V rovu pred odtočnim sifonom Pivke jame pa je močneje izražena prelomna cona 80-90^0.

Podorna dvorana Pivke jame Veliki vdor (slika 34) se je oblikovala v tektonskih conah smeri 70^0.

Jamska vhoda v Pivko in Črno jamo se, glede na podatke površinskega geološkega kartiranja, nahajata v območju 400-500 m prekrivanja dveh desnozmičnih Dinarsko usmerjenih prelomov (Čar & Šebela, 1997). Če se osredotočimo le na ožje območje vhodnega brezna Pivka jame (slika 35), se je le-to oblikovalo v nateznih razpoklinskih conah smeri skoraj sever-jug. Ob normalnih prelomih s smerjo vpada 120/75 je nastal klinasti jarek (Čar & Šebela, 1997).

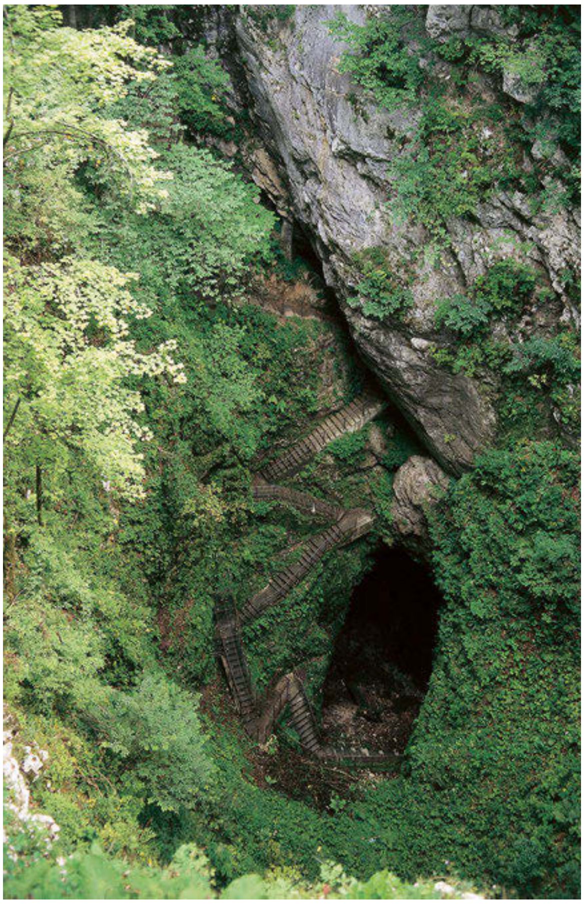
syncline and anticline gently flexible limestone bedding planes, namely in the cross-Dinaric direction. These folds prove that beside the main pressures (NE-SW) which formed the Postojna anticline there existed also pressures in the direction almost NS and NW-SE.

Črna jama and Pivka jama are already developed in the NE flank of the Postojna anticline. From the E collapse doline to Črna jama we come into the collapse chamber where Matevžev rov, Vilharjev rov and lateral passages in the N part are accesible. The collapse blocks were scaled off from the bedding ceiling.

Both Pivka jama upstream sumps are formed in tectonic zones of strikes 135/60 and 135/70, along which horizontal movements can be seen. In the passage in front of the Pivka jama downstream sump the fault zone 80-90^0 is more strongly expressed.

The Pivka jama collapse chamber Veliki vdor (Figure 34) was formed in tectonic zones of the strike 70^0.

According to the surface geological mapping data the Pivka jama and Črna jama cave entrances are located in the two right strike-slip Dinaric direction faults covering 400-500 m wide area (Čar & Šebela, 1997). If we concentrate only to the narrow Pivka jama entrance shaft area (Figure 35), it was shaped in tension fissured zones of almost N-S direction. With the normal faults with the dip and strike 120/75 there appeared a wedge-shaped depression (Čar & Šebela, 1997).



Slika 35. Vhodno brezno v Pivka jamo (foto S. Šebela).
Figure 35. Entrance shaft to Pivka jama (photo S. Šebela).

7.3. Geološke značilnosti jamskih profilov

Na primeru sistema Postojnskih jam sem po geoloških kriterijih obdelala 96 prečnih profilov. Uporabila sem italijanske prečne profile narejene v letih 1933-34 (skupaj 74 prečnih profilov) in novo izmerjene prečne profile (skupaj 22), katerih meritve so bile opravljene leta 1994 (IZRK ZRC SAZU). Na prilog 1 so prikazani prečni profili v še enkrat večjem merilu kot tloris jamskih rovov. Prečni profili niso razporejeni v enakomernih razdaljah, največ jih je v predelu rovov Postojnske jame.

Oblike jamskih prečnih profilov kažejo oblikovanje po geoloških strukturnih parametrih, in sicer tektonsko pretrtih conah in plastnatosti, pri čemer so še posebno očitne lezike poudarjene z medplastnimi zdrsi. Podrobno tektonsko-litološko kartiranje namreč kaže, da se je velik delež jamskih rovov oblikoval prav po slednjih, zato sem njihovo vlogo še posebno izpostavila.

Na jamskih načrtih prikazujejo prečni profili le morfološke značilnosti rova, medtem ko so geološke značilnosti prikazane le redko. S podrobnim opisom odvisnosti oblike prečnega profila od geološke zgradbe sem poskušala uvesti geološki pristop do vzporejanja posameznih odsekov jamskih rovov glede na enak način oblikovanja. Pri tem sem upoštevala današnje stanje, ki predstavlja bolj ali manj ohranjene nekdanje - inicialne strukture. Povdariti želim, da gre za geološke zasnove oblikovanja, ki so določljive iz današnje oblike prečnih profilov.

Začetni del Rova podpisov (prečni profil 3-3*, slika 6), Biospeleološke postaje (prečni profil 8-8*) in odsek rova (prečni profil 6-6*) med dvorano Veliki dom in Biospeleološko postajo so oblikovani po lezikah poudarjenih z medplastnimi zdrsi. Dvorana Veliki dom (prečni profil 5-5*) ima podorni značaj, ki je zaradi danes še aktivnega vodnega toka precej zabrisan. Prečni profil 9-9* je oblikovan v prečno Dinarski prelomni coni z delno kombinacijo plastnatosti in predstavlja enega manj poškodovanih prvotnih rovov v obliki pokončne leče.

V južnem delu Podzemeljske Pivke sta predvsem prečna profila 96-96* in 95-95* oblikovana po plastnatosti ter po tektonsko pretrtih conah. V obeh primerih gre za še aktivno delovanje vodnega toka. Prečni profil 94-94* ima v srednjem delu nekoliko svojsko obliko, ki kaže na uravnavo z vodnim tokom in sedimenti.

V predelu jame, kjer so prečni profili od 10-10* do 15-15*, gradi jamske stene zelo debelo plastnat apnenec. Prečni profili so podorno oblikovani, pri čemer se je podorni material luščil iz tektonsko pretrtih con in deloma plastnatosti. Kongresna dvorana (prečna profila 14-14* - vzhodni rov in 15-15*) je oblikovana v močni prelomni coni 100/70-80.

V primeru prečnega profila 20-20* govorimo o kombinaciji oblikovanja rova v tektonsko pretrtih conah

7.3. Cave Cross-Section Geological Characteristics

As regards geological criteria I processed 96 cross-sections of the Postojnska jama Cave System. I applied Italian cross-sections made in the years 1933-34 (all together 74 cross-sections), and newly measured cross-sections (all together 22) where the measurements were made in 1994 (IZRK ZRC SAZU). In Annex 1 the cross-sections are presented in a scale twice that of ground plan. Cross-sections are not spread equally throught the system, the majority of them being in the Postjnska jama passages section.

Cave cross-section forms show the formation in relation to geological structural parameters, that is to tectonically fractured zones and bedding, whereby the particularly evident bedding planes are emphasised by interbedded movements. Thus a detailed tectonic-lithological mapping shows that many of the cave passages have been formed according to the bedding, therefore, I have particularly exposed their role.

In the cave maps, the cross-sections show only the morphological characteristics of passages, while geological characteristics are rarely presented. By a detailed description of a cross-section form's dependence on a geological structure I have attempted to introduce a geological approach to individual cave passages sections with the same mode of formation. In so doing I have paid regard to the present-day state which represents more or less the preserved former (initial) structure. I wish to stress geological schemes of formation which are definable from the point of the present-day cross-sections form.

The Rov podpisov (cross-section 3-3*, Figure 6) and Biospeleološka postaja (cross-section 8-8*) initial part, and the passage section (cross-section 6-6*) between the Veliki dom chamber and Biospeleološka postaja are formed along bedding planes emphasised by interbedded movements. The Veliki dom chamber (cross-section 5-5*) has a collapse characteristic which is quite blurred due to a still active watercourse. The cross-section 9-9* is formed in the cross-Dinaric fault zone with a partial bedding combination, and it represents one of less damaged primary passages in the form of an upright lens.

In the S part of Podzemeljska Pivka there are above all the cross-sections 96-96* and 95-95* influenced by bedding and tectonically fractured zones. In both cases the watercourse is still active. The cross-section 94-94* has in its central part a ratherpeculiar form which shows its adjustment to the watercourse and to sediments.

In the cave section where there are cross-sections 10-10* to 15-15* the cave walls are made of a very thick-bedded limestone. The cross-sections are collapse formed, wherein the collapse material was scaled off in plastnatosti. Prečni profili 22-22*, 24-24* in 27-27* so jasno oblikovani v lezikah.

Na obliko prečnih profilov 28-28* in 32-32* je močno vplivala plastnatost. V primeru prečnega profila 32-32*, poteka rov vzporedno s slemenitvijo plasti in medplastnimi zdrsi, medtem ko poteka v primeru prečnih profilov 30-30* in 31-31* prečno na slemenitev plasti.

Iz Pisanega rova je predstavljenih 10 prečnih profilov. Nekateri kot 37-37*, 38-38* in 43-43* so oblikovani podorno po plastnatosti in tektonsko pretrtih conah, drugi, kot 35-35*, 36-36*, 39-39* in 42-42*, predstavljajo nizke rove, ki kažejo na zapolnitev in preoblikovanje s sedimenti. V takih primerih ni mogoče določiti vodilnih geoloških strukturnih elementov po katerih so se oblikovali prečni profili. Prečni profil 41-41* je oblikovan v notranji prelomni coni prečno Dinarske smeri.

Predel sistema Postojnskih jam od odcepa Pisanega rova do vznožja Velike gore zajema 6 prečnih profilov. Izmed njih so prečni profili 46-46*, 47-47*, 48-48*, 49-49* in 50-50* oblikovani v plastnatosti in le deloma v porušenih in zdrobljenih conah.

Prečni profil 51-51*, ki poteka od Ruskega mostu čez Veliko goro prikazuje največjo podorno dvorano v sistemu Postojnskih jam nastalo po tektonsko pretrtih conah, plastnatosti in medplastnih zdrsih. Severovzhodni del dvorane se je razvil v močni Dinarsko usmerjeni prelomni coni. Posamezne zdrobljene in porušene cone, ki povzročajo lokalno oblikovanje dvorane, uvrščamo v zunanjo prelomno cono.

Prečni profili 65-65*,63-63*,62-62*,53-53* ter deloma 64-64* in 54-54* so jasno oblikovani v plastnatosti, pri čemer je za profile 65-65*,63-63* in 62-62* značilen tudi podor po plastnatosti. Prečni profil 55-55* kaže oblike rova, ki sledi plastnatosti in prelomni coni. Profil 56-56* pa je na vzhodni strani rova zanimiv predvsem zaradi podora po lezikah, ki so poudarjene z medplastnimi zdrsi.

Profili 57-57*, 60-60* in 61-61* so oblikovani po plastnatosti, pri čemer je 57-57* tudi v kombinaciji s prelomno cono in podorom po plastnatosti, profil 61-61* pa zajema teme antiklinale.

Male jame zajemajo 6 prečnih profilov. Prečni profil 80-80* je oblikovan s podorom po plastnatosti, prečni profil 79-79* pa je nastal v porušeni coni. V Ozkem rovu se nahajajo prečni profili 85-85*, 86-86* in 87-87*. Po obliki so značilni za freatični rov, ki je nastal v tektonsko pretrtih conah in plastnatosti.

V Zgornjem Tartarusu sta profila 76-76* in 77-77* razvita v plastnatosti in tektonskih conah. Profila 71-71* in 78-78* kažeta delno oblikovanje po plastnatosti, predvsem pa sledove zapolnitve rova s sedimenti. Profil 72-72* v Spodnjem Tartarusu je odvisen od močne prelomne cone. Prečna profila 73-73* in 74-74* sta zelo neznačilnih oblik, vendar oblikovana po plastnatosti in tektonskih conah. V tem delu jame

from tectonically fractured zones, and partially from bedding. Kongresna dvorana (cross-sections 14-14* - E passage and 15-15*) is formed in the strong fault zone 100/70-80.

In the case of cross-section 20-20* we talk about a passage formation combination in tectonically fractured zones and bedding. The cross-sections 22-22*, 24-24* and 27-27* are clearly formed in bedding planes.

Bedding has strongly influenced the 28-28* and 32-32* cross-sections form. In the case of cross-section 32-32* the passage runs parallel to the bedding plane and interbedded movements ridging, while in cross-sections 30-30* and 31-31* it runs transverse to the bedding plane ridging.

Ten cross-sections from Pisani rov are presented. Some of them, like 37-37*, 38-38* and 43-43*, are collapses formed as to bedding and tectonically fractured zones; others, like 35-35*, 36-36*, 39-39* and 42-42*, represent low passages which indicate filling up and re-forming by sediments. In such cases it is not possible to determine the leading geological structural elements according to which cross-sections were formed. Cross-section 41-41* is formed in the cross-Dinaric direction inner fault zone.

The part of the cave from the Pisani rov branch to the Velika gora foothill includes 6 cross-sections. Among them the cross-sections 46-46*, 47-47*, 48-48*, 49-49* and 50-50* are formed in bedding, and only partially in broken and crushed zones.

The cross-section 51-51* which runs from Ruski most over Velika gora presents the greatest collapse chamber in the Postojnska jama cave system originated along tectonically fractured zones, bedding and interbedded movements. The NE part of the chamber was developed in the strong Dinaric direction fault zone. Individual crushed and broken zones which cause local chamber formation are classified into the outer fault zone.

Cross-sections 65-65*, 63-63*, 62-62*, 53-53* and partly 64-64* and 54-54* are clearly formed in bedding, while for cross-sections 65-65*, 63-63* and 62-62* the collapse along bedding is also characteristic. Cross-section 55-55* indicates the forms of a passage which follows bedding and a fault zone. The cross-section 56-56* in the E passage side is interesting mainly due to collapse along bedding planes which are emphasised by interbedded movements.

Cross-sections 57-57*, 60-60* and 61-61* are formed along bedding, wherein 57-57* is also in combination with the fault zone and collapse along bedding, and cross-section 61-61* includes the anticline crest.

Male jame include 6 cross-sections. Cross-section 80-80* is formed by collapse along bedding, and cross-section 79-79* was formed in the broken zone. In Ozki rov are cross-sections 85-85*, 86-86* and 87-87*. Their form is characteristic for a phreatic passage which was formed in tectonically fractured zones and bedding.

so rovi še vedno pod vplivom občasnih poplav podzemeljske Pivke.

Otoška jama je predstavljena s tremi prečnimi profili (priloga 1, prečni profili 68-68*, 69-69* in 70-70*). Plasti vpadajo 50^0 proti jugozahodu. Prečni profil 70-70* zajema podorno dvorano in aktivni rov Podzemeljske Pivke. Vodilne geološke strukture oblikovanja so bile lezike in tektonske cone. Lego zgornjega rova Otoške jame in spodnjega rova Podzemeljske Pivke prikazuje prečni profil 68-68*. V tem primeru sta oba prečna profila oblikovana po lezikah in medplastnih zdrsih.

V rovu Podzemeljske Pivke so oblike prečnih profilov 93-93*, 92-92* in 91-91* značilne za aktivni vodni rov, ki je deloma oblikovan po plastnatosti in deloma v tektonsko pretrtih conah. Tudi prečna profila 90-90* in predvsem 89-89* sta nastala v plastnatosti in zdrobljeni coni.

Vhod v Črno jamo (prečni profil 66-66*) se je odprl zaradi udornice v bližini rova ter odnašanja materiala z vodnim tokom.

Vhodno, krajše brezno Magdalene jame (profil 67-67*) se je oblikovalo v razpoklinski coni s smerjo vpada 110^0.

Na podlagi 96 prečnih profilov iz sistema Postojnskih jam, lahko podobno raziščemo tudi prečne profile iz drugih jam. Že iz morfološke oblike prečnega jamskega profila lahko, z določeno verjetnostjo, sklepamo na oblikovanje rova po geoloških strukturnih elementih.

In Zgornji Tartarus cross-sections 76-76* and 77-77* are developed in bedding and tectonic zones. Cross-sections 71-71* and 78-78* indicate a partial formation along bedding, but mainly traces of the passage filling up with sediments. Cross-section 72-72* in Spodnji Tartarus depends on a strong fault zone. Cross-sections 73-73* and 74-74* are of very uncharacteristic forms, but formed along bedding and tectonic zones. In this part of the cave the passages are still under influence of the occasional underground Pivka floods.

Otoška jama is represented by three cross-sections (Annex 1, cross-sections 68-68*, 69-69* and 70-70*). The bedding planes dip 50^o towards the SW. Cross-section 70-70* includes the collapse chamber and the Podzemeljska Pivka active passage. The leading geological formation structures were bedding planes and tectonic zones. The upper Otoška jama passage position and the lower Podzemeljska Pivka passage position are presented in the cross-section 68-68*. In this case both cross-sections are formed along bedding planes and interbedded movements.

In the Podzemeljska Pivka passage the forms of cross-sections 93-93*, 92-92* and 91-91* are characteristic of an active water passage which is partially formed along bedding, and partially in tectonically fractured zones. Also cross-sections 90-90* and above all 89-89* were formed in bedding and in the crushed zone.

The entrance to Črna jama (cross-section 66-66*) opened due to the collapse doline near the passage, and to the watercourse sweeping away the material.

The E Magdalena jama shorter shaft (cross-section 67-67*) was formed in the fissured zone with the dip strike 110^0.

On the basis of the 96 cross-sections in Postojnska jama cave system we can similarly study cross-sections in other caves as well. Already from the cross-section morphological form we may, with reasonable probability, explain the passage formation from the geological structural elements.

7.4. Interpretacija oblikovanja nekaterih izbranih prečnih jamskih profilov

Za preučevanje današnjih speleomorfoloških oblik prečnih profilov sem izmed 96 izbrala 17 prečnih profilov (priloga 3), ki so še posebno značilnih oblik. To so prečni profili 3-3*, 4-4*, 8-8*, 9-9*, 12-12*, 17-17*, 19-19*, 20-20*, 21-21*, 22-22*, 39-39*, 47-47*, 51-51*, 74-74*, 88-88*, 89-89* in 90-90*. Pri tem sem se osredotočila na današnjo morfološko obliko prečnega profila in ovrednotila primarno in sekundarno stanje. Primarno stanje predstavljajo še danes ohranjene freatične oblike rova, sekundarno stanje pa podori ali z abrazijo mehanskih delcev zabrisano ali preoblikovano prvotno stanje. V prečnih jamskih profilih lahko danes

7.4. Some Selected Cave Cross-Section Interpretations

To study the present-day cave cross-section forms I have selected 17 out of 96 cross-sections (Annex 3) which are of specially characteristic forms. These are 3-3*, 4-4*, 8-8*, 9-9*, 12-12*, 17-17*, 19-19*, 20-20*, 21-21*, 22-22*, 39-39*, 47-47*, 51-51*, 74-74*, 88-88*, 89-89* and 90-90*. Thus I have focused on the present-day cross-section morphological form, and deduced its primary and secondary states. The primary state is presented today by the phreatic passage form where it is still preserved, and the secondary state by collapses, or a primary state blurred or re-formed by mechanical abrasion. Today we can observe partially opazujemo deloma spremenjene primarne oblike. Pogostejše je sekundarno oblikovanje, ki pa vendar kaže določeno skladnost s prvotnimi zasnovami.

Prečni profili 3-3*, 4-4* in 8-8* predstavljajo primarne oblike, pri čemer sta se 3-3* in 8-8* oblikovala v leziki poudarjeni z medplastnimi zdrsi, medtem ko se je prečni profil 4-4* oblikoval v porušeni coni. V primeru prečnega profila 8-8* ni mogoče govoriti samo o primarni obliki, saj je predvsem zahodni del oblikovan s pomočjo abrazije mehanskih delcev.

Obliko prečnega profila 12-12* nakazuje sekundarno preoblikovanje. Ves spodnji del profila sestavljajo podorni bloki, ki so se odlomili po plastnatosti in izsuli iz zdrobljenih in porušenih con. Na prvotno freatično obliko rova je moč slutiti v levem delu, kjer ni bilo močnejše abrazije s pomočjo mehanskih delcev.

V zgornjem delu prečnega profila 17-17* se da določiti primarno obliko. Današnje stanje profila predstavlja nekoliko razširjen primarni rov, ki je v spodnjem delu profila zabrisan z delovanjem abrazije mehanskih delcev.

Prečni profil 19-19* je v današnjem stanju močno preoblikovan, kar je posledica abrazije mehanskih delcev. Le v desnem delu profila so sledovi primarnega freatičnega rova, oblikovanega v porušeni coni. Oblika stropa kaže na paragenezo.

Primarno oblikovanje v prelomni coni in plastnatosti je opazno v zgornjem delu prečnega profila 20-20*. Spodnji del je oblikovan s pomočjo abrazije mehanskih delcev.

Prečni profil 21-21* kaže primarno in sekundarno oblikovanje. Zgornji del profila se je oblikoval v zdrobljenih in porušenih conah, spodnji del profila pa z abrazijo mehanskih delcev.

Primarno in sekundarno oblikovanje po plastnatosti se opazi v prečnem profilu 22-22*.

Oblika prečnega profila 39-39* kaže sekundarno preoblikovanje, in sicer z abrazijo mehanskih delcev v zgornjem delu in zaponitvijo s sedimenti v spodnjem delu. V prečnem profilu 47-47* je opaziti primarno in sekundarno stanje. V prelomni coni je verjetno prišlo do manjšega izsutja ter odlomov po plastnatosti. S ponovnim delovanjem vodnega toka se je staro podorno oblikovanje prečnega profila ublažilo.

Prečni profil 51-51* je močno sekundarno preoblikovan. Dno profila prekrivajo podorni bloki. Zgornji del se je razvil v odlomih po plastnatosti in medplastnih zdrsih ter v izsutju iz zdrobljenih con. Le v skrajnem zahodnem delu je primarni freatični rov, ki je delno spremenjen z abrazijo mehanskih delcev.

Prečni profili 74-74*, 88-88*, 89-89* in 90-90* imajo freatično obliko, ki je delno preoblikovana zaradi zapolnitve rova s sedimenti.

S 17 izbranimi prečnimi profili sem prikazala osnovne oblike, ki so značilne za sistem Postojnskih jam. Pri tem so prvotne oblike nekaterih prečnih profilov le delno spremenjene in kažejo primarno oblikovanje po

modified primary forms in the cave cross-sections. The secondary formation is more frequent, but it shows a certain congruity with primary schemes.

Cross-sections 3-3*, 4-4* and 8-8* represent primary forms, wherein 3-3* and 8-8* were formed in bedding plane emphasised by interbedded movements, while cross-section 4-4* was formed in the broken zone. In cross-section 8-8* case it is not possible to talk about the primary form, as the W part is mainly formed by means of mechanical abrasion.

Cross-section 12-12* form is characterised by the secondary re-forming. All the lower cross-section part consists of collapse blocks which were broken away along bedding, and spread out from crushed and broken zones. The primary phreatic passage form might be detected in the left part where there was no stronger abrasion.

In the upper cross-section 17-17* part the primary form can be determined. The present cross-section state represents a slightly enlarged primary passage which is blurred by mechanical abrasion activity in the lower part.

As a consequence of mechanical abrasion cross-section 19-19* is strongly re-formed in today's state. Only in the right cross-section part there are traces of a primary phreatic passage formed in the broken zone. The ceiling configuration indicates paragenesis.

The primary formation in the fault zone and bedding is perceivable in the upper part of cross-section 20-20*. The lower part is formed by mechanical abrasion.

Cross-section 21-21* shows primary and secondary formation. The upper cross-section part was formed in crushed and broken zones, and the lower part by mechanical abrasion.

The primary and secondary formation according to bedding is noticed in the cross-section 22-22*.

The cross-section 39-39* form shows a secondary re-forming, i.e. by mechanical abrasion in the upper part, and by filling up with sediments in the lower part. In cross-section 47-47* one can see both the primary and secondary states. In the fault zone was probably induced a smaller spreeding out and breaking away along bedding. The old cross-section collapse formation was modified by repeated stream activity

Cross-section 51-51* is strongly secondarily re-formed. The bottom is covered by collapse blocks. The upper part was developed as collapse resulting from bedding, interbedded movements and spill out from crushed zones. Only in the extreme W part there is a primary phreatic passage which is partially modified by mechanical abrasion.

Cross-sections 74-74*, 88-88*, 89-89* and 90-90* have the phreatic form which is partially re-formed due to the passage filling up with sediments.

By 17 selected cross-sections I have presented basic forms which are characteristic for the Postojnska jama cave system. The primary forms of some of them tektonsko pretrtih conah ali lezikah, ki so mnogokrat poudarjene z medplastnimi zdrsi. Inicialne oblike rovov so večkrat zabrisane s podori ali preoblikovane zaradi zapolnitve s sedimenti.

cross-sections are only partially modified, and show primary formation along the tectonically fractured zones or bedding planes which are often emphasised by interbedded movements. The initial passage forms are often blurred by collapses, or re-formed owing to filling up with sediments.

7.5. Geološke značilnosti oblikovanja podornih dvoran

Največje prostore v sistemu Postojnskih jam predstavljajo podorne dvorane. Vse so oblikovane po geoloških strukturnih elementih.

Če primerjamo litološki stolpec (slika 2) v katerem so razviti rovi sistema Postojnskih jam s podornimi dvoranami, lahko zaključimo, da so največje podorne dvorane, kot npr. Velika gora, Veliki dom in Koncertna dvorana, razvite v debeloplastnatem apnencu, manjše pa v tanjše plastnatem apnencu.

Na primeru vseh podornih dvoran v sistemu Postojnskih jam opazujemo prisotnost močnih regionalno pomembnejših prelomnih con. Tektonska premikanja v teh prelomnih conah so povzročila odpadanje blokov tudi po plasteh. Odpadli bloki so se kopičili v podorni stožec. Istočasno je moral še vedno obstajati tudi stalni oziroma vsaj občasni vodni tok, ki je odnašal del podornega materiala, pri čemer je podorna dvorana rasla in se širila.

V slovenskih jamskih sistemih so podorne dvorane zelo pogoste. Martelova dvorana v Škocjanskih jamah je s prostornino 2.100.000 m^3 do sedaj največja znana podorna dvorana pri nas (Mihevc, 1995).

Največja podorna dvorana v sistemu Postojnskih jam je Velika gora (Šebela, 1995 b), katere prostornino ocenjujemo na 240.000 m^3. Pri tem je potrebno poudariti, da po dnu Martelove dvorane v Škocjanskih jamah še vedno teče aktivni vodni tok (reka Reka), medtem ko je Velika gora izven območja občasnih poplav reke Pivke. Ker ne moremo zagotovo oceniti debeline podornega stožca na Veliki gori, je prostornina podorne dvorane lahko še nekoliko večja od ocenjene.

Za podorne dvorane v jamskih rovih je značilno večanje praznega prostora pod površjem, s tem da s stropa ali s strani odpadajo večji ali manjši bloki kamnine. Pri tem je še posebno ugoden stalni ali občasni vodni tok, ki odnaša odpadni material. Vzrok za odpadanje podornih blokov je največkrat mehanska nestabilnost jamskega prostora, katere vzrok je v mehansko porušeni kamnini.

Davies (1951) je zagovarjal, da je obstojnost stropa oziroma celotnega podzemeljskega prostora odvisna tudi od debeline, lege in trdnosti skladov.

V fazah razvoja jame prihaja do rušenja zaradi tvorbe brezen v bližini starejših rovov, nenadnih poplav,

7.5. Geological Characteristics of Collapse Chamber Formation

Collapse chambers represent the greatest spaces in the Postojnska jama cave system. They are all formed as a result of geological structural elements.

If we compare the lithological column (Figure 2), wherein the Postojnska jame cave system passages with collapse chambers are developed, we may conclude that the greatest collapse chambers, e.g. Velika gora, Veliki dom and Koncertna dvorana, are developed in thick-bedded limestone, and smaller ones in thinner-bedded limestone.

By the example of all the collapse chambers in the Postojnska jama cave system we observe the presence of strong, regionally more important fault zones. Tectonic movements in these fault zones were caused by falling away of blocks, also along bedding planes. The fallen off blocks were being heaped up into a collapse cone. At the same time there should have still existed a permanent or at least periodical watercourse, which kept sweeping away a part of the collapse material, and thus the collapse chamber was becoming larger.

Collapse chambers are very frequent on Slovene cave systems. Martelova dvorana in Škocjanske jame is, with its volume of 2,100,000 m^3, the greatest known collapse chamber in Slovenia (Mihevc, 1995).

The greatest collapse chamber in the Postojnska jama system is Velika gora (Šebela, 1995 b) whose volume is estimated to be 240,000 m^3. It is necessary to stress that at the bottom of Martelova dvorana in Škocjanske jame there is still an active watercourse (the Reka river), while Velika gora is outside the Pivka river periodical floods region. Since we cannot reliably estimate the collapse cone thickness at Velika gora, the total collapse chamber volume might even be a little greater than the estimated one.

Enlargement of an empty space below the surface is characteristic for collapse chambers by greater or smaller blocks of rock falling off from the ceiling or sides. A permanent or periodic watercourse which sweeps away the waste material is particularly convenient here. The reason that the collapse blocks fall off is most frequently the mechanical instability of the cahmber, and the immediate cause is the mechanically fractured rock.

Davies (1951) argued that the ceiling or the exsveže prenikajoče vode, rasti mineralov v razpokah, zmrzali (White & White, 1969) ter zniževanja površja.

Glavni razlog vseh podorov je mehanični razpad znotraj plasti, med plastmi ali med razpokanimi bloki (Ford & Williams, 1989).

Jameson (1991) je proučeval podore v Friars Hole Cave System in drugih jamah v ZDA. Podori ne nastajajo samo zaradi rušenja ampak tudi zaradi rasti kristalov sadre in eksfoliacije. Procesi, ki privedejo do nastanka podorov, so najmanj trije:

- raztapljanje
- kemična rast in alteracija
- mehanska preobremenitev.

Po Gamsu (1965) je podor Velike gore preusmeril reko Pivko proti Otoški jami, nadaljnji podori pa so jo prisilili k izdelavi nižje, še sedaj aktivne vodne etaže.

Gospodarič (1968 b) je ločil dve razvojni in štiri razpadne faze sistema Postojnskih jam, ki jih uvršča v pleistocen. Ko vodni tokovi ne dosežejo več rova ter v njem nastaja siga in pride do podorov, govorimo o tretji razpadni fazi. Povezava jame s površjem in zapolnitev rova zaradi popolnega udora stropa sodita v zadnjo, četrto razpadno fazo.

Napetostno polje se v okolici jame neprestano spreminja, kar ima za posledico rušenje v različnih fazah razvoja kraškega sistema (Brenčič, 1993).

Največje podorne dvorane sistema Postojnskih jam so v danes neaktivnih rovih (Šebela, 1994 b). Pri podrobnem pregledu tektonskih razmer sistema Postojnskih jam in pri primerjavi z javljanji podornih dvoran opazimo nekatere zakonitosti. Vse podorne dvorane so v področjih tektonskih nestabilnosti, to je v ali med prelomnimi conami.

V podornih dvoranah, kjer so dokaj sveži odlomi, kar pomeni, da se vodni tok po zadnjem podoru ni več pojavil v teh dvoranah, večkrat najdemo prelomne ploskve s tektonskimi drsami. To kaže na območja tektonsko najintenzivnejših premikanj.

Ena izmed podornih dvoran (priloga 1, prečni profil 61-61*) je razvita v temenu antiklinale, kjer opazujemo medplastne zdrse, ki predstavljajo spremljajoče deformacije gubanja. V temenu antiklinale ni izrazitih prelomnih con. Bloki apnenca so se luščili s stropa zaradi nestabilnosti povzročene z aktivnostjo medplastnih zdrsov.

Pri preučevanju podorov v kraških jamah se postavi vprašanje v katero obdobje lahko postavimo oblikovanje podorov. Podorno preoblikovani rovi, in sicer še posebno taki, kjer na stenah ni sledov vodnega toka, kot npr. stenskih kotlic, faset, predstavljajo v današnjem stanju enega zadnjih aktivnosti večanja rovov seveda pred odlaganjem sige na podorne bloke. Določitev starosti stalagmitov na podornih blokih kaže le okvirno starost, saj ne more upoštevati obdobja od prvih procesov podiranja do obdobja rasti sige.

Na primeru podornih dvoran iz sistema Postojnskih jam lahko zanesljivo trdimo, da so oblikovane v

istence of the entire underground space also depends on the thickness, position and solidity of bedding planes.

In the cave development phases breaking occures owing to the formation of shafts in the vicinity of older passages, sudden floods, fresh percolation water, minerals growing in fissures, frost (White & White, 1969), and lowering of the surface.

The main reason for all the collapses is a mechanical breakdown inside a bedding plane, between bedding planes or between fissured blocks. (Ford & Williams, 1989).

Jameson (1991) studied collapses in the Friars Hole Cave System and other caves in the U.S.A. Collapses do not result just because of breaking, but also due to the growth of gypsum crystals and exfoliation. There are at least three processes which initiate the formation of collapses:

- solubility
- chemical growth and alteration
- mechanical overloading.

According to Gams (1965) the Velika gora collapse diverted the Pivka river towards Otoška jama, and further collapses forced it to create a lower, now still active water channel.

Gospodarič (1968 b) distinguished two developing and four breakdown phases of the Postojnska jama cave system, which he placed in the Pleistocene. When watercourses do not reach a passage any more, and so the flowstone is created and collapses occur, we talk about the third breakdown phase. A cave connection with the surface, and the passage filling up due to a complete ceiling collapse belong to the last, fourth breakdown phase.

In the cave vicinity the tension field is constantly changing, and it causes breaking in different Karst System developing phases. (Brenčič, 1993).

The greatest Postojnska jama system collapse chambers are in the now inactive passages (Šebela, 1994 b). By a detailed survey of the system tectonic conditions, and by a comparison with collapse chambers occurring, we notice some justification for this. All the collapse chambers are in the areas of tectonic instability, that is in or between fault zones.

In the collapse chambers where there are quite fresh fallen blocks, which means that the watercourse has not appeared any more in these chambers since the last collapse, we frequently find fault planes with tectonic movements. It indicates the tectonically most intensive movement areas.

One of the collapse chambers (Annex 1, cross-section 61-61*) is developed in the anticline crest where we observe interbedded movements which represent accompanying folding deformations. In the anticline crest there are no expressive fault zones. Limestone blocks were scaled off from the ceiling owing to the instability caused by interbedded movement activity.

By studying collapses in the karst caves a skladu z geološkimi strukturnimi elementi. Podorne dvorane so se najbolj intenzivno oblikovale v občasno zaliti coni, dokler se ni vodni tok povsem umaknil v druge dele jame. Z zadnjimi tektonskimi premikanji ob prelomnih conah ter z odpadanjem podornih blokov po lezikah, poudarjenih z medplastnimi zdrsi ter z zadostnim odnašanjem materiala, so se podorne dvorane večale do današnjih razsežnosti.

question is raised as to which period we may put the collapse formation in. Passages reshaped by collapse, especially those where there are no watercourse traces such as wall potholes and scallops, represent the result of the final passages enlargement activities, before the flowstone deposited on the collapse blocks. The age of stalagmites growing on the collapse blocks gives only an approximate age for the present passage form, as it is not possible to take account of the interval between the first collapse processes and the flowstone growth period.

From the example of the Postojnska jama cave system collapse chambers we may confidently assert that they are formed in accordance with geological structural elements. Collapse chambers were most intensively formed in a periodically watered zone, before the watercourse has completely removed into other cave sections. By the last tectonic movements along fault zones, and by the collapse blocks falling off along bedding planes emphasised by interbedded movements, and by sufficient material being swept away, the collapse chambers have been enlarged up to the it present state.

7.6. Statistična analiza pogostosti smeri tektonsko pretrtih con v sistemu Postojnskih jam

Z rozetami sem prikazala pogostost smeri tektonskih con v sistemu Postojnskih jam. Pri statistični obdelavi nisem ločevala različnih vrst con, kot npr. porušenih con od razpoklinskih ali zdrobljenih. Vse tektonske cone sem za statistično analizo združila v enotno cono. Najpogostejša smer tektonsko pretrtih con, merjenih v rovih sistema Postojnskih jam, je zastopana z 19,2 % (smer 330-345^0 pri razdelitvi intervalov na 15^0, slika 37), oziroma z 12,7 % (smer 320-330^0 pri razdelitvi intervalov na 10^0, slika 38). V smeri sever-jug oziroma SV-JZ prevladuje z 16,5 % smer 0-15^0 pri razdelitvi intervalov na 15^0 (slika 36) in z 9,2 % smer 10-20^0 pri razdelitvi intervalov na 10^0 (slika 37).

Največ rovov sistema Postojnskih jam je razvitih v Dinarski smeri, in sicer je s 16,3 % zastopana smer 315-330^0 pri razdelitvi intervalov na 15^0 (slika 38) in s 10,6% smer 310-320^0 pri razdelitvi intervalov na 10^0 (slika 39). V smeri sever-jug oziroma prečno Dinarski smeri je zastopanih 13,5 % rovov, ki predstavljajo smer 0-15^0 pri razdelitvi 15^0 (slika 38) oziroma 9 % rovov v smeri 20-30^0 pri razdelitvi intervalov na 10^0 (slika 39).

Primerjava rozet smeri tektonsko pretrtih con (slika 36 in slika 37) in smeri jamskih rovov sistema Postojnskih jam (slika 38 in slika 39) kaže po statistični obdelavi dobro primerljivost. Vrednost za glavni vektor je v primeru rovov $345{,}18^0$, v primeru tektonsko pretrtih con pa $344{,}12^0$. Interval zaupanja je v primeru tektonsko pretrtih con $8{,}82^0$, pri usmeritvi jamskih rovov pa $11{,}68^0$. Standardna deviacija pri meritvah smeri

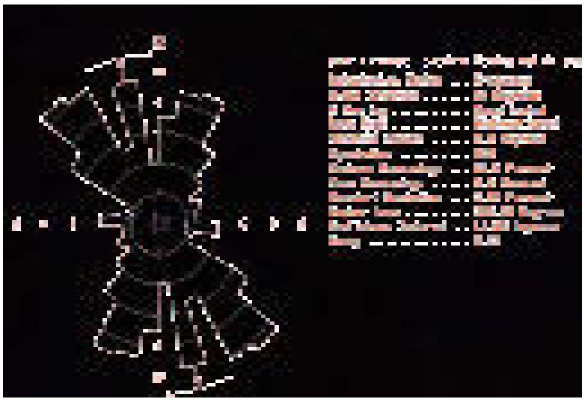
7.6. Statistical Analysis of the Posto-jn-ska jama Cave System Tectonically Fractured Zones Direction Prevalence

I demonstrated the Postojnska jama cave system tectonic zones direction prevalence by rose graphs. In the statistical processing I did not distinguish different zone types, as for instance broken zones from fissured or crushed zones. For the statistical analysis I united all the tectonic zones into one. The most frequent tectonically fractured zones direction measured in the Postojnska jama cave system passages is represented by 19.2% (330-345^0 strike with repartition of intervals by 15^0, Figure 37), or by 12.7% (320-330^0 strike with repartition of intervals by 10^0, Figure 38) respectively. In the N-S direction or NE-SW the 0-15^0 direction prevails by 16.5% with repartition of intervals by 15^0, Figure 36), and the 10-20^0 direction by 9.2% with repartition of intervals by 10^0, Figure 37).

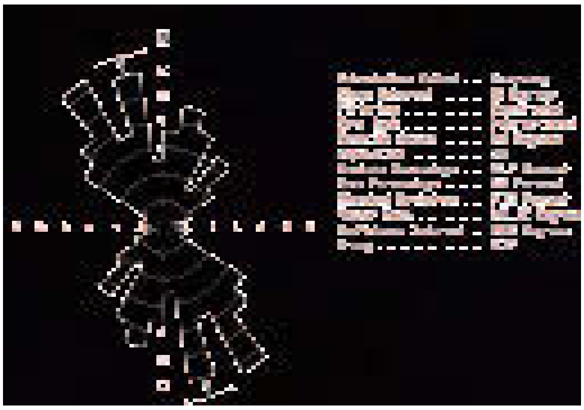
Most of the passages are developed in the Dinaric direction. 16.3% of passages represent the 315-330^0 direction with repartition of intervals by 15^0 (Figure 38), and 10.6% the 310-320^0 direction with repartition of intervals by 10^0 (Figure 39). In the N-S or the cross-Dinaric direction respectively, there are included 13.5% of passages which represent the 0-15^0 direction with repartition of intervals by 15^0 (Figure 38) and 9% of passages into the 20-30^0 direction with repartition of intervals by 10^0 (Figure 39).

The comparison of the tectonically fractured zones directions rose graphs (Figure 36 and Figure 37), and the Postojnska jama cave system passage directions (Figure 38 and Figure 39) indicates a good agreement by

Slika 36. Slemenitev tektonsko pretrtih con v sistemu Postojnskih jam (razdelitev intervalov na 15^0).
Figure 36. Tectonically fractured zones directions in the Postojnska jama cave system (partition of intervals by 15^0).

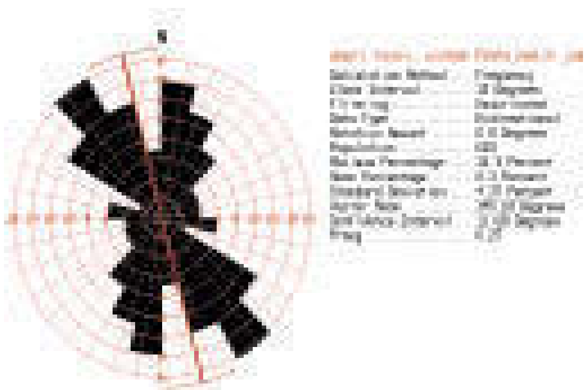


Slika 39. Smer rovov sistema Postojnskih jam (razdelitev intervalov na 10^0).
Figure 39. Passage directions of the Postojnska jama cave system (partition of intervals by 10^0).



Slika 37. Slemenitev tektonsko pretrtih con v sistemu Postojnskih jam (razdelitev intervalov na 10^0).
Figure 37. Tectonically fractured zones directions in the Postojnska jama cave system (partition of intervals by 10^0).

Slika 40. Slemenitev plasti v sistemu Postojnskih jam (razdelitev intervalov na 15^0).
Figure 40. Bedding planes direction in the Postojnska jama cave system (partition of intervals by 15^0).



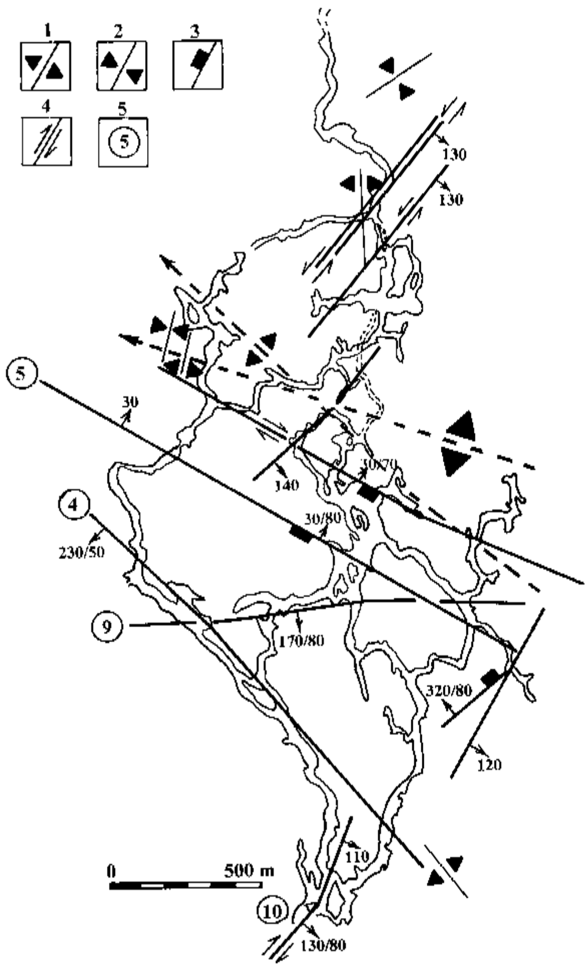
Slika 38. Smer rovov sistema Postojnskih jam (razdelitev intervalov na 15^0).
Figure 38. Passage directions of the Postojnska jama cave system (partition of intervals by 15^0).

Slika 41. Slemenitev plasti v sistemu Postojnskih jam (razdelitev intervalov na 10^0).
Figure 41. Bedding planes direction in the Postojnska jama cave system (partition of intervals by 10^0).

tektonsko pretrtih con je 3,73% (pri razdelitvi intervalov na 10^0, slika 37) in meritvah smeri rovov 2,97% (pri razdelitvi intervala na 10^0, slika 39).

Ker se je pri terenskem kartiranju jamskih rovov, kot pomembno vodilo pokazala plastnatost, sem prikazala tudi pogostost slemenitve plasti merjenih v rovih sistema Postojnskih jam (slika 40 in slika 41). Zajela sem 131 meritev, izmed katerih je statistično najbolj zastopana smer 315-330^0 (23,7% pri razdelitvi intervalov na 15^0, slika 40) oziroma smer 320-330^0 (23,7% pri razdelitvi intervalov na 10^0, slika 41).

Primerjava slemenitve plasti (slika 40 in slika 41) in poteka rovov v sistemu Postojnskih jam (slika 38 in slika 39), kaže nekoliko slabšo primerjavo kot skladnost tektonsko pretrtih con s smerjo rovov. Najpogostejša smer plasti se odlično pokriva z najpogostejšo smerjo rovov, ki je 315-330^0, pri razdelitvi intervalov na 15^0. Očitna razlika pa nastopi pri vlogi slemenitve plasti za rove, ki potekajo v smeri 10-30^0. Rovi sistema Postojnskih jam, razviti v prečno Dinarski smeri in smeri skoraj sever-jug, se glede na rezultate rozet ne ravnajo po plasteh, ki so v tej smeri zastopane z manj kot 5%. Čeprav gre po statistični analizi za značilnejšo navezanost rovov teh smeri na potek tektonsko pretrtih con, pa moramo upoštevati možnost, da so se rovi v prečno Dinarski smeri in smeri skoraj sever-jug lahko razvili



Slika 42. Generalizacija tektonskih razmer v sistemu Postojnskih jam. **1** antiklinala, **2** sinklinala, **3** prelom z vertikalnim premikom, **4** prelom s horizontalnim premikom, **5** oznaka prelomov.

Figure 42. Tectonic conditions generalisation in the Postojn-ska jama cave system. **1** anticline, **2** syncline, **3** fault with vertical movement, **4** fault with horizontal movement, **5** faults indication.

the statistical processing. In the case of the passages the main vector value is 345.18^0, in the case of tectonically fractured zones is 344.12^0. The confidence interval is in example of tectonically fractured zones 8.82^0, and for the cave passages direction 11.68^0. By measuring tectonically fractured zones the standard deviation is 3.73% (with repartition of intervals by 10ş, Figure 37), and by measuring the passages orientation 2.97% (with repartition of intervals by 10^0, Figure 39).

As by the caves passages terrain mapping the bedding appeared to be as an important guidance, I also presented the bedding planes frequency in the Postojnska jama cave system passages (Figure 40 and Figure 41). I included 131 measurements among which the 315-330^0 direction is statistically most strongly represented (23.7% with repartition of intervals by 15^0, Figure 40) or the 320-330^0 direction (23.7% with repartition of intervals by 10^0, Figure 41).

The bedding plane direction comparison (Figure 40 and Figure 41) with the passage direction in the Postojnska jama cave system (Figure 38 and Figure 39) shows a poorer agreement than that of the tectonically fractured zones with the passage directions. The most frequent bedding plane direction is perfectly covered by the most frequent passages direction which is 315-330^0 with repartition of intervals by 15^0. But an evident difference appears with the bedding plane direction role for passages which run in the 10-30^0 direction. As regards the rose graphs the Postojnska jama system passages, developed in the cross- Dinaric direction and of an almost N-S direction, do not follow the bedding planes which are represented in this direction by less than 5%. Though according to the statistical analysis there is a more characteristic passage attachment of these directions to the tectonically fractured zones, we have to pay regard to the possibility that the passages in the cross-Dinaric direction and the direction of nearly N-S could also develop along the dip bedding plane which is not visible from the rose graphs data (Figure 40 and tudi po vpadni ravnini plasti, ki pa iz podatkov rozet (slika 40 in slika 41) ni vidna, saj rozete prikazujejo slemenitev plasti ne pa tudi smeri vpada.

Rozeta pogostosti slemenitve plasti v rovih sistema Postojnskih jam prikazuje glavni vektor z vrednostjo 312,48^0, ki se razlikuje od glavnega vektorja smeri rovov (345,18^0) in smeri tektonsko pretrtih con (344,12^0). Interval zaupanja je 14,26^0, standardna deviacija pa 5,39%, pri razdelitvi intervalov na 10^0 (slika 41).

7.7. Model tektonske zgradbe postojnskega krasa in interpretacija oblikovanja jamskih rovov

Sistem Postojnskih jam leži v širšem smislu na ozemlju Zunanjih Dinaridov, za katere je značilno narivanje in gubanje proti jugu in jugozahodu (Jurkovšek et al., 1996).

Starejše tektonske deformacije so nastale zaradi regionalne kompresije v smeri severovzhod-jugozahod v kredi in paleogenu. Gre za Dinarske strukture, kot regionalne gube v smeri severozahod-jugovzhod in reverzne prelome v isti smeri, ki so nastali zaradi kolizije Jadranske mikro plošče z Evropsko ploščo (Jurkovšek et al., 1996).

Začetek flišne sedimentacije in s tem razpad Jadransko-Dinarske karbonatne platforme na področju Postojne s pomočjo nanoplanktona uvrščajo v zgornji paleocen (Rižnar, 1997).

Po Placerju (1981) je po odložitvi eocenskega fliša na področju Postojne prišlo do narivanja tektonske enote Javorniško-snežniške grude na fliš postojnske kotline. Narivanje se je vršilo na meji med eocenom in oligocenom (Placer, 1981) in je potekalo v smeri od severovzhoda proti jugozahodu (Placer, 1996). Pri tem je prišlo tudi do gubanja, ki se kaže v Postojnski antiklinali in Studenški sinklinali, katerih osi potekata v smeri severozahod-jugovzhod (priloga 1).

Znani rovi sistema Postojnskih jam potekajo v obeh krilih Postojnske antiklinale (slika 42). Zaenkrat še neznani vodni rovi med Pivko jamo in Planinsko jamo pa prečkajo tudi Studenško sinklinalo (Čar & Gospodarič, 1984).

Vergenca osne ravnine Postojnske antiklinale je 7-14^0 proti jugozahodu (Šebela, 1994 b), kar kaže na močnejše pritiske v smeri od severovzhoda proti jugozahodu kot od jugozahoda proti severovzhodu (slika 43).

K spremljajočim deformacijam gubanja prištevamo tudi medplastne zdrse v obeh krilih, kot tudi v temenu Postojnske antiklinale. Medplastni zdrsi in odprte razpoke med plastmi se kažejo kot zelo pomemben faktor pri nastajanju in oblikovanju jamskih rovov sistema Postojnskih jam. Medplastne zdrse najdemo v vseh plasteh litološkega stolpca (d=825 m) zgornje krednega apnenca (slika 2) v katerem so razviti jamski rovi.

Figure 41), as the rose graphs show the bedding plane direction, and not the dip direction.

The bedding plane direction frequency rose graph in the Postojnska jama cave system passages show the main vector value of 312.48^0 which is different from the main passages direction vector (345.18^0), and the tectonically fractured zones direction (344.12^0). The thrust interval is 14.26^0, and the standard deviation 5.39% with repartition of intervals by 10^0 (Figure 41).

7.7. Postojna Karst Tectonic Structure Model and Interpretation of the Cave Passage Formation

In a broader sense the Postojnska jama cave system lies in the region of Outer Dinarids whose characteristics are overthrusting and folding towards the S and SW (Jurkovšek et al., 1996).

The older tectonic deformations originated from a regional compression in the direction of NE – SW in the Cretaceous and Palaeogene period. There are Dinaric structures as regional folds in the NW – SE direction, and reverse faults in the same direction which occured owing to the collision of the Adriatic micro plate with the European plate (Jurkovšek et al., 1996).

The beginning of the flysch sedimentation, and by that the Adriatic-Dinaric carbonate platform disintegration, in the Postojna area is dated by means of nanoplankton in the Upper Palaeocene (Rižnar, 1997).

According to Placer (1981) overthrusting of the Javorniki-Snežnik tectonic unit onto the Postojna basin flysch occured after the deposition of the Eocene flysch in the Postojna area. The overthrusting was at the border between Eocene and Oligocene (Placer, 1981), and ran from the NE to the SW direction (Placer, 1996). There was also folding which is shown in the Postojna anticline and Studeno syncline where the axes run in the NW-SE direction (Annex 1).

The known passages of the Postojnska jama cave system run in both flanks of the Postojna anticline (Figure 42). The still unknown water passages between Pivka jama and Planinska jama cross also the Studeno syncline (Čar & Gospodarič, 1984).

The Postojna anticline axial vergence is 7-14^0 towards the SW (Šebela, 1994 b), which indicates stronger pressures from the NE to SW direction than from SW to NE direction (Figure 43).

Among accompanying folding deformations we also have interbedded movements in both flanks, as well as in the Postojna anticline crest. The interbedded movements and open fissures along bedding planes are a very important factor in the origin and formation of the cave passages in the cave system. We find interbedded movements in all bedding planes of the Upper Cretaceous limestone (Figure 2) (d = 825 m) in which

Slika 43. Model tektonske zgradbe in interpretacija oblikovanja jamskih rovov .

1: Starejše tektonske deformacije (Kreda-Paleogen), kompresija v smeri SV-JZ, oblikovanje Dinarskih struktur (gube in reverzni prelomi v Dinarski smeri SZ-JV in normalni prelomi v prečno Dinarski smeri SV-JZ) (Jurkovšek et al., 1996) Sedimentacija fliša se začne že v zgornjem paleocenu (Rižnar, 1997) in se nadaljuje v eocen. Po odložitvi fliša se na meji med eocenom in oligocenom vrši narivanje in gubanje v smeri od SV-JZ (Placer, 1981,1996).

2: Rezultat gubanja je Postojnska antiklinala, ki seka starejšo antiklinalo. Glavni pritiski so se pri formiranju obeh gub spreminjali. Gre za zamik smeri glavnih napetosti v obratni smeri urinega kazalca za 25^0. Ob gubanju so nastali medplastni zdrsi, zaradi močnejših pritiskov od SV pa opazujemo vergenco osne ravnine Postojnske antiklinale proti JZ za $7\text{-}14^0$.

3: V neogenu in kvartarju je regionalna kompresija v smeri S-J. Ob tem je prišlo do desnozmičnih prelomov v Dinarski smeri in sekundarnih gub v prečno Dinarski smeri SV-JZ (Jurkovšek et al., 1996).

a nariv, **b** antiklinala, **c** normalni prelom, **d** zmični prelom, **e** smer glavne napetosti,

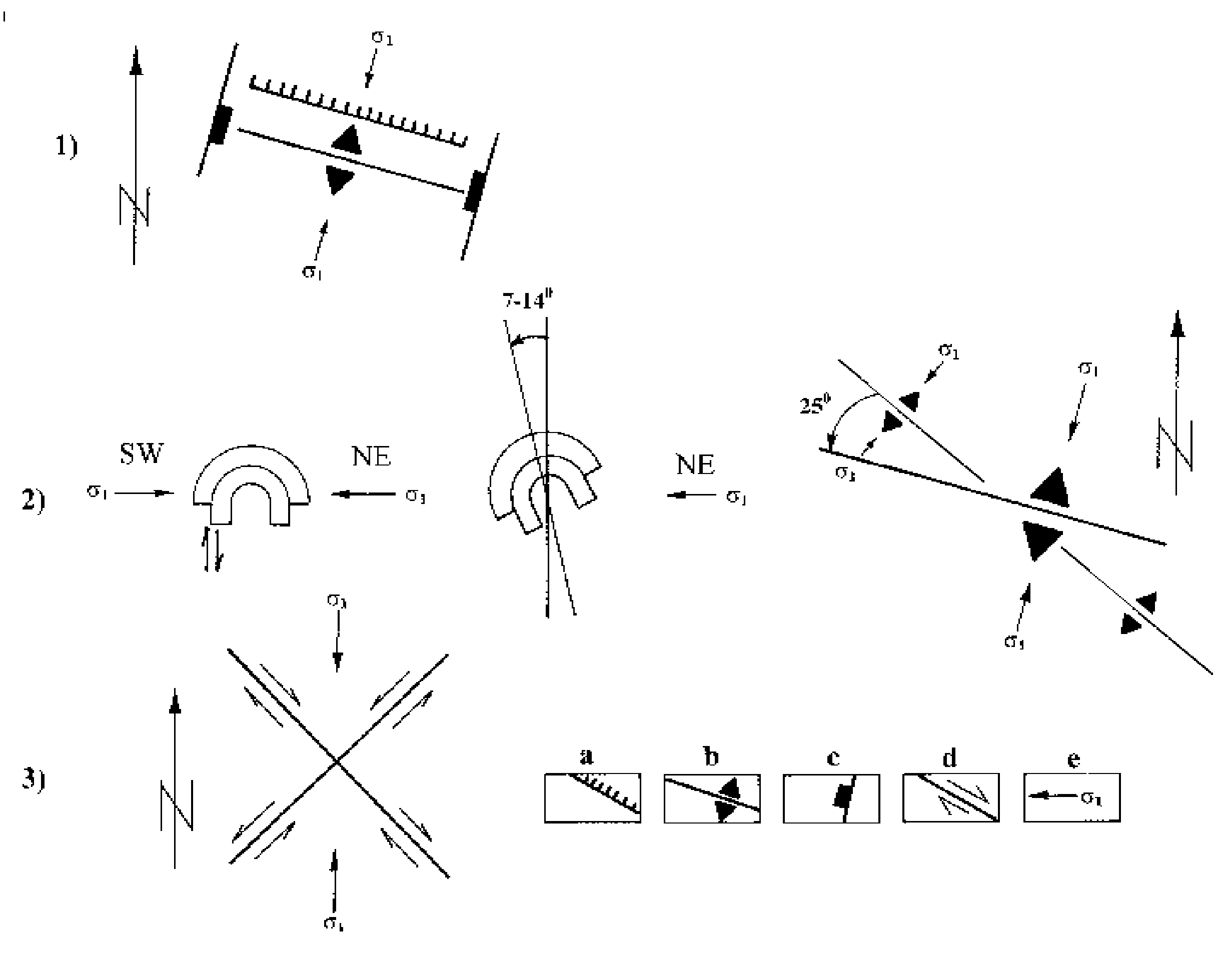
Figure 43. Tectonic structure model and cave passages formation interpretation.

1: Older tectonic deformations (Cretaceous-Palaeogene), compression in the NE-SW direction, formation of Dinaric structures (folds and reverse faults in the NW-SE Dinaric direction), and normal faults in the NE-SW cross-Dinaric direction (Jurkovšek et al., 1996). The flysch sedimentation already begins in the Upper Palaeocene (Rižnar, 1997), and continues to Eocene. After deposition of flysch, at the boundary line between Eocene and Olygocene, there appear overthrusting and folding in the NE-SW direction (Placer, 1981, 1996).

2: The folding result is the Postojna anticline which crosses over an older anticline. Main pressures were being modified by formation of both folds. It is about the main pressure strike-slip in the anticlockwise direction for 25^0. Interbedded movements were created by folding, and owing to the stronger pressures from NE we observe the Postojna anticline axis plane vergence towards SW for $7\text{-}14^0$.

3: In Neogene and Quaternary the regional compression is in the N-S direction. Thereby appeared right strike-slip faults in the Dinaric direction, and secondary folds in the NE-SW cross-Dinaric direction (Jurkovšek et al., 1996).

a overthrust, **b** anticline, **c** normal fault, **d** strike-slip fault, **e** main pressure direction,



Z geološkim kartiranjem jamskih rovov (priloga 1) sem določila tudi antiklinalo, ki poteka od Skalnega rova v Magdaleni jami, preko Ruskega rova, Čarobnega vrta v Pisani rov. Njena os je od osi Postojnske antiklinale odmaknjena za 25^0 proti severovzhodu (oz. 25^0 proti jugozahodu). Njeno teme je ožje kot teme Postojnske antiklinale, ki je v regionalnem smislu glavna guba na področju sistema Postojnskih jam. Med Perkovim in Vilharjevim rovom v Podzemeljski Pivki se osi obeh antiklinal srečata. Ker je glede na geološko kartiranje na površju nad jamskimi rovi zvezno določljiva le Postojnska antiklinala, menimo, da le-ta seka drugo antiklinalo, ki jo sledimo iz Skalnega rova Magdalene jame do Pisanega rova.

Na podlagi Schmidtove mreže (slika 11), kjer so prikazani poli plasti apnenca v jamskih rovih, je poleg Postojnske antiklinale izražena tudi antiklinala katere osna ravnina je od smeri sever-jug odmaknjena proti zahodu za 5^0. Gre za antiklinalo med Črno in Pivko jamo (priloga 1), ki je nastala zaradi kompresije v smeri skoraj vzhod-zahod.

Pri geološkem kartiranju jamskih rovov sistema Postojnskih jam sem določila tudi manjše in slabše izražene antiklinale in sinklinale (slika 42), kot je Postojnska antiklinala. Antiklinala in sinklinala v Martelovi dvorani imata prečno Dinarsko smer osi. Pritiski za nastanek takšnih gub so obstajali v smeri severozahod-jugovzhod. Ti pritiski so deformirali tudi Postojnsko antiklinalo, ki tone proti severozahodu (Čar & Gospodarič, 1984).

Gospodarič (1965) omenja dvojne raze na lezikah v sistemu Postojnskih jam. Ene ustrezajo pritiskom gubanja v smeri severovzhod-jugozahod in druge pritiskom v smeri severozahod-jugovzhod.

Po Čarju & Gospodariču (1984) so prelomne deformacije mlajše od narivnih in deformacij gubanja. Placer (1981) uvršča prelamljanje v miocen in pliocen.

Deformacije v neogenu in kvartarju so povezane z regionalnimi pritiski v generalni smeri sever-jug, ki je nastala zaradi premika Jadranske plošče proti severu in njene rotacije v nasprotni smeri urinega kazalca. Ob tem je prišlo praviloma do desnih horizontalnih premikov, pri čemer so iz reverznih prelomov prve faze nastali zmični prelomi (Jurkovšek et al., 1996).

Današnja kompresija v JZ Sloveniji je v smeri sever-jug (Bressan, et al., 1998).

Izmed prelomnih deformacij so najstarejši prelomi v prečno Dinarski smeri (SV-JZ). Glede na idejno skico Gospodariča (1965), so bili ti prelomi lahko aktivni že ob narivanju in gubanju. Tudi po Jurkovšku et al. (1996) naj bi prečno Dinarski normalni prelomi nastali kot sekundarne strukture gubanja in reverznega prelamljanja že v kredi in paleogenu (slika 43). Druge generacije so Dinarsko usmerjeni prelomi, tretje generacije so reaktivirane prečno Dinarske smeri. Najmlajši so Dinarsko usmerjeni desno zmični prelomi prelomne cone Predjamskega preloma, ki sekajo vse starejše strukture (Čar & Gospodarič, 1984).

the cave passages are developed.

By geological mapping of the cave passages (Annex 1) I have also fixed the anticline which runs from Skalni rov in Magdalena jama over Ruski rov and Čarobni vrt into Pisani rov. Its axis differs from that of the Postojna anticline axis for 25^0 towards NE (or 25^0 towards SW). Its crest is narrower than the Postojna anticline crest which is the main fold in the Postojnska jama cave system area. Both anticline axes cross each other between Perkov rov and Vilharjev rov in Podzemeljska Pivka. Since only the Postojna anticline is continuously definable above the cave passages by the surface geological mapping, we believe that it crosses another anticline which we follow from Skalni rov of Magdalena jama to Pisani rov.

On the basis of the Schmidt's net (Figure 11) where the limestone bedding plane poles in the cave passages are presented, there is also expressed an anticline whose axis plane differs from the N-S direction by 5^0 towards the W. It is the anticline between Črna jama and Pivka jama (Annex 1) which sprang up owing to a compression in an almost E-W direction.

By geological mapping of the cave system passages I have also fixed smaller and more poorly expressed anticlines and synclines (Figure 42) than the Postojna anticline. In Martelova dvorana the anticline and syncline have the cross-Dinaric axis direction. Pressures to cause such folds existed in the NW – SE direction. These pressures also deformed the Postojna anticline which sinks towards NW (Čar & Gospodarič, 1984).

Gospodarič (1965) mentions twofold abrasions on bedding planes in the Postojnska jama cave system. Some correspond to the folding pressures in the NE – SW direction, and others to the pressures in the NW – SE direction.

According to Čar & Gospodarič (1984) the fault deformations are younger than the overthrusting and folding ones. Placer (1981) classifies faulting into Miocene and Pliocene.

Deformations in Neogene and Quaternary are connected with regional pressures in the general N-S direction which took place owing to the Adriatic plate movement towards the N and its anticlockwise rotation. As a rule there appeared right horizontal movements where from the first phase reverse faults there sprang up strike-slip faults (Jurkovšek et al., 1996).

The present-day compression in the SW Slovenia is in the N-S direction (Bressan et al., 1998).

The oldest faults are in the cross-Dinaric direction (NE-SW). According to Gospodarič (1965) these faults could be already active by overthrusting and folding. Jurkovšek et al. (1996) state that the cross-Dinaric normal faults occured as secondary folding and reverse faulting structures in the Cretaceous and Palaeogene periods (Figure 43). Other generations are the Dinaric direction faults, and third generations are in the reac-

V zadnjih letih se z raziskavami krednih in paleogenskih karbonatnih kamnin za formacijsko geološko karto JZ Slovenije vse bolj uveljavlja možnost, da moramo začetek narivanj, gubanj in prelamljanj postaviti že v kredo in paleogen (Jurkovšek et al., 1996), to je v obdobje razpada Jadransko-Dinarske karbonatne platforme ter formiranja flišnega bazena in nastajanja fliša. Po odložitvi eocenskega fliša je tektonsko dogajanje reaktiviralo tudi že obstoječe strukturne nezveznosti.

Določitev obdobja in vrste aktivnosti tektonskih deformacij v JZ Sloveniji je osnova za razumevanje začetkov razvoja jamskih rovov sistema Postojnskih jam. Očitna navezanost in oblikovanje rovov po medplastnih zdrsih, kaže da so bile za začetni razvoj rovov vodilne tektonske deformacije, ki so nastale ob formiranju Postojnske antiklinale.

Že leta 1965 je Gams poudaril, da vsebuje obilna literatura o sistemu Postojnskih jam le redke navedbe o razvoju rovov. Vsi se strinjajo v tem, da je suho etažo Postojnske jame izoblikovala Pivka, oziroma njena predhodnica. Glede smeri njenega toka pa ni enotnega mišljenja.

Gams (1965) je razvojne faze skalnih rovov iz kvartarja opredelil po nadmorskih višinah današnjih stropov. Pri tem loči:

- faza I - Pisani rov (539-545 m)
- faza II - Lepe jame (537 m)
- faza III - Male jame (520-525 m)
- faza IV - Kristalni rov (519-522 m)
- faza V - Podzemeljska Pivka (511 m (ponor reke Pivke) - 496 m(odtočni sifon reke Pivke v Pivka jami)).

Skokovito znižanje vodnega pretoka je bilo po drugi fazi, zato pravilneje govorimo le o dveh glavnih fazah s petimi podfazami (Gams, 1965,77).

Moj namen ni bil določiti obdobja hidroloških aktivnosti posameznih rovov, ampak ovrednotiti današnje stanje oblike rovov v odvisnosti od geoloških strukturnih elementov. Rove (priloga 4) sem razdelila v štiri glavne skupine. Ločim odseke, ki predstavljajo aktivni (Podzemeljska Pivka) ali neaktivni vodni rov (vsi ostali rovi) ter potekajo v tektonsko pretrtih conah (a) ali plastnatosti (b) in odseke, kjer so podori razviti v tektonsko pretrtih conah (c) ali plastnatosti (d). Jamski rovi kjer ni bilo možno zanesljivo določiti njihovega oblikovanja po geoloških strukturnih elementih, so označeni z oznako e (priloga 4). Ti rovi so preoblikovani z jamskimi sedimenti ali pa predstavljajo le izkušenim potapljačem dostopne sifonske rove.

Na podlagi današnjega stanja rovov lahko postavimo nekatere zaključke tudi o razvoju jame. Pri tem se pojavi vprašanje vodilnih geoloških struktur, ki so usmerjale podzemeljske vode.

Z osnovno statistiko so prikazani 4-je grafi (slika 44, 45, 46 in 47). V danes neaktivnih rovih sistema Postojnskih jam je večji delež rovov oblikovan po tektonsko pretrtih conah (29 %) kot po plastnatosti 12 % (slika

tivated cross-Dinaric directions. The youngest are the Dinaric direction fault zone right strike-slip faults of the Predjamski fault which cross all the older structures (Čar & Gospodarič, 1984).

In recent years in the course the Cretaceous and Palaeogene carbonate rock researches for the SW Slovenia geological map there has been put forward the possibility that the beginning of overthrusting, folding and faulting should already be set into the Cretaceous and Palaeogene period (Jurkovšek et al., 1996), i.e. into the period of the Adriatic-Dinaric carbonate platform disintegration, and the flysch basin and flysch formation. After the deposition of Eocene flysch the tectonic occurrence also reactivated the already existing structural incongruities.

Periods and types of tectonic deformation activities in the SW Slovenia is the basis for e understanding the Postojnska jama cave system passages development origins. The evident passage relation and formation along interbedded movements indicate that for the initial passages development the principal tectonic deformations were those which occured with the Postojna anticline formation.

Already in 1965 Gams emphasised that the copious literature on the Postojnska jama system contains only a few references to the passage development. All of them agree that the Postojnska jama dry level was formed by the Pivka river or its predecessor. As regards its stream course opinion is not agreed.

Gams (1965) defined the rock passage development phases from Quaternary according to the present-day ceilings height above sea level. He thus distinguishes:

- Phase I – Pisani rov (539-545 m)
- Phase II – Lepe jame (537 m)
- Phase III – Male jame (520-525 m)
- Phase IV – Kristalni rov (519-522 m)
- Phase V – Podzemeljska Pivka (511 m (the Pivka river sink) – 496 m (the Pivka river downstream sump in Pivka jama)).

The watercourse main abrupt decrease took place after the second phase, so more correctly we talk only about two main phases with five sub-phases (Gams, 1965, 1977).

My intention is not to define the particular passage hydrological activity periods, but to evaluate the present-day passage form as dependent on geological structural elements. I have divided the passages (Annex 4) into four main groups. I distinguish sections which represent an active (Podzemeljska Pivka), or an inactive water passage (all other passages), and run in the tectonically fractured zones (a), or bedding (b), and sections where collapses are developed in the tectonically fractured zones (c), or bedding (d). Those cave passages where there was no possibility of defining their formation reliably according to geological structural elements are marked by the label e in Annex 4. These passages

44). Danes aktivni vodni rovi so v enakem razmerju oblikovani po tektonsko pretrtih conah kot po plastnatosti (slika 45). V primeru neaktivnih in aktivnih rovov je 30% oziroma 38% rovov takih, kjer ni bilo možno določiti vodilnih geoloških struktur. V neaktivnih rovih so ti rovi večinoma močno spremenjeni zaradi zapolnitev z jamskimi sedimenti ali pa so močno zasigani, v aktivnih rovih pa gre večinoma za sifonske rove.

Precejšen delež (29 %) neaktivnih jamskih rovov predstavlja podorno preoblikovane rove (slika 44). Le nekoliko večji delež podorov (16 %) se je oblikoval po tektonsko pretrtih conah, kot po plastnatosti (13 %). V danes še aktivnih rovih sistema Postojnskih jam je le 10 % rovov podornih, 6 % po tektonsko pretrtih conah in 4 % po plastnatosti (slika 45).

Če združimo vse rove sistema Postojnskih jam (slika 46), ugotovimo, da jih je 28 % oblikovanih po tektonskih strukturnih elementih in 18 % po plastnatosti. Podorno preoblikovanih rovov je 20 % (11 % po tektonsko pretrtih conah in 9 % po plastnatosti). Dobra tretjina (34 %) predstavlja rove, kjer geološki strukturni elementi niso bili določljivi.

Slika 47 prikazuje ločene podatke za neaktivne (a,b,c,d,e) in aktivne (a1,b1,c1,d1,e1) rove sistema Postojnskih jam.

Menim, do so bila za razvoj jamskih rovov posebno ugodna sečišča tektonsko pretrtih con z ravninami lezik. V takih delih je voda lažje napredovala in si tako večala svoje poti, in sicer v smeri tektonsko pretrtih con ali lezik.

V stranskih rovih, kot so Kristalni rov, Pisani rov, Rov brez imena, Čarobni vrt, se je v določenem obdobju voda zadrževala le ob večjih poplavah, medtem ko je bil glavni rov sistema Postojnskih jam še vedno aktiven. To potrjujejo tudi večja debelina jamskih sedimentov.

Podorne dvorane so danes v največjem deležu oblikovane po plasteh in lezikah poudarjenih z medplastnimi zdrsi ter močneje izraženih, predvsem Dinarskih, prelomnih conah.

Eden glavnih vzrokov spreminjanja poteka aktivnega vodnega rova je znižanje gladine podzemne vode. Ohranjeni nekdanji freatični rovi, današnji neaktivni rovi preoblikovani s podori, še vedno aktivni rov Podzemeljske Pivke in občasni ali stalni sifoni so osnovne značilnosti današnjega sistema Postojnskih jam.

are re-shaped by cave sediments, or they represent sump passages only accessible for experienced divers.

On the basis of the state of passages today we may also set forth some conclusions about the cave development. From this appears a question of principal geological structures which directed the underground waters.

Four graphs presented the basic statistics (Figures 44, 45, 46 and 47). In the inactive passages of the present Postojnska jama Cave System the more are formed along the tectonically fractured zones (29%) than along the bedding 12% (Figure 44). Today's active water passages are formed along the tectonically fractured zones and along the bedding in equal proportions (Figure 45). In the case of inactive and active passages there are 30% or 38% of passages respectively where there is no possibility of determining principal geological structures. Among inactive passages these passages are mainly highly modified due to filling up with cave sediments, or they are heavily covered with flowstone, but among the active passages they are mainly sump passages.

Many (29%) of the inactive cave passages are represented passages re-formed by collapse (Figure 44). More of the collapses (16%) were re-formed along tectonically fractured zones than along bedding (13%). In the still active Postojnska jama cave system passages only 10% are collapse passages, 6% being along tectonically fractured zones, and 4% along bedding (Figure 45).

If we unite all the Postojnska jama cave system passages (Figure 46), we find that 28% of them are formed along tectonic structural elements, and 18% along the bedding. There are 20% of collapse re-formed passages (11% along tectonically fractured zones and 9% along bedding). More than a third (34%) of them represents passages where geological structural elements were not definable.

Figure 47 shows the data grouped as inactive (a,b,c,d,e) and active (a1,b1,c1,d1,e1) passages.

I suppose that tectonically fractured zones intersections with bedding planes were especially favourable for the cave passages development. In such sections water got along more easily, and thus enlarged its routes, i.e in the tectonically fractured zones and bedding planes direction.

At a certain period water was present only during the greater floods in the lateral passages like Kristalni rov, Pisani rov, Rov brez imena, Čarobni rov, while the Postojnska jama cave system main passage was still active. That is also confirmed by a greater thickness of cave sediments in the lateral passages.

Most of the collapse chambers are nowadays formed along bedding planes and bedding planes emphasised by interbedded movements, and more strongly expressed, mainly in the Dinaric fault zones.

One of the main reasons for changing active

Slika 44. Oblikovanje neaktivnih rovov sistema Postojnskih jam. **a** rovi oblikovani po tektonsko pretrtih conah, **b** rovi oblikovani po plastnatosti, **c** podor po tektonsko pretrtih conah, **d** podor po plastnatosti, **e** nedoločljivi rovi.

Figure 44. Postojnska jama cave system inactive passage formation. **a** passages formed along tectonically fractured zones, **b** passages formed along bedding, **c** collapse along tectonically fractured zones, **d** collapse along bedding, **e** indefinable passages.

Slika 45. Oblikovanje aktivnih rovov sistema Postojnskih jam. **a1** rovi oblikovani po tektonsko pretrtih conah, **b1** rovi oblikovani po plastnatosti, **c1** podor po tektonsko pretrtih conah, **d1** podor po plastnatosti, **e1** nedoločljivi rovi.

Figure 45. Postojnska jama cave system active passage formation. **a1** passages formed along tectonically fractured zones, **b1** passages formed along bedding, **c1** collapse along tectonically fractured zones, **d1** collapse along bedding, **e1** indefinable passages.

Slika 46. Združeni podatki oblikovanja neaktivnih in aktivnih rovov po geoloških strukturnih elementih. **a** rovi oblikovani po tektonsko pretrtih conah, **b** rovi oblikovani po plastnatosti, **c** podor po tektonsko pretrtih conah, **d** podor po plastnatosti, **e** nedoločljivi rovi.

Figure 46. United data of the inactive and active passage formation along geological structural elements. **a** passages formed along tectonically fractured zones, **b** passages formed along bedding, **c** collapse along tectoni-cally fractured zones, **d** collapse along bedding, **e** indefinable passages.

Slika 47. Podatki oblikovanja neaktivnih in aktivnih rovov po geoloških strukturnih elementih. **a, a1** rovi oblikovani po tektonsko pretrtih conah, **b, b1** rovi oblikovani po plastnatosti, **c, c1** podor po tektonsko pretrtih conah, **d, d1** podor po plastnatosti, **e,e1** nedoločljivi rovi.

Figure 47. Inactive and active passage formation data along geological structural elements. **a, a1** passages formed along tectonically fractured zones, **b, b1** passages formed along bedding, **c,c1** collapse along tectonically fractured zones, **d, d1** collapse along bedding, **e,e1** indefinable passages.

water passage courses is the underground water level. Preserved former phreatic passages, the now inactive passages re-shaped by collapses, the still active Podzemeljska Pivka passage, and periodical or permanent sumps are basic characteristics of the Postojnska jama cave system today.

7.8. Speleomorfološke in geološke značilnosti jam v bližini sistema Postojnskih jam

Na območju sistema Postojnskih jam je po podatkih Katastra jam IZRK ZRC SAZU registriranih okrog 50 krajših in daljših jam, brezen in spodmolov. Čeprav te jame navadno nimajo direktne zveze s sistemom Postojnskih jam, pa so nekatere ostanek stare podzemeljske drenaže. Na sliki 48 so s katastrskimi številkami označeni vhodi v najpomembnejše jame v okolici Postojne.

Jame, ki danes niso več prehodne do rovov sistema Postojnskih jam, vendar so glede na njihov položaj lahko v preteklosti bile so: Jama na poti, Zguba jama, jama Koliševka, jama Risovec, Betalov spodmol in Jama pod Pečno rebrijo. Lekinka je edina jama, ki je povezana z aktivnim vodnim tokom Podzemeljske Pivke.

7.8. Speleo-Morphological and Geological Characteristics of caves in the Vicinity of the Postojnska jama Cave System

According to the IZRK ZRC SAZU Caves Cadastre data there are registered about 50 shorter and longer caves, shafts and rock shelters in the Postojnska jama system area. Although these caves are usually not directly connected with the system, some of them are remains of former underground drainage. In Figure 48 the entrances into the most important caves in the Postojna vicinity are indicated by the numbers in the Caves Cadastre.

The caves which are no longer connected with the Postojnska jama cave system passages, but according to their position they could once have been passable, are as follows: Jama na poti, Zguba jama, Koliševka cave, Risovec cave, Betalov spodmol and Jama pod Pečno rebrijo. Lekinka is the only cave connected with the active Podzemeljska Pivka watercourse.

Tabela 1. Osnovni speleološki podatki sistema Postojnskih jam in nekaterih okoliških jam (vir: Kataster jam IZRK ZRC SAZU).
Table 1. The Postojnska jama cave system and some surrounding caves basic speleological data (source: IZRK ZRC SAZU Caves Cadastre).

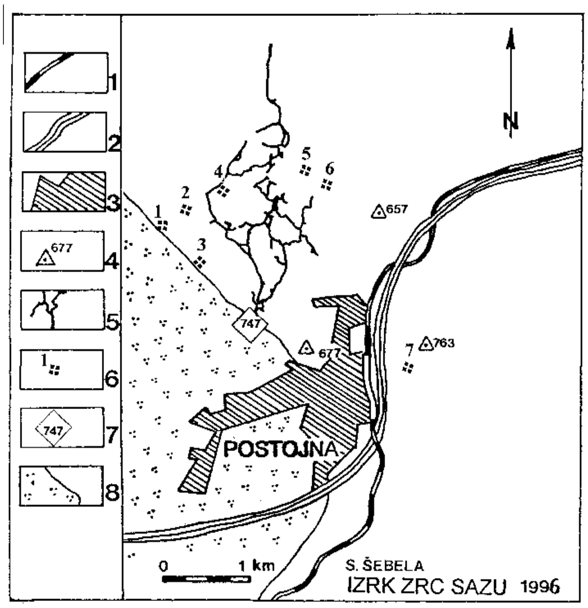
ime *name*	*kat.št.* *Cad. no*	*dolžina m* *length m*	*globina m* *depth m*	*n.m.v. vhoda* *a.s.l. of entrance m*
Jama na poti	583	65	32,5	570
Lekinka	1867	730	4	515
sistem Postojnskih jam	747	19.555	115	511
Zguba jama	6290	122	4	561
jama Koliševka	147	246	29	562
jama Risovec	3883	78	5	532
Betalov spodmol	473	174	4	537
Jama pod Pečno rebrijo	1577	203	25	647

JAMA NA POTI (KAT. ŠT. 583)

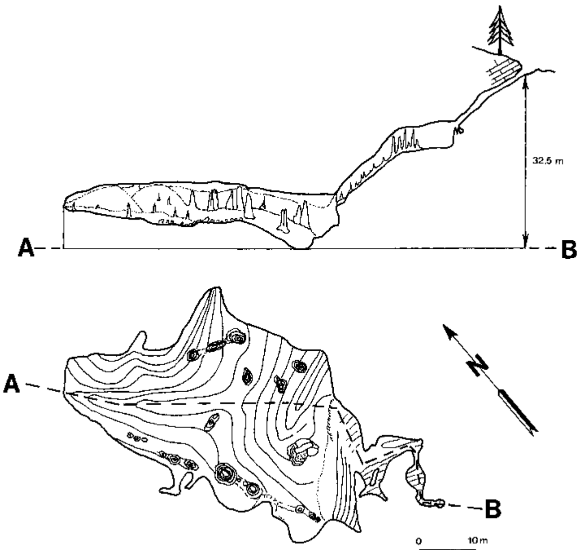
Gospodarič (1969 a) omenja Jamo na poti (kat. št. 583), za katero domneva, da je nekdanje nadaljevanje Pisanega rova proti severu in severozahodu. Jamo na poti sicer prvi omenja Martel (1894). Vhod v jamo (n.m.v. 570 m) po Martelu, širok okrog 1 m, so odkrili člani Anthrona kot dihalnik pozimi na gozdni poti proti Črni in Pivka jami leta 1889. Odstranili so le nekaj zemlje, da so lahko vstopili v jamo. Po Martelu (1894) se je jama oblikovala v plastnatosti. Severozahodni del jame je podoren in je v genetski zvezi z eno od velikih dolin na površju. Dolžina jame je 65 m in globina 35 m

JAMA NA POTI (CAD. NO. 583)

Gospodarič (1969) makes mention of Jama na poti (Cad. No. 583) which he assumes to have been a former continuation of Pisani rov towards the N and NW. Besides, Jama na poti was first described by Martel (1894). The cave entrance (570 m a.s.l.) about 1 m wide according to Martel, was discovered as a winter breathing hole by a forest path to Črna jama and Pivka jama by the Anthron cave club members in 1889. They removed some soil to enter the cave. Martel (1894) states the cave was formed in bedding. The NW part of the cave has collapsed, and has genetic connection



Slika 48. Položaj Jame pod Pečno rebrijo glede na tloris sistema Postojnskih jam in okoliške jame. **1** železnica, **2** avtocesta, **3** mesto, **4** nadmorska višina, **5** tloris sistema Postojnskih jam, **6** jamski vhod, **7** katasterska številka jame (***1** Betalov spodmol, **2** Risovec, **3** Lekinka, **4** jama Koliševka, **5** Jama na poti, **6** Zguba jama, **7** Jama pod Pečno rebrijo*), **8** eocenski fliš in zgornje kredni apnenec.
Figure 48. Jama pod Pečno rebrijo position in relation to the Postojnska jama cave system and surrounding caves. **1** railway, **2** highway, **3** town, **4** height above sea level, **5** Postojnska jama cave system ground plan, **6** cave entrance, **7** cave cadastre number (***1** Betalov spodmol, **2** Risovec, **3** Lekinka, **4** jama Koliševka, **5** Jama na poti, **6** Zguba jama, **7** Jama pod Pečno rebrijo*), **8** Eocene flysch and Upper Cretaceous limestone.



Slika 49. Jama na poti (vir: Kataster jam IZRK ZRC SAZU).
Figure 49. Jama na poti (source: IZRK ZRC SAZU Caves Cadastre).

(slika 49). Jama je bogato zasigana. Kljub določeni legi jame po italijanskem katastru (VG) danes ni dostopna, saj so jo zaradi ceste povsem zasuli.

Jama na poti leži okrog 300 m severozahodno od najsevernejše točke Pisanega rova in je v n.m.v. 537,5 m, severni del Pisanega rova pa v 535 m, kar kaže na določeno povezavo, to je na možno nekdanje (pred oblikovanjem Velike Jeršanove doline) nadaljevanje Pisanega rova proti SZ.

Gospodarič (1969 a) omenja, da je v Jami na poti, tako kot v sistemu Postojnskih jam, znana poplavna ilovica. Ta je sem zašla že takrat, ko Velika Jeršanova dolina še ni prekinjala Pisanega rova, kar dokazuje, da se je Velika Jeršanova dolina najbolj poglobila po naplavini flišne ilovice (Gospodarič, 1969 a). Ob raziskavah v Čarobnem vrtu Postojnske jame so ta pomembni speleološki proces uvrstili v prvi würmski poledenitveni sunek (Gospodarič, 1968 b).

with one of big dolines on the surface. The cave length is 65 m, and the depth 35 m (Figure 49). The cave is rich in flowstone formations. In spite of the cave specific position given in the Italian cadastre (VG), it is not now accessible, as it was completely filled up in making a road.

Jama na poti lies about 300 m NW from the most N point of Pisani rov. It is 537.5 m a.s.l., and the Pisani rov N part at 535 m, which indicates some connection, i.e. a possible former (before Velika Jeršanova dolina) continuation of Pisani rov towards NW.

Gospodarič (1969 a) mentioned that in Jama na poti there is known to be flood clay, as in the Postojnska jama cave system. It came here before Velika Jeršanova dolina had interrupted Pisani rov, which proves that Velika Jeršanova dolina was deepened most after the flysch clay alluvium was deposited (Gospodarič, 1969 a). By researches in the Čarobni vrt part of the Postojnska jama cave this important speleological process was classified into the first Würm Glacial Stage (Gospodarič, 1968 b).

ZGUBA JAMA (KAT. ŠT. 6290)

Zguba jamo (VG 583, kat. št. 6290) je prvi odkril Kraigher s sodelavci (Martel, 1894) na vzhodni strani Male Jeršanove doline.

Dolga je 122 m in globoka +4 m (slika 50). Vhod v jamo je visok okrog 1 m in širok 1,5 m ter leži v nadmorski višini 561 metrov, kar je, 26 metrov na vhodu in 30 m na koncu jame, višje kot je nivo najbližjega dela sistema Postojnskih jam, to je Pisanega rova (n.m.v. 535 m). Ena od razlag je, da je bila Zguba jama povezana s Pisanim rovom kot višji desni rov, oziroma da predstavlja star nivo rovov. Mala Jeršanova dolina je prekinila možno zvezo med Zguba jamo in Pisanim rovom.

Zguba jama poteka večinoma po plastnatosti, posamezni odseki pa so skladni s potekom tektonsko pretrtih con (slika 50). Jamski rov kaže dobro ohranjene freatične oblike. Glede na številne fasete lahko sklepamo na smer vodnega toka od JV proti SZ.

Jama je razvita v zg. krednem apnencu. Pri točki 11 (slika 50) so plasti blago antiklinalno upognjene. Najbolj izrazita prelomna cona s smerjo vpada 120^0 je v skrajnem JV delu jame. Širina zdrobljene do porušene cone je do 1m. V tem delu jame so podorni bloki, ki so odpadli iz te prelomne cone, zaprli domnevno nadaljevanje rova.

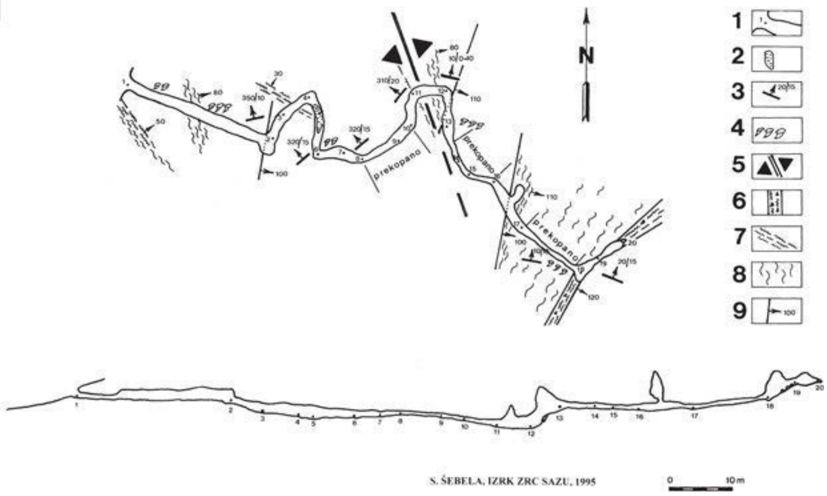
ZGUBA JAMA (CAD. NO. 6290)

Zguba jama (VG 583, Cad. No. 6290) was first discovered by Kraigher with co-workers (Martel, 1894) on the Mala Jeršanova dolina E side.

It is 122 m long and +4 m deep (Figure 50). The cave entrance is about 1 m high and 1.5 m wide, and it lies at 561 m above sea level which is higher than the nearest Postojnska jama Cave System level, namely Pisani rov (535 m a.s.l.), by 26 m at the entrance and 30 m at the cave end. One of the explanations is that Zguba jama was connected with Pisani rov as a higher right passage, or it may represent an old passage level. Mala Jeršanova dolina destroyed the link between Zguba jama and Pisani rov.

Zguba jama runs mainly along bedding, and particular sections are congruent with the course of the tectonically fractured zones (Figure 50). The cave passage shows well- preserved phreatic forms. From the numerous scallops we may infer the watercourse direction to be from SE towards NW.

The cave is developed in Upper Cretaceous limestone. At the point 11 (Figure 50) the bedding planes are gently anticline flexible. The most expressive fault zone with the strike dip 120^0 is in the outmost SE part of the cave. The crushed to broken zone width is up to 1 m. In this part of the cave the collapse blocks which fell off from this fault zone closed the supposed passage continuation.



Slika 50. Zguba jama (tloris jame J. Hajna, geologija S. Šebela). **1** tloris jame, **2** stoječa voda, **3** smer in vpad plasti zgornje krednega apnenca, **4** rudistni ostanki, **5** antiklinala, **6** zdrobljena cona s tektonsko brečo, **7** porušena cona, **8** razpoklinska cona, **9** smer in vpad prelomne ploskve.

Figure 50. Zguba jama (cave ground plan by J. Hajna, geology by S. Šebela). **1** cave ground plan, **2** stagnant water, **3** Upper Cretaceous limestone bedding plane strike and dip, **4** rudist remains, **5**-anticline, **6** crushed zone with tectonic breccia, **7** broken zone, **8** fissured zone, **9** fault plane strike and dip.

LEKINKA (KAT. ŠT. 1867)

Geološke, hidrološke in speleološke raziskave Lekinke z ozirom na sistem Postojnskih jam sta zelo temeljito prikazala Gospodarič in Habič (1966). Lekinka (slika 48) je vodoravna vodna jama v katero ponika Črni potok. Njena dolžina je 730 m, nadmorska višina vhoda pa 515 m, kar je 4 m višje kot ponor Pivke na

LEKINKA (CAD. NO. 1867)

Geological, hydrological and speleological researches on Lekinka, in relation to the Postojnska jama system were thoroughly presented by Gospodarič and Habič (1966). Lekinka (Figure 48) is a horizontal cave into which Črni potok brook sinks. It is 730 m long, and the entrance height above sea level is 515 m which vhodu v sistem Postojnskih jam (Kataster jam IZRK ZRC SAZU).

Skozi Lekinko odteka voda proti severovzhodu k rovu Podzemeljske Pivke. Po Gospodariču in Habiču (1966) je Lekinka med jamami Postojnskega krasa iz mlajšega obdobja, saj v njej ni podorov niti debelih plasti sedimentov, ki bi pokrivali skalno dno.

Lekinka se konča z neprehodnim sifonom, ki je v zračni črti oddaljen od Podzemeljske Pivke še približno 150 m (Gospodarič & Habič, 1966). V letu 1998 potekajo intenzivne potapljaške raziskave, da bi Lekinko povezali z rovom Podzemeljske Pivke (Vrhovec, 1998, osebno sporočilo).

Vhod v jamo se je oblikoval v zgornje krednem apnencu, ki je močno pretrt. Ob prelomni ploskvi 310/40 je prišlo do vertikalnega premikanja. Izrazita je tudi prelomna ploskev 50^0, ki je del širše zdrobljene cone Predjamskega preloma. Opaziti pa je moč tudi porušeno cono 110^0.

is 4 m higher than the Pivka sink in the Postojnska jama cave system (IZRK ZRC SAZU Caves Cadastre).

Through Lekinka the water flows off NE to the Podzemeljska Pivka passage. According to Gospodarič and Habič (1966) Lekinka is, among the Postojna karst caves, from the earlier period, as there is no collapses nor thick sediment beds which would cover the rocky floor.

Lekinka ends by an impassable sump which is approximately 150 m in a direct line away from Podzemeljska Pivka (Gospodarič & Habič, 1966). In 1998 intensive diving attempts are being made to connect Lekinka with the Podzemeljska Pivka passage (Vrhovec, 1998, personal report).

The cave entrance was formed in Upper Cretaceous limestone which is strongly fractured. A vertical movement was induced along the fault zone 310/40. The fault plane 50^0 which is a part of a larger Predjama fault crushed zone is also expressive, and it is possible to notice also the broken zone 110^0.

JAMA KOLIŠEVKA (KAT. ŠT. 147)

Speleološki opis jame Koliševke podajata Michler & Hribar (1959, 168). Njeno starost vzporejata z zgornjim, najstarejšim delom sistema Postojnskih jam (Michler & Hribar, 1959, 170).

Vhod v jamo se odpira v nadmorski višini 562 m, globina jame je 29 m in dolžina 246 m. Rovi so 25 m višje kot spodaj ležeči jamski vodni rov Podzemeljske Pivke (slika 48).

Gospodarič in Habič (1966) sta etažo jame Koliševke povezala s skalno polico pri Sv. Andreju v višini med 530 in 536 m.

JAMA KOLIŠEVKA (CAD. NO. 147)

Jama Koliševka cave speleological description is presented by Michler & Hribar (1959, 168). They make its age parallel to oldest section of the upper Postojnska jama cave system (Michler & Hribar, 1959, 168).

The cave entrance opens at 562 m above sea level, its depth is 29 m, and its length 246 m. The passages are 25 m higher than the Podzemeljska Pivka water passage beneath (Figure 48).

Gospodarič and Habič (1966) connected the Jama Koliševka cave level with the ledge near Sv. Andrej church at a height between 530 and 536 m.

JAMA RISOVEC (KAT. ŠT. 3883)

Današnji vhod so umetno izkopali, saj so po močnem prepihu sklepali na nadaljevanje jame. Vhod je v nadmorski višini 532 m. Do danes izmerjeni jamski rovi merijo 78 m. V bistvu gre za 2 jami, ena je spodmol, druga pa je, na vhodnem delu umetno prekopan, rov.

Vhod v jamo (slika 48) se je oblikoval na sečišču pomembnejših tektonskih con 70-80/80-90 in 120-130/80. Jama Risovec je torej razvita v dveh tektonskih smereh Dinarski in prečno Dinarski. Še posebno je zanimiv freatični rov 1,5 x 1,5 m, ki se je oblikoval v prelomni ploskvi 70^0. Rov je nagnjen proti JV.

Brodar (1970) je poudaril, da je jama Risovec nekdanji aktivni ponor, kar dokazujejo flišni prodniki in debele plasti sedimentov. V globjih jamskih plasteh spodmola so našli paleolitsko vsebino (Brodar, 1970).

JAMA RISOVEC (CAD. NO. 3883)

The present entrance was artificially excavated as a strong draught suggested the cave continuation. The entrance is at 532 m height above sea level. The measured cave passages are now 78 m long. In fact there are two caves, one is a rock shelter, and the other one is passage, artificially dug through at its E part.

The cave entrance (Figure 48) was formed at the intersection of the more important tectonic zones 70-80/80-90 and 120-130/80. Jama Risovec cave is thus developed in two tectonic directions, the Dinaric and cross-Dinaric. The phreatic passage 1.5 x 1.5 m is especially interesting, and it was formed in the fault plane 70^0. The passage dips towards SE.

Brodar (1970) stressed that the Jama Risovec cave is a former active sink, which is proved by flysch boulders and a thick bed of sediments. In the deeper rock shelter beds, palaeolithic contents were found (Brodar, 1970).

BETALOV SPODMOL (KAT. ŠT. 473)

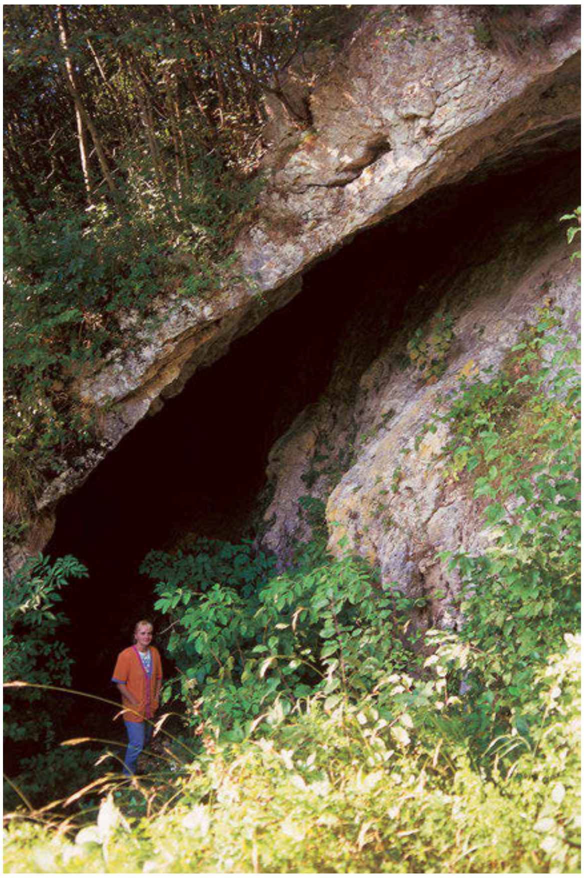
Dolžina jame je 174 m (+ 28 m stranska dvorana), globina pa 4 m. Nadmorska višina vhoda je 537 m. Današnji vhod v Betalov spodmol (slika 51) po svojih razsežnostih prekaša nekdanjega, kar je posledica obsežnega arheološkega izkopavanja. Jama je v splošnem usmerjena od juga proti severu in SZ.

Vhod v jamo je razvit v lezikah poudarjenih z medplastnimi zdrsi. Apnenec vpada proti JZ za 30-50^0. V tem delu je, tako kot na celotnem kontaktu apnenec-fliš, močno izražena prelomna cona 30-40/70-80, ki jo štejemo k širši prelomni coni Predjamskega preloma. Dobro so izražene tudi prečno Dinarske porušene cone 110/90.

Arheološke najdbe v Betalovem spodmolu potrjujejo, da gre za eno najstarejših pri nas odkritih paleolotskih najdb (Brodar, 1948-49).

JAMA POD PEČNO REBRIJO (KAT. ŠT. 1577)

Jugozahodno pod hribom Pečna reber (763 m) je vhod v 203 m dolgo Jamo pod Pečno rebrijo (slika



Slika 51. Vhod v Betalov spodmol (foto S. Šebela)
Figure 51. Entrance to Betalov spodmol (photo S. Šebela).

BETALOV SPODMOL (CAD. NO. 473)

The cave is 174 m long (+28 m side chamber) and 4 m deep. The entrance height above sea level is 537 m. The present entrance to Betalov spodmol (Figure 51) is larger than the formerly, as a consequence of extensive archaeological excavations. The cave is generally oriented from S to N and NW.

The entrance is developed in bedding planes emphasised by interbedded movements. The limestone dips towards SW for 30-50^0. In this section, as well as in the whole limestone-flysch contact, the fault zone 30-40/70-80 is strongly expressed, and it is enumerated to the Predjama fault larger fault zone. The cross-Dinaric broken zones 110/90 are also well expressed.

Archaeological finds in Betalov spodmol prove that we are talking about one of the oldest palaeolithic discoveries in Slovenia (Brodar, 1948-49).

JAMA POD PEČNO REBRIJO (CAD. NO. 1577)

To the SW beneath the Pečna reber hill (763 m) there is an entrance to the 203 m long Jama pod Pečno rebrijo (Figure 48). The cave consists of two passages and two shafts. The entrance one is 12.5 m deep and lies at 647 m a.s.l. The shaft in the S passage is 11.5 m deep.

The cave is developed in Upper Cretaceous limestone. In the N passage we can observe one entire bedding plane of limestone which is very rich in rudist remains. The limestone bedding plane dip and strike in the passage E section are 230/30, and in other sections 260/30. The N passage dips from E to W. Likewise the former watercourse direction in the phreatic passage is shown by scallops on the passage walls. The S passage is much more horizontal and runs in the Dinaric direction NW-SE.

The N passage is more characteristically developed along bedding planes than the S one, and runs in two main directions (Figure 52). To the E from the point 24 there is the cave passage direction 260^0, and it deviates from the bedding plane dip strike for 30^0 towards the N. Another passage direction is 290^0, and includes the section between the points 22 and 24. It deviates for 30^0 from the bedding plane dip strike towards the W. The third part of the passage has the same direction as the E part of the passage, but there the passage is parallel to the bedding plane dip and strike.

The N passage which is 120 m long passes from the lower limestone bedding plane to the upper which means that the passage dip angle is smaller than the limestone dip angle. Thus the N passage is not throughout in the same bedding plane what perhaps looks like with an inaccurate cave survey. The N passage is thus not parallel to the bedding plane dip strike all the ways long, but it deviates from it in the passage's E and central

48). Jama je sestavljena iz dveh rovov in dveh brezen. Vhodno brezno je globoko 12,5 m in leži v n.m.v. 647 m. Brezno v južnem rovu je globoko 11,5 m.

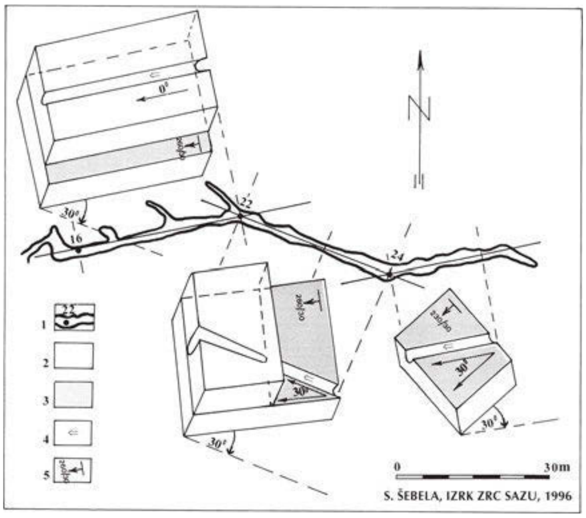
Jama je razvita v zgornje krednih apnencih. V severnem rovu lahko vseskozi opazujemo eno plast apnenca, ki je zelo bogat z rudistnimi ostanki. Smer vpada plasti apnenca v vzhodnem delu rova je 230/30 in v ostalih delih 260/30. Severni rov se spušča od V proti Z. Prav tako smer nekdanjega vodnega toka v freatičnem rovu kažejo tudi fasete na stenah rova. Južni rov je mnogo bolj horizontalen in poteka v Dinarski smeri SZ-JV.

Severni rov je bolj značilno razvit po lezikah kot južni in poteka v dveh glavnih smereh (slika 52). Vzhodno od točke 24 je smer jamskega rova 260^0 in odstopa od smeri vpada plasti za 30^0 proti severu. Druga smer rova je 290^0 in zajema predel med točkama 22 in 24. Od smeri vpada plasti odstopa za 30^0 proti zahodu. Tretji del rova ima prav tako smer kot vzhodni del rova, vendar je tu rov vzporeden s smerjo vpada plasti.

Severni rov, ki je dolg 120 m, prehaja iz spodnje lezike apnenca v zgornjo, kar pomeni, da je vpadni kot rova manjši kot vpadni kot apnenca. Severni rov tako ni vseskozi v isti leziki, kot morda izgleda ob nenatančnem ogledu jame. Rov tudi ni vseskozi vzporeden s smerjo vpada plasti, ampak odstopa od te smeri, in sicer v vzhodnem in osrednjem delu rova za 30^0 proti severu (slika 52).

Severni rov Jame pod Pečno rebrijo je morfološko podoben rovu Zguba jame, vendar je nekoliko večjih dimenzij kot rov Zguba jame. Med obema jamam je okrog 2 km zračne razdalje. Ločuje ju tudi močna prelomna cona imenovana Postojnska vrata. Gre za večkrat reaktivirano prelomno cono v smeri NNE-SSW, ki je s svojo tektonsko aktivnostjo lahko prekinila možno nadaljevanje Jame pod Pečno rebrijo proti zahodu in njeno možno povezavo s sistemom Postojnskih jam in Zguba jamo.

Jama pod Pečno rebrijo, in sicer predvsem njen severni rov, je ohranila sledove prvotnega freatičnega oblikovanja znotraj najmanj dveh lezik. Danes jama nima več aktivne hidrološke funkcije, z vseh strani pa njeno nadaljevanje prekinjajo oziroma zakrivajo podori, ki so vezani na potek prelomnih con v smeri SZ-JV in SV-JZ.



Slika 52. Prostorska projekcija freatičnega rova v Jami pod Pečno rebrijo. Debelina apnenca v blok diagramih je 3x povečana. **1** tloris rova s poligonskimi točkami, **2** zgornja plast zgornje krednega apnenca, **3** spodnja plast zgornje krednega apnenca, **4** smer starega vodnega toka, **5** smer in vpad plasti apnenca.

Figure 52. Phreatic passage space projection in Jama pod Pečno rebrijo. The limestone thickness in block diagrams is 3 times magnified. **1** passage ground plan with polygon points, **2** Upper Cretaceous limestone upper bedding plane, **3** Upper Cretaceous limestone lower bedding plane, **4** old water flow direction, **5** limestone bedding plane strike and dip.

section for 30^0 towards N (Figure 52).

The Jama pod Pečno rebrijo N passage is morphologically similar to the Zguba jama passage, but is of rather larger dimensions. The direct distance between the two caves is about 2 km. They are also distinguished by a strong fault zone called Postojnska vrata. It is a fault zone reactivated several times in the NNE-SSW direction which could have destroyed a possible continuation of Jama pod Pečno rebrijo towards the W, and its possible connection with the Postojnska jama and Zguba jama.

Jama pod Pečno rebrijo, and above all its N passage, preserved the primary phreatic formation traces inside two bedding planes at least. Today, the cave has no active hydrological function any more, and from all sides its continuity has been destroyed or covered by collapses which are connected with the fault zones course in the NW-SE and NE-SW directions.

8.0. TEKTONSKO-LITOLOŠKO KARTIRANJE POVRŠJA NAD SISTEMOM POSTOJNSKIH JAM

8.1. Interpretacija letalskih posnetkov

Za pomoč pri kartiranju površja smo uporabili letalske posnetke. Tako kot v primeru Predjame (Šebela, 1995 a) so na Inštitutu za geodezijo in fotogrametrijo (Fakulteta za arhitekturo, gradbeništvo in geodezijo) v Ljubljani tudi za površje nad sistemom Postojnskih jam naredili povečave letalskih posnetkov v merilu 1:5.000.

S pomočjo stereoskopskega opazovanja dveh letalskih posnetkov si najlažje ustvarimo reliefno sliko terena, ki ga raziskujemo. Na tak način lahko določimo potek tektonskih linij, ki predstavljajo značilno morfologijo terena. Pri tem je potrebno poudariti, da na letalskih posnetkih ne moremo ločiti različnih vrst tektonskih con med seboj, kot npr. razpoklinskih od porušenih ali zdrobljenih. Tudi ni mogoče ločiti prelomnih deformacij od narivnih, litološko pogojenih linij od tektonskih ter različnih vpadnih kotov tektonskih con. Vse te pomanjkljivosti zahtevajo, da podatke, ki smo jih določili z interpretacijo letalskih posnetkov, preverimo in dopolnimo na terenu.

Na prilogi 5 so prikazani geološki strukturni elementi, določeni z interpretacijo letalskih posnetkov nad sistemom Postojnskih jam.

Pogostost smeri tektonskih con določenih iz opazovanja letalskih posnetkov je prikazana na slikah 53 in 54. Najbolj pogoste so tektonske cone v smeri 310-325^0 (20,6%), pri razdelitvi na 15^0 (slika 53) oziroma 310-320^0 (13,8%), pri razdelitvi intervalov na 10^0 (slika 54).

Prečno Dinarska smer 40-50^0 je zastopana z manj kot 6%, pri razdelitvi intervalov na 10^0 (slika 54) in z manj kot 10% (smer 30-45^0) pri razdelitvi intervalov na 15^0 (slika 53).

Standardna deviacija je 4,12% pri razdelitvi intervalov na 10^0 in 6,15 % pri razdelitvi na 15^0, interval zaupanja pa znaša 12,01^0.

Primerjava rozet smeri tektonskih con določenih s terenskim kartiranjem (slika 57 in 58) in s pomočjo letalskih posnetkov (slika 53 in 54), kaže manjše razlike. Najbolj pogosto zastopana smer tektonskih con je po obeh metodah primerljiva le v skupnem intervalu

8.0. TECTONIC-LITHOLOGICAL MAPPING OF THE SURFACE ABOVE THE POSTOJNSKA JAMA CAVE SYSTEM

8.1. Interpretation of the Aerial Photographs

We used aerial photographs to assist in mapping the surface. As in the case of Predjama (Šebela, 1995 a) aerial photographs were magnified to a scale of 1:5,000 for the surface above the Postojnska jama cave system at the Institute of Geodesy and Photogrammetry (Faculty of Architecture, Civil Engineering and Geodesy) in Ljubljana.

By stereoscopic observation of two aerial photographs we most easily create a relief picture of the territory we are investigating. In such a way we can define the course of tectonic lines which represent the characteristic morphology of the area territory. It is necessary to stress that in the aerial photographs we cannot distinguish different types of tectonic zones among them, e.g. fissured from broken or crushed. It is likewise not possible to distinguish fault deformations from overthrust ones, lithologically conditional lines from tectonic ones, and different tectonic zone dip angles. All these deficiencies demand checking and make up the data we have defined by the aerial photographs interpretation on the territory.

In Annex 5 there are presented geological structural elements, defined by the interpretation of the aerial photographs over the Postojnska jama cave system.

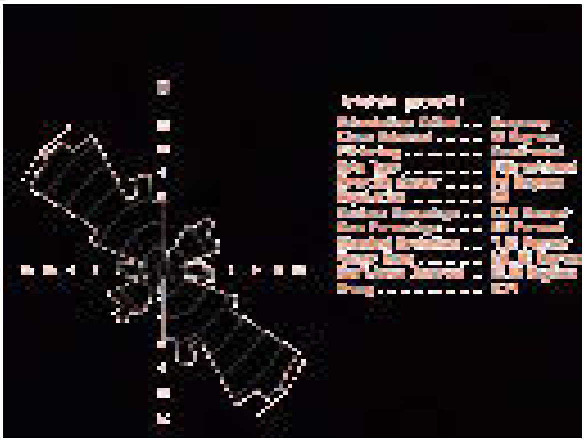
The tectonic zones directions defined by the aerial photographs observation frequency are presented in Figures 53 and 54. The most frequent are the tectonic zones in the 310-325^0 direction (20.6%) with repartition by 15^0 (Figure 53), or 310-320^0 (13.8%) with repartition of intervals by 10^0 (Figure 54) respectively.

The cross-Dinaric direction 40-50^0 is represented by less than 6% with repartition of intervals by 10^0 (Figure 54), and by less than 10% (direction 30-45^0) with repartition of intervals by 15^0 (Figure 53)

The standard deviation is 4.12% with repartition of intervals by 10^0, and 6.15% with repartition of intervals by 15^0, and the trust interval is 12.01^0.

The rose graphs comparison of tectonic zones orientation defined by the territory mapping (Figures 57

Slika 53. Pogostost smeri tektonsko pretrtih con določenih z interpretacijo letalskih posnetkov površja nad Postojnskim jamskim sistemom (razdelitev intervalov na 15^0).
Figure 53. Tectonically fractured zones directions frequency defined by the surface over the Postojnska jama cave system aerial photographs interpretation (partition of intervals by 15^0).



Slika 54. Pogostost smeri tektonsko pretrtih con določenih z interpretacijo letalskih posnetkov površja nad Postojnskim jamskim sistemom (razdelitev intervalov na 10^0).
Figure 54. Tectonically fractured zones directions frequency defined by the surface over the Postojnska jama cave system aerial photographs interpretation (partition of intervals by 10^0).

20^0. Pri povečavi letalskih posnetkov v merilo 1:5.000 je lahko prišlo do napak pri orientaciji, kar pomeni, da bi bila potrebna korekcija severa med vzhodnim in zahodnim delom slike letalskega posnetka.

Če vizuelno primerjamo potek tektonsko pretrtih con določenih z interpretacijo letalskih posnetkov (priloga 5) s tektonsko pretrtimi conami iz podrobnega tektonsko-litološkega kartiranja (priloga 6), je opazna dobra medsebojna povezava.

Še posebno se ujemajo tektonsko pretrte cone št. 1, 2, 4, 8, 9 in 10, medtem ko so tektonsko pretrte cone št. 3, 5, 6 in 7 na letalskih posnetkih nekoliko manj izrazite. Vzrok je lahko v različni vegetaciji terena ali pa v različni morfološki izraženosti določenih tektonskih con, kar povzroča slabšo interpretacijo letalskih posnetkov.

and 58), and by means of aerial photographs (Figures 53 and 54) shows minor differences. By applying both methods the most frequently represented tectonic zones direction is comparable only by the common interval 20^0. By magnifying aerial photographs to the scale of 1:5,000 orientation errors might appear, which means that a correction of N between the E and W side of the aerial photograph would be necessary.

If we visually compare the tectonically fractured zones course defined by the aerial photographs interpretation (Annex 5) with the tectonically fractured zones from detailed tectonic-lithological mapping (Annex 6), a good interacting connection is noticed.

The tectonically fractured zones Nos. 1, 2, 4, 8, 9 and 10 benefit particularly well, while the tectonically fractured zones Nos. 3, 5, 6 and 7 are a bit less expressive in the aerial photographs. The reason may be found in the different vegetation, or in different morphological expressiveness of the particular tectonic zones, which cause a poorer aerial photograph interpretation.

8.2. Litološko kartiranje površja

S podrobnim tektonsko-litološkim kartiranjem površja nad sistemom Postojnskih jam v merilu 1:2.500 smo zajeli zgornje kredni apnenec ter stik apnenca z eocenskim flišem. Skupna debelina plasti apnenca v litološkem stolpcu je 1.200 m (slika 2).

Po Rižnarju (1997) je tankoplastnat apnenec, ki vsebuje gomolje roženca, zgornje cenomanijske starosti. Na površju nad rovi sistema Postojnskih jam so to najstarejše razgaljene kamnine, ki jih najdemo severno in severovzhodno od Nemčjega vrha. Gospodarič (1976)

8.2. Lithological Mapping of the Surface

By detailed tectonic-lithological mapping of the surface over the Postojnska jama Cave System in the scale of 1:2,500 we have encompassed the Upper Cretaceous limestone and the limestone contact with the Eocene flysch. The total limestone thickness in the lithological column is 1,200 m (Figure 2).

According to Rižnar (1997) the thin-bedded limestone which contains nodules of cherts is of the Upper Cenomanian age. On the surface over the Postojnska je ta horizont uvrščal v turonij. Prevladuje siv do temno siv, tanko plastnat apnenec. Debelina kartiranih plasti (slika 2, c_1) je 165 m. Tanko plastnat apnenec vpada proti severu oziroma severovzhodu za 5-10^0. Na sliki 55, kjer so na Schmidtovi mreži prikazani poli plasti na površju nad sistemom Postojnskih jam, so najstarejše plasti predstavljene v skrajnem severovzhodnem delu.

Sledi debelo plastnat apnenec, katerega skupna debelina ne preseže 50 m (slika 2, c_2).

Zelo debelo plastnat, bel, spariten apnenec, ki gradi Magdaleno goro, Nemčji vrh in površje nad Pisanim rovom uvršča Rižnar (1997) še vedno v zgornji cenomanij. Na Nemčjem vrhu so v njem številni makroskopski ostanki hondrodont. Debelina belega apnenca s hondrodontami je nekaj metrov, debelina svetlega sparitnega apnenca, ki nima toliko fosilnih ostankov pa do 110 m (slika 2, c_4). Po Šribarju (1995) prištevamo hondrodontni horizont v spodnji turonij.

Ponekod so v spodnjem in zgornjem delu opisanega zelo debelo plastnatega belega apnenca postopni prehodi v prav tako zelo debelo plastnat svetlo rjav apnenec, ki doseže debelino do 35 m (slika 2, c_3).

V temenu Postojnske antiklinale so v posameznih poljih razgaljene ene najstarejših plasti kartiranega terena, ki pripadajo cenomaniju in turoniju. Med Magdaleno goro in Nemčjim vrhom teh plasti ni opaziti. Za to obstajata dve razlagi. Po prvi vse plasti niso bile enakomerno erodirane, po drugi je v tem delu os antiklinale globje, kot npr. na Magdaleni gori in Nemčjem vrhu. Domnevamo, da apnenec v tem delu ni bil erodiran v takšni meri kot na Magdaleni gori ali Nemčjem vrhu.

V splošnem velja, da je vpad plasti na severovzhodnem krilu antiklinale manjši kot na jugozahodnem (slika 55), saj gre za proti JZ nagnjeno gubo.

Na jugozahodnem krilu antiklinale so geološki elementi vpada plasti zelo konstantni. Vpadajo proti jugozahodu v povprečju za 30-40^0. Debelina plasti na

jama cave sytem this is the oldest bare rock which can be found N and NE from Nemčji vrh. Gospodarič (1976) classified this horizon as Turonian. There prevails grey to dark grey thin-bedded limestone. The mapped bedding thickness (Figure 2, c_1) is 165 m. The thin-bedded limestone dips towards N or NE respectively for 5-10^0. In Figure 55 where in the Schmidt's net the bedding poles are presented on the surface over the Postojnska jama cave system, there are the oldest beds presented in the most NE section.

There follows thick-bedded limestone whose total thickness does not exceed 50 m (Figure 2, c_2).

Rižnar (1997) still classifies the very thick-bedded, white, sparitic limestone which builds up Magdalena gora, Nemčji vrh, and the surface over Pisani rov, as Upper Cenomanian. In Nemčji vrh there are numerous microscopic remains of *Chondrodonta*. The white limestone thickness with *Chondrodonta* is some metres, and the light sparitic limestone with not as many fossil remains up to 110 m (Figure 2, c_4). According to Šribar (1995) the *Chondrodonta* horizon is being included in the Lower Turonian.

In places there are gradual transitions and likewise very thick-bedded light brown limestone in the lower and upper section of the very thick-bedded white limestone already mentioned which achieve a thickness of 35 m (Figure 2, c_3).

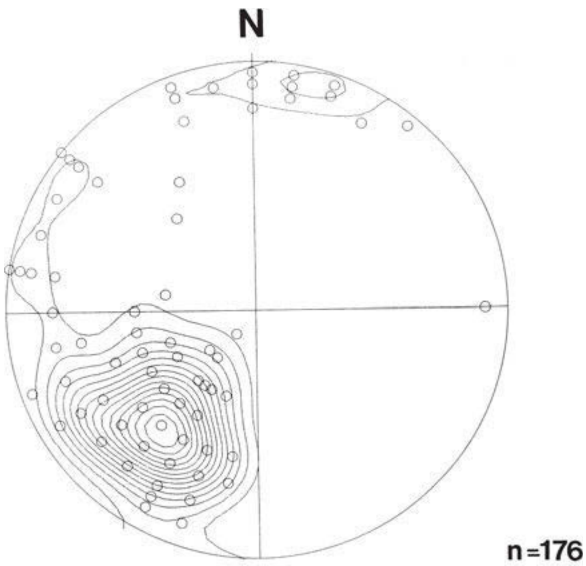
In the particular area of the Postojna anticline crest there are among the oldest mapped territory visible beds, and they belong to Cenomanian and Turonian. These beds are not noticed between Magdalena gora and Nemčji vrh. There are two explanations for this. Firsty all the bedding planes were not symmetrically eroded, and secondly the anticline axis in this section is deeper than e.g. at Magdalena gora and Nemčji vrh.

It is generally true that the bedding plane dip in the anticline's NE flank is smaller than in the SW one (Figure 55), as there is an inclined fold towards the SW.

In the SW flank of the anticline the bedding plane dip geological elements are very constant. They dip towards SW for 30-40^0 on average. In this anticline flank the bedding thickness is various, but there is mainly the thick-bedded limestone (0.5 to 1 m).

In the lithological column there follows the Turonian thick-bedded brown-grey coloured limestone (Figure 2, c_5). It is 290 m thick. Over the whole territory this limestone dips towards SW for 30-40^0 on average. Among fossil remains rudists are the most common.

The Senonian bedding planes begin with a very



Slika 55. Schmidtova mreža – geološki elementi plasti apnenca na površju nad Postojnskim jamskim sistemom (n=176).

Figure 55. Schmidt's net – limestone bedding planes geological elements on the surface over the Postojnska jama cave system (n=176).

tem krilu antiklinale je različna, večinoma pa gre za debelo plastnat apnenec (0,5 do 1 m).

V litološkem stolpcu sledi turonijski debelo plastnat apnenec rjavo sive barve (slika 2, c_5). Njegova debelina je 290 m. Na celotnem terenu vpadajo ti apnenci proti jugozahodu povprečno za 30-40^0. Od fosilnih ostankov prevladujejo rudisti.

Senonijske plasti se začno z zelo debelo plastnatim apnencem rjavo sive barve, ki je ponekod zelo bogat z rudistnimi ostanki. Debelina tega horizonta je 420 m (slika 2, c_6).

Debelo plastnat apnenec senonijske starosti je najbolj izrazit ob ponoru ponikalnice Pivke. Debelina horizonta je 130 m.

Po raziskavah Rižnarja (1997) najdemo med vhodom v Postojnsko jamo in slepo dolino Risovec bazalne sedimente fliša (apnenčeva breča z vložki konglomerata in laporja), ki so odloženi erozijsko diskordantno na karbonatne platformske sedimentne kamnine (slika 2, c_8). Po starosti uvrščamo člen v thanetij, ypresij (Pc_2, E_1), njegova debelina je nekaj metrov (Rižnar, 1997).

Najmlajše sedimentne kamnine predstavlja eocenski fliš (slika 2, c_9).

thick-bedded brown-grey coloured limestone which is very rich in rudist remains in places. This horizon is 420 m thick (Figure 2, c_6).

The thick-bedded limestone of the Senonian age is most expressive by the sump of river Pivka. The horizon is 130 m thick.

Between the Postojnska jama cave entrance and the Risovec blind valley, according to researches by Rižnar (1997), we find basal flysch sediments (limestone breccia with pieces of conglomerate and shale) which are erosive discordantly deposited on the carbonate platform sedimentary rocks (Figure 2, c_8). The link is classified as Thanetian, Ypresian (Pc_2, E_1), and it is some metres thick (Rižnar, 1997).

The youngest sedimentary rocks are represented by the Eocene flysch (Figure 2, c_9).

8.3. Tektonsko kartiranje površja

Površje nad sistemom Postojnskih jam leži v širšem regionalnem smislu med Idrijskim prelomom na severovzhodu in Predjamskim na jugozahodu (priloga 1). Na terenu, ki sem ga podrobno tektonsko kartirala v merilu 1:2.500 (priloga 6), ločimo starejše deformacije narivanja in gubanja od mlajših prelomnih deformacij.

Na preučevanem terenu je teme Postojnske antiklinale najbolj določljivo le nekaj metrov južno od vrha Magdalene gore (priloga 6, kota 625 m v skrajnem severnem delu), kar se dobro ujema s podatki kartiranja severozahodno od tod (Čar, 1982) in kartiranjem Rižnarja (1997). Teme antiklinale zajema 25-50 meterski pas.

V nadaljevanju je moč slediti antiklinali na severnem pobočju Nemčjega vrha (priloga 6, kota 632), kar se dobro ujema tudi s podatki iz jamskih rovov. Nadaljevanje antiklinale proti jugovzhodu je slabše določljivo. Glede na smer vpada plasti apnenca poteka antiklinala po severnem robu Velike Jeršanove doline. Kaže, da so v tem delu kasnejše prelomne deformacije močno spremenile in zabrisale njen potek. Druga možnost je, da je njeno teme sestavljeno iz več manjših, sekundarno zgubanih plasti, na kar kaže velika neurejenost elementov vpada plasti na njenem temenu. Podobne razmere je v jami opisoval Gospodarič (1976).

Splošna smer osi Postojnske antiklinale je severozahod-jugovzhod. Glede na podatke, ki sem jih dobila v jami in glede na položaj temena antiklinale na površju, lahko zaključim, da je osna ravnina nagnjena proti jugozahodu. Vergenca gube je 7-14^0 proti jugozahodu,

8.3. Tectonic Mapping of the Surface

In a larger regional sense the surface over the Postojnska jama Cave System lies between the Idrija fault in the NE and the Predjama fault in the SW (Annex 1). On the territory which I have tectonically mapped in detail at the scale of 1:2,500 (Annex 6), we distinguish the older deformations of overthrusting and folding from the younger fault deformations.

In the studied area the Postojna anticline crest is most definable only some metres S from the top of Magdalena gora (Annex 6, Hill 625 m in the extreme N section), which agrees well with the mapping data to the NW from there (Čar, 1982), and mapping by Rižnar (1997). The anticline crest encompasses a 25-50 m wide zone.

It is further possible to follow the anticline on the N and NW slope of Nemčji vrh (Annex 6, Hill 632), which also agrees well with the cave passages data. The further anticline towards the SE is less definable. According to the limestone bedding dip and strike the anticline runs along the S edge of Velika Jeršanova dolina. It seems that later fault deformations strongly modified and blurred its course. Another possibility indicates that its crest consists of many smaller, secondarily folded beds, which is indicated by a great bedding plane dip disorder of geological elements at its crest. Similar conditions in the cave was being described by Gospodarič (1976).

The general Postojna anticline crest direction is NW – SE. According to data I have obtained in the gre za asimetrično, deloma proti jugozahodu nagnjeno gubo. Glavni pritiski za takšno deformacijo so bili torej usmerjeni od severovzhoda proti jugozahodu. Takšne pritiske poudarja tudi Placer (1996) pri zgradbi Soviča.

Postojnska antiklinala tone proti severozahodu (Gospodarič, 1976; Čar, 1983). Njeno teme spremljajo vzporedne prelomne cone, ki so v genetski zvezi z oblikovanjem antiklinale. Najbolj so izrazite v bližini Nemčjega vrha. Tudi medplastni zdrsi so v genetski zvezi z gubanjem oziroma predstavljajo sekundarne deformacije gubanja.

Razmere severno od Nemčjega vrha kažejo, da je bil v tem delu skoraj ves del senonijskih plasti (840 m) erodiran.

Gubanju so sledile prelomne deformacije, ki so najmlajše tektonske deformacije na tem terenu. Njihovo genetsko razdelitev sem povzela po Čarju in Gospodariču (1984). Na prilogi 6 so pomembnejše prelomne cone označene s številkami od 1 do 10.

Čar je 1982 opozoril na stare prelomne deformacije smeri severovzhod-jugozahod, na katere je navezal položaj Postojnskih vrat ter večje udornice med sistemom Postojnskih jam in Planinsko jamo. Takim deformacijam ustrezata prelomni coni št. 8 in 10. Tudi potek jamskih rovov dela Podzemeljske Pivke in Pivke jame lahko povezujemo z omenjenima prelomnima conama.

Čar in Gospodarič (1984) sta kot prvo generacijo prelomnih deformacij določila prelomne sisteme v smeri severovzhod-jugozahod. Na prilogi 6 sta tako usmerjeni prelomni coni št. 8 in 10, medtem ko ima prelomna cona št. 9 splošno smer vzhod-zahod.

Prelomno cono št. 9 (160-170^0) je mogoče slediti preko celotnega terena. Mlajše, Dinarsko usmerjene prelomne cone, in sicer št. 1, 2, 3, 4, 5 in 6 jo sekajo in zamikajo. Najdaljši neprekinjen odsek, ki znaša okrog 300 m, je med prelomnima conama št. 4 in 5. Na sečišču z mlajšo Dinarsko prelomno cono št. 4, se je ob prelomni coni št. 9 oblikovala udornica Stara apnenica in nekoliko severno manjša udornica Kafrna dolina.

Ob prelomni coni št. 8 in Dinarsko usmerjenih prelomnih conah št. 1, 2 in 3 se je oblikovala nekdanja slepa dolina Risovec. Prelomna cona št. 8 je z Dinarskimi prelomnimi conami prekinjena in močno deformirana, tako da ji je moč slediti le po odsekih. Zanimivo je, da prelomno cono št. 5 celo seka. Po Čarju & Gospodariču (1984) so prelomi tretje generacije reaktivirani prečno Dinarski prelomi, če le-ti sledijo istim conam, tako da je v tem primeru to smiselna razlaga.

Na skrajnem severnem in severovzhodnem delu terena (priloga 6) sem našla dve prelomni coni, ki sta vzporedni prelomni coni št. 9.

Prečno Dinarske smeri 1. in verjetno 3. generacije (Čar & Gospodarič, 1984) je prelomna cona št. 10. Ob vhodu v sistem Postojnskih jam se je ob eni od prelomnih ploskev oblikovala morfološka stena. Prelomna cona št. 10 je verjetno del širše vzporedne prelomne cone prečno Dinarske smeri. Tako kot sekajo Dinarske

cave, and according to the anticline crest position on the surface, I may conclude that the axis plane is inclined towards SW. The fold vergence is 7-14^0 towards the SW, it is an asymmetric, partially towards the SW inclined fold. Main pressures for such a deformation were from NE towards SW. Such pressures are also stressed by Placer (1996) in the Sovič construction.

The Postojna anticline sinks towards the NW (Gospodarič, 1976; Čar, 1983). Its crest is accompanied by parallel fault zones which are in a genetic connection with the anticline formation. They are most expressive at Nemčji vrh. Likewise the interbedded movements are in a genetic connection with folding, or they represent secondary folding deformations.

The conditions to the N from Nemčji vrh show that in this section almost the entire part of the Senonian beds (840 m) was eroded.

Folding was followed by fault deformations which are the youngest tectonic deformations on this area. I summarised their genetic repartition from Čar and Gospodarič (1984). In Annex 6 the more important fault zones are indicated by numbers from 1 to 10.

In 1982 Čar drew attention to the old fault deformations in the NE – SW direction when he established the Postojnska vrata position, and the large collapse dolines between the Postojnska jama cave system and Planinska jama. The fault zones Nos. 8 and 10 correspond to such deformations. We may likewise connect a part of the Podzemeljska Pivka and Pivka jama cave passages with these fault zones.

Čar and Gospodarič (1984) defined the fault systems in the NE – SW direction as the first generation of fault deformations. In Annex 6 fault zones Nos. 8 and 10 are thus oriented, while fault zone No. 9 has a general direction E-W.

Fault zone No. 9 (160-170^0) is possible to follow over the whole territory. The younger Dinaric oriented fault zones, i.e. Nos. 1, 2, 3, 4, 5 and 6 cross it and move it. The longest uninterrupted section of about 300 m lies between fault zones Nos. 4 and 5. At the intersection with the younger fault zone No. 4, along fault zone No. 9, there was formed the Stara apnenica collapse doline, and a little to the N the smaller Kafrna dolina collapse doline.

Along fault zone No. 8 and the Dinaric oriented fault zones Nos. 1, 2 and 3 there was formed the former Risovec blind valley. Fault zone No. 8 is disconnected and strongly deformed by Dinaric fault zones, therefore, it might be followed just along the sections. It is interesting that it even crosses fault zone No. 5. According to Čar and Gospodarič (1984) the third generation faults are reactivated cross-Dinaric faults if they follow the same zones, thus in this case it is a reasonable explanation.

In the extreme N and NE part of the territory (Annex 6) I found two fault zones which are parallel to fault zone No. 9.

prelomne cone cono št. 8, prekinjajo tudi prelomno cono št. 10. Ta je zopet nekoliko bolj močna na vzhodnem delu terena, kjer jo seka prelomna cona št. 5 (priloga 6).

Dinarsko usmerjene prelomne cone so na prilogi 6 označene s številkami od 1 do 7. Po Čarju & Gospodariču (1984) so Dinarske prelomne cone 2. in 4. generacije. Prelomne cone št. 2, 3, 4, 5, 6 in 7 so verjetno 2. in 4. generacije, medtem ko je prelomna cona št. 1 4. generacije.

Severno od prelomne cone št. 1 poteka prelomna cona št. 2 (priloga 6). Proti jugovzhodu se prelomna cona št. 2 priključi drugi coni, ki se v začetku nekdanje slepe doline Risovec odceplja od prelomne cone št. 1. V smeri proti ponornemu vhodu v sistem Postojnskih jam se izrazitost zdrobljene cone št. 2 zmanjša, saj prehaja v porušeno cono. Dinarska smer vpada prelomne cone št. 2 se spreminja od 60^0 na severozahodnem delu terena preko 40^0 severno od hriba Kacul do 70^0 pri vhodu v sistem Postojnskih jam.

Današnji vhod v Otoško jamo (slika 56) je oblikovan v zdrobljeni coni, ki proti severu prehaja v porušeno 60^0. Približno po 70 metrih proti jugovzhodu se ta naslanja na prelomno cono št. 3. Od slepe doline Risovec do večje udorne vrtače zahodno od Stare apnenice so geološki elementi prelomne cone št. 3 210/80. Proti jugovzhodu se prelomna cona št. 3 cepi v severnejšo porušeno cono 50^0 in južnejšo šibkejšo prelomno cono enake smeri.

Prelomna cona št. 4 je ena opaznejših na terenu, saj jo lahko zvezno sledimo čez celoten teren. Njena

Fault zone No. 10 is of the 1^{st} and probably 3^{rd} generation cross-Dinaric direction (Čar & Gospodarič, 1984). By the Postojnska jama cave system entrance a morphological wall along one of the fault planes was formed. Fault zone No. 10 is probably a part of a larger parallel cross-Dinaric direction fault zone. In the same way as the Dinaric fault zones cross fault zone No. 8, they also disconnect fault zone No. 10. This is again somehow stronger in the E part of the territory, where it is crossed by fault zone No. 5 (Annex 6).

In Annex 6 the Dinaric oriented fault zones are indicated by numbers from 1 to 7. As to Čar and Gospodarič (1984) they are the 2^{nd} and 4^{th} generation Dinaric fault zones. Fault zones Nos. 2, 3, 4, 5, 6 and 7 are probably of the 2^{nd} and 4^{th} generations, while fault zone No. 1 is of the 4^{th} generation.

To the N from fault zone No. 1 there runs fault zone No. 2 (Annex 6). Towards SE fault zone No. 2 joins another zone which diverges from fault zone No. 1 at the beginning of the Risovec blind valley. In the direction towards the river entrance the expressiveness of crushed zone No. 2 decreases, as it passes over to the broken zone. Fault zone No. 2 with Dinaric dip and strike modifies from 60^0 in the NW territory section, over 40^0 in the N from the Kacul hill, to 70^0 at the Postojnska jama entrance.

The present Otoška jama entrance (Figure 56)

Slika 56. Vhod v Otoško jamo (foto S. Šebela).
Figure 56. Entrance to Otoška jama (photo S. Šebela).

notranja prelomna cona je široka 2 do 10 m, zunanja, ki jo sestavlja močna porušena cona, pa 25 do 50 m. Na severozahodnem delu terena vpada proti jugozahodu, na jugovzhodnem delu proti severovzhodu oziroma je subvertikalna, medtem ko pred ponornim vhodom v sistem Postojnskih jam zopet vpada proti jugozahodu.

Med prelomnimi conami št. 4 in 5 ter 9 na jugu, so na celotnem raziskanem terenu (priloga 6) kraški površinski pojavi najbolj razviti. V debelo plastnatem apnencu so zelo dobro izraženi sistemi škrapelj, ki so se oblikovali v razpoklinskih in porušenih conah. Širina porušeno-razpoklinskega sistema je do 750 m. V njem so posamezne porušene ali razpoklinske cone, široke do 100 m. Cone potekajo v smeri 100-120^0 ter v smeri sever-jug, kar je v soglasju s Čarjem (1982), ki ugotavlja, da smeri pretrtih con znotraj porušeno-razpoklinskih sistemov varirajo za 20-30^0. Glede na njihov položaj predstavljajo vezne cone med Dinarsko usmerjenimi prelomnimi conami. Zelo pogosti so postopni prehodi v bočni smeri, kot tudi v smeri slemenitve iz ene vrste tektonske cone v drugo. Kot je ugotovil že Čar (1982), so porušene in predvsem razpoklinske cone za vodo dobro prepustne.

Dinarsko usmerjena prelomna cona št. 5 je na terenu zelo izražena. V njenem severozahodnem delu je razvit morfološko dobro opazen niz vrtač. Še posebno močno je izražena v predelu, kjer se ji s severozahoda priključi skoraj vzporedna prelomna cona. Slednja, za razliko od prelomne cone št. 5, tudi prekinja prelomno cono 120^0, ki predstavlja nadaljevanje prečno Dinarske prelomne cone št. 8.

Po vzhodnem pobočju Magdalene gore poteka do 100 m široka prelomna cona, ki je na prilogi 6 označena s št. 6. Na njenem severovzhodnem delu se od nje odceplja močna prelomna cona št. 7, v kateri so se oblikovale večje vrtače in celo del Velike Jeršanove doline.

Na Nemčjem vrhu so kamnine tektonsko zelo pretrte, saj ležijo med prelomnima conama št. 6 in 7. Njegovo severovzhodno pobočje je morfološko precej strmo, tako da pobočni grušč prekriva izdanke apnenca, kar pri kartiranju otežuje določitev geoloških strukturnih elementov. Kljub temu sem lahko določila dve močnejši prelomni coni, ki se severozahodno od Nemčjega vrha združita v enotno porušeno do zdrobljeno cono. Severnejša prelomna cona je še posebno dobro določljiva južno od Velike Jeršanove doline. Na Nemčjem vrhu so jasno izražene tudi prečno Dinarske porušene do zdrobljene cone 130-150^0.

Velika Jeršanova dolina se je oblikovala po prelomni coni št. 7 ter porušeni do zdrobljeni coni 70-80^0.

Najmlajša prelomna cona, ki je 4.generacije (Čar & Gospodarič, 1984), je Dinarsko usmerjena in je na prilogi 6 označena s št.1. Predstavlja tektonsko zdrobljeno cono, ki ji sledimo še pred dolino Risovec, vzdolž stika fliš-apnenec, mimo vhoda v sistem Postojnskih jam in naprej proti jugovzhodu. Notranja prelomna cona je

is formed in the crushed zone which passes over into the broken zone 60^0 towards N. After approximately 70 metres towards the SE it leans against fault zone No. 3. From the Risovec blind valley to a bigger collapse doline in the W from Stara apnenica, the fault zone No. 3 geological elements are 210/80. Towards the SE fault zone No. 3 is split into a more N broken zone 50^0 and a more S weaker fault zone of the same strike.

Fault zone No. 4 is one of the more visible on the territory, as it can be continously followed over the entire territory. Its inner fault zone is 2 to 10 m wide, and its outer one which consists of a strong broken zone, is 25 to 50 m wide. In the NW territory section it dips towards the SW, in the SE section towards the NE, or it is sub-vertical, while in front of the Postojnska jama river sink entrance it dips again towards SW.

Among fault zones Nos. 4 and 5, and 9 in the S, the karst surface features are the most developed on the whole territory studied (Annex 6). In the thick-bedded limestone the fissure systems which were formed in fissured and broken zones are very well expressed. The broken-fissured system width is 750 m. Therein are particular broken or fissured zones up to 100 m wide. The zones run in the 100-120^0 dip direction, and in the N-S direction, what is in conformity with Čar (1982) who states that the fractured zones inside the broken-fissured systems vary for 20-30^0. According to their position they represent connective zones among Dinaric oriented fault zones. There are very frequent gradual crossings in the lateral direction, as well as in the ridging direction from one tectonic type zone into another. As Čar (1982) already stated, the broken and above all the fissured zones are well permeable to water.

The Dinaric oriented fault zone No. 5 is well expressed on the territory. In its NW section a morphologically well noticed series of dolines is developed. It is especially strongly expressed in the region where an almost parallel fault zone joins to it from the NW. In contrast to fault zone No. 5 the parallel fault zone also disconnects the fault zone 120^0 which represents the cross-Dinaric fault zone No. 8 continuity.

Along the E slope of Magdalena gora there runs a fault zone up to 100 m wide which is indicated by No. 6 in Annex 6. In its NE section there diverges from it the strong fault zone No. 7 wherein bigger dolines and even a part of Velika Jeršanova dolina were formed.

At Nemčji vrh the rocks are tectonically strongly fractured, as they lie between fault zones Nos. 6 and 7. Its NE slope is morphologically quite steep, thus the slope gravel covers the outcrops of limestone, which makes the geological structural elements definition mapping difficult. In spite of that I could define two stronger fault zones which in the NW from Nemčji vrh join into a united broken to crushed zone. The more N fault zone is especially well defined in the S from Velika Jeršanova dolina. At Nemčji vrh the cross-Dinaric broken to široka do 10 m, zunanja pa do 50 m. V zdrobljeni coni je apnenec porušen do stopnje tektonske breče. V zunanji prelomni coni sledimo spremljajoče vzporedne porušene cone, ponekod pa tudi prečne porušene do zdrobljene cone. Tak primer je dobro viden na hribu Kacul ter pri vhodu v jamo Lekinko, kjer je smer vpada porušenih do zdrobljenih con 110^0.

Ob prelomnih ploskvah v prelomni coni št. 1 so ponekod opazni sledovi tektonskih premikov vendar ni bilo mogoče zanesljivo določiti smeri in velikosti premikov.

Prelomna cona št.1 seka vse starejše deformacije terena in je genetsko najmlajša. Glede na njen položaj na severovzhodnem robu Pivške kotline, jo lahko upravičeno uvrščamo v zunanjo prelomno cono Predjamskega preloma. Na to ugotovitev se sklicuje tudi Placer (1996).

Če prenesemo genetsko klasifikacijo prelomnih con iz leta 1984 (Čar & Gospodarič) na teren nad sistemom Postojnskih jam, so 1. generacije prelomne cone št. 8, 9 in 10. Druge generacije so Dinarsko usmerjene prelomne cone, ki prevladujejo na celotnem terenu kot št. 2, 3, 4, 5, 6 in 7. Reaktivirani prečno Dinarski prelomi, kot št. 8 in 10 so 3. generacije. Najbolj jasen primer za 4. generacijo, ki predstavlja Dinarske prelome, ki sekajo vse starejše strukture, je na terenu nad sistemom Postojnskih jam prelomna cona št. 1, ki je del širše prelomne cone Predjamskega preloma.

Pri površinskem terenskem geološkem kartiranju ob Dinarsko usmerjenih prelomnih conah nismo zasledili več meterskih horizontalnih ali vertikalnih premikov.

crushed zones $130\text{-}150^0$ are also clearly expressed.

Velika Jeršanova dolina was formed along fault zone No. 7, and along the broken and crushed zone $70\text{-}80^0$.

The youngest fault zone, which is of the 4^{th} generation (Čar & Gospodarič, 1984), is Dinaric oriented, and indicated by No. 1 in Annex 6. It represents a tectonically crushed zone which is followed in front of the Risovec valley, along the flysch-limestone contact by the Postojnska jama cave system entrance, and further to the SE. The inner fault zone is up to 10 m wide, and the outer one up to 50 m. In the crushed zone the limestone is broken to tectonic breccia level. In the outer fault zone we follow accompanying parallel broken zones, and in places also transverse broken to crushed zones. Such a case is well visible on the Kacul hill, and at the Lekinka cave entrance where the broken to crushed zones dip direction is 110^0.

Along the fault planes in the fault zone No. 1 traces of tectonic movements are noticed in places, but it was not possible reliably to define these movement's direction and size.

Fault zone No. 1 crosses all the older territory deformations, and is genetically the youngest. According to its position at the NE Pivka basin edge we may rightly classify it in the Predjama fault outer fault zone. Placer (1996) also agrees with this statement.

If we transfer the fault zones genetic classification from 1984 (Čar & Gospodarič) onto the territory over the Postojnska jama system, the 1^{st} generations are fault zones Nos. 8, 9 and 10. The 2^{nd} generations are Dinaric oriented fault zones which prevail over the entire territory as Nos. 2, 3, 4, 5, 6 and 7. The reactivated cross-Dinaric faults, as Nos. 8 and 10, are the 3^{rd} generations. The most clear example for the 4^{th} generation which represents those Dinaric faults which cross all the older structures is fault zone No. 1 on the territory over the Postojnska jama cave system, which is part of a larger fault zone of the Predjama fault.

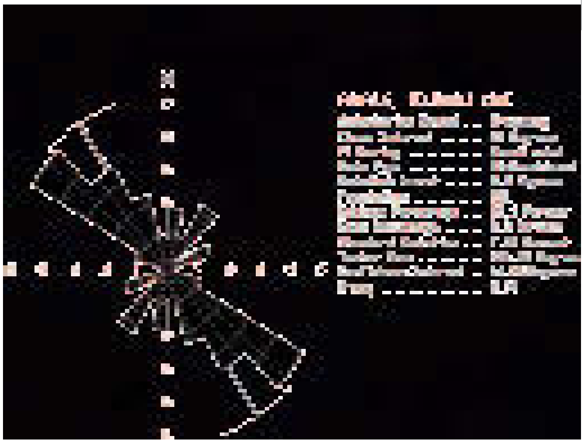
After the surface territory geological mapping along the Dinaric oriented fault zones we did not detect bigger horizontal or vertical movements.

8.4. Statistična analiza pogostosti smeri tektonsko pretrtih con na površju

Pogostosti smeri tektonsko pretrtih con, ki sem jih dobila s podrobnim kartiranjem površja nad jamskimi rovi, sem prikazala z rozetami (slika 57 in 58). Najpogostejša smer tektonsko pretrtih con na površju nad rovi sistema Postojnskih jam je zastopana s 25,1% (smer $300\text{-}315^0$ pri razdelitvi intervalov na 15^0, slika 57), oziroma s 17,5% (smer $320\text{-}330^0$ pri razdelitvi intervalov na 10^0, slika 58). Prečno Dinarska smer $30\text{-}45^0$ je zastopana z 11% (pri razdelitvi intervalov na 15^0, slika 57).

8.4. Statistical Analisys of the Tectonically Fractured Zone Direction Frequencies on the Surface

I have presented the tectonically fractured zones direction frequency which I obtained by a detailed mapping of the surface over the cave passages by rose graphs (Figures 57 and 58). The most frequent tectonically fractured zones direction on the surface over Postojnska jama cave system passages is represented by 25.1% ($300\text{-}315^0$ direction with repartition of intervals by 15^0, Figure 57), or by 17.5% ($320\text{-}330^0$ direction with repartition of intervals by 10^0, Figure 58) respectively.



Slika 57. Rozeta, pogostost smeri tektonsko pretrtih con na površju nad sistemom Postojnskih jam (razdelitev intervalov na 15^0).

Figure 57. Rose graph, tectonically fractured zones directions frequency on the surface over the Postojnska jama cave system (partition of intervals by 15^0).

Glede na statistično analizo pogostosti smeri tektonsko pretrtih con na površju nad sistemom Postojnskih jam so najpogostejše Dinarsko usmerjene tektonske cone.

Standardna deviacija je 4,76% (pri razdelitvi intervalov na 10^0, slika 58) in 7,09% (pri razdelitvi intervalov na 15^0, slika 57), interval zaupanja pa 14,25^0.

Primerjava rozet smeri tektonsko pretrtih con merjenih v jamskih rovih (slika 36 in 37) in tektonsko pretrih con merjenih na površju (slika 57 in 58) kaže različne najbolj pogosto zastopane smeri. Vzrok moramo iskati v različnem merilu terenskega geološkega kartiranja v jamskih rovih (1:500) in na površju (1:2.500), kot tudi v sami izbiri podatkov za statistično analizo. V primeru tektonskih con v sistemu Postojnskih jam so statistično ovrednotene le tektonske meritve v jamskih rovih, ne pa tudi tektonske cone, ki potekajo po kamnini med rovi. Z rozetama na slikah 57 in 58 pa smo zajeli širše površje nad jamskimi rovi, pri čemer ni vključena Pivka jama.

Primerjava pogostosti smeri tektonskih con določenih s podrobnim kartiranjem površja in tektonskih con določenih z interpretacijo letalskih posnetkov kaže na določene razlike. Pri razdelitvi intervalov na 10^0 je smer 320-330^0 najbolj pogosto zastopana pri terenskih meritvah (slika 58), smer 310-320^0 pa pri tektonskih conah določenih na podlagi letalskih posnetkov (slika 54). Če združimo intervale v večji razpon (20-30^0), so podatki bolj primerljivi.

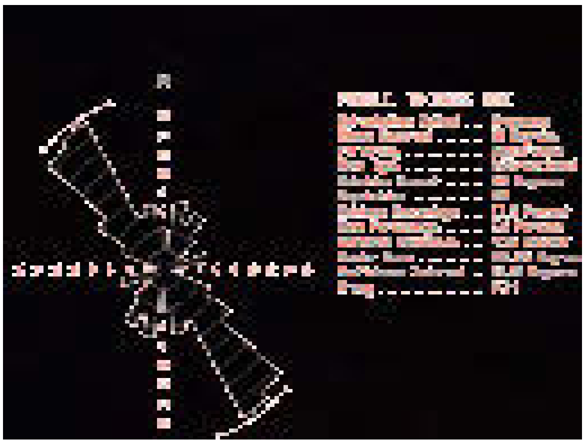
The cross-Dinaric direction 30-45^0 is represented by 11% (with repartition of intervals by 15^0, Figure 57).

According to the statistical analysis of the tectonically fractured zones direction frequency on the surface over the Postojnska jama Cave System the most frequent are the Dinaric oriented tectonic zones.

The standard deviation is 4.76% (with repartition of intervals by 10^0, Figure 58), and 7.09% (with repartition of intervals by 15^0, Figure 57), and the trust interval 14.25^0.

Comparison of the tectonically fractured zones direction rose graphs measured in the cave passages (Figures 36 and 37), and the tectonically fractured zones measured on the surface (Figures 57 and 58) show different most frequently represented directions. The reason should be sought in the different territory geological mapping scales in the cave passages (1:500) and on the surface (1:2,500), as well as in the statistical analysis data choice itself. In the Postojnska jama cave system tectonic zones example only the tectonic measurements in the cave passages are statistically evaluated, and not the tectonic zones which run among passages along the bedrock. But by the rose graphs in Figures 57 and 58 we have encompassed a larger area over the cave passages, wherein Pivka jama is not included.

The tectonic zones direction frequency comparison defined by a detailed mapping of the surface, and the tectonic zones defined by the aerial photographs interpretation points out some particular differences. With repartition of intervals by 10^0 the 320-330^0 direction is most frequently represented with the territory measurements (Figure 58), and the 310-320^0 direction with the tectonic zones defined on the basis of aerial photographs (Figure 54). If we unite the intervals into a larger ratio (20-30^0), the data are more comparable.



Slika 58. Rozeta, pogostost smeri tektonsko pretrtih con na površju nad sistemom Postojnskih jam (razdelitev intervalov na 10^0).

Figure 58. Rose graph, tectonically fractured zones directions frequency on the surface over the Postojnska jama cave system (partition of intervals by 10^0).

8.5. Morfološke značilnosti kraškega površja

Pri podrobnem tektonsko-litološkem kartiranju površja nad sistemom Postojnskih jam sem proučevala tudi morfološke značilnosti, povezane z geološko strukturo. Pri tem je največja pozornost posvečena razporeditvi vrtač, udornic in slepih dolin (slika 59) v odvisnosti od tektonsko-litoloških zakonitosti.

8.5.1. Vrtače

Na površju nad sistemom Postojnskih jam je teren razčlenjen s številnimi vrtačami in udornicami (slika 59). Čar in Gospodarič (1984) sta za površje nad Pivko in Črno jamo naredila detaljno geološko karto. Določila sta tudi več tipov vrtač glede na geološke značilnosti. Na povezavo oblikovanja podornih dvoran v rovih JV dela sistema Postojnskih jam in vrtač nad podornimi dvoranami v povezavi z aktivnostjo istih tektonskih con smo opozorili v letu 1996 (Šebela).

V predelu med hribom Kacul, slepo dolino Risovec in Staro apnenico v debelo plastnatem do masivnem apnencu skoraj ni vrtač. Tudi v predelu JV od Kafrne doline skoraj ni vrtač, vendar gre tu za umetno spremenjeno kraško površje, saj je bil v tem delu vojaški poligon. Največja gostota vrtač je v pasu med Nemčjim vrhom in Staro apnenico ter v pasu okrog Pivka jame.

Med jamo Koliševko in Staro apnenico opazujemo na severnem in severovzhodnem pobočju številnih vrtač podorne bloke in grušč. Pobočni material se je večinoma luščil po lezikah poudarjenih z medplastnimi zdrsi. Pomembno vlogo pa so imele tudi tektonsko pretrte cone, ki potekajo v smeri S-J, oziroma od severa odstopajo za 10-20^0 proti vzhodu. Razpoklinske do porušene cone so lahko široke do 100 m, gre pa za odprte razpoke, ki so dobro prevodne za vodo, tako v vertikalni kot horizontalni smeri. Pod temi vrtačami ni znanih jamskih rovov.

Nekatere večje vrtače se združujejo v nize, ki so se oblikovali v prelomnih conah Dinarske smeri. Tak primer je v prelomnih conah št. 4, 5 in predvsem 7 (priloga 6).

Na površju neposredno nad rovi sistema Postojnskih jam je 42 vrtač (slika 59). Nekaj manj kot polovica, in sicer 40,47 % vrtač (17 primerov) je oblikovanih nad podornimi dvoranami. Te vrtače, kot tudi podorne dvorane, so oblikovane v regionalno najmočneje izraženih prelomnih conah in so tako genetsko vezane na tektonsko pretrte cone. Vertikalno prenikanje v vadozni coni je na takih mestih običajno zelo dobro, kar dokazujejo tudi kamini na stropih podornih dvoran.

Vrtače nad podornimi dvoranami najdemo nad

8.5. Morphological Characteristics of the Karst Surface

By a detailed tectonic-lithological mapping of the surface over the Postojnska jama cave system I have also studied morphological characteristics connected with the geological structure. The greatest attention was devoted to sort out dolines, collapse dolines and blind valleys (Figure 59) in dependence on tectonic-lithological legitimacy.

8.5.1. Dolines

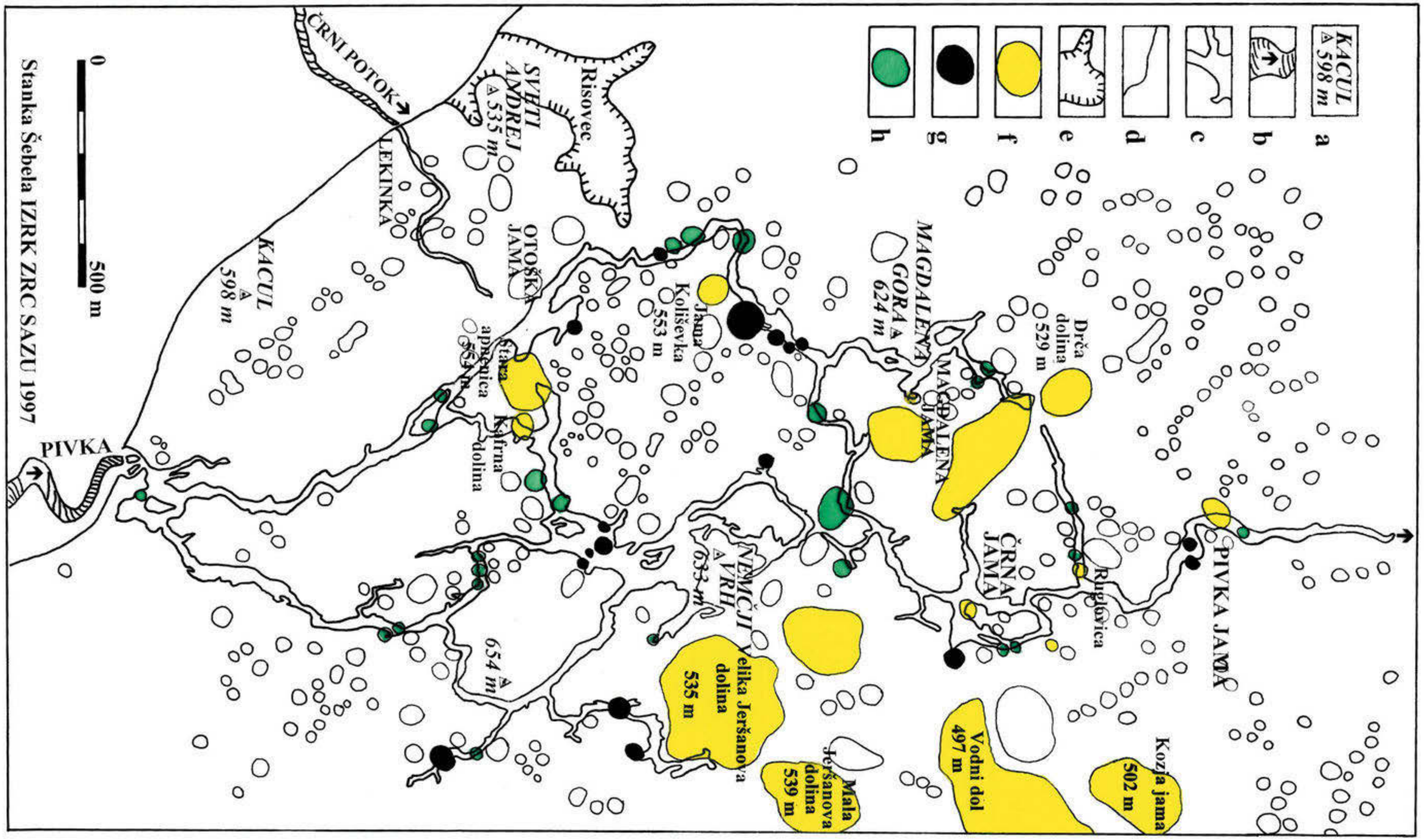
On the surface over the Postojnska jama cave system the territory is broken by numerous dolines and collapse dolines (Figure 59). Čar and Gospodarič (1984) made a detailed geological map of the surface over Pivka jama and Črna jama. They also defined many types of dolines according to geological characteristics. In 1996 (Šebela) we pointed out the connection of collapse chamber formation in the SE passages of Postojnska jama cave system and dolines over collapse chambers, in connection with the same tectonic zones activity.

In the area between Kacul hill, Risovec blind valley and Stara apnenica in the bedded to massive limestone there are almost no dolines. Likewise in the area SE from Kafrna dolina valley there are almost no dolines, but there is about an artificially modified karst surface, as in this was a military training area. The greatest density of dolines is in the zone between Nemčji vrh and Stara apnenica, and in the zone around Pivka jama.

Between the jama Koliševka cave and Stara apnenica on the numerous dolines N and NE slope we observe collapse blocks and gravel. The slope material was mainly scaled off along bedding planes emphasised by interbedded movements. An important role was played also by tectonically fractured zones which run in the N-S orientation, or deviate from N to E for 10-20^0. Fissured to broken zones can be up to 100 m wide, and there are opened fissures which carry water well in both vertical and horizontal directions. No known cave passages are under these dolines.

Some bigger dolines are grouped in lines were formed along the Dinaric direction fault zones. Such a case is in fault zones Nos. 4, 5 and especially 7 (Annex 6).

On the surface directly over the Postojnska jama cave system passages there are 42 dolines (Figure 59). A little less than half, i.e. 40.47%, of these dolines (17 examples) are formed over collapse chambers. The dolines, as well as collapse chambers, are formed in the region's most strongly expressed



Slika 59. Položaj udornic, vrtač, slepih dolin glede na lego rovov sistema Postojnskih jam. **a** nadmorska višina hriba, **b** reka ali potok in smer toka, **c** tloris jamskih rovov, **d** kontakt apnenec-fliš, **e** slepa dolina, **f** udornica in nadmorska višina dna, **g** vrtače nad podornimi dvoranami, **h** vrtače nad jamskimi rovi.

Figure 59. Position of collapse dolines, dolines, blind valleys in relation to the Postojnska jama cave system passages position. **a** hill height above sea level, **b** river or stream with flow direction, **c** cave passage ground plan, **d** limestone-flysch contact, **e** blind valley, **f** collapse doline and bottom height above sea level, **g** dolines over collapse chambers, **h** dolines over cave passages.

Rovom brez imena, Pisanim rovom, stranskim rovom v Lepih jamah, Koncertno dvorano, Otoško jamo, Martelovim podorom, Kraigherjevo dvorano, Črno jamo in Pivka jamo.

Vrtače, ki so nad podornimi dvoranami, se od ostalih vrtač na terenu morfološko ne razlikujejo. Edino povezavo v nastanku med podornimi dvoranami in vrtačami nad njimi lahko najdemo v regionalno močneje izraženih prelomnih conah.

V Rovu brez imena (stranski rov V od kote hriba 654 m) sta podorna dvorana in vrtača, ki je 67 m nad njo oblikovani v prečno Dinarski tektonski coni 290-300/80-90. V jamskem rovu opazujemo na zunanji prelomni ploskvi sledove vertikalnega premikanja, kjer se je SZ blok glede na JV spustil. Tudi na površju v vrtači najdemo tektonsko pretrto cono prav take smeri kot v jami.

Nad Pisanim rovom (severno od Rova brez imena) sta 2 vrtači nad podornima dvoranama. Severnejša podorna dvorana je manjših dimenzij, saj je zaprta s podornimi bloki. Razvita je v prelomni coni 140^0, ki je na površju ne moremo slediti, saj leži teren v JV pobočju Velike Jeršanove doline in je morfološko precej spremenjen.

Boljši primer predstavlja druga vrtača nad Pisanim rovom, ki se je oblikovala v Dinarski prelomni coni s smerjo vpada 20^0. Trideset metrov pod površjem lahko sledimo isti prelomni coni, ki pa ima nekoliko drugačno smer in vpad (30/60). Ob tej prelomni coni lahko v jami določimo horizontalne premike, in sicer levi zmik.

Nad Koncertno dvorano (južno od Nemčjega vrha) je razdalja do površja 30 m. Nad podorno dvorano so 4 vrtače, ki so v genetski zvezi z Dinarsko prelomno cono 30-40/80-90. V podorni dvorani lahko določimo vertikalno premikanje, kjer se je SV blok glede na JZ dvignil.

Nad podornima dvoranama Martelov podor in Kraigherjevo dvorano (severno od jame Koliševke) so na površju razvite 4 vrtače, katerih oblikovanje je, tako kot oblikovanje podornih vrtač, vezano na iste Dinarsko usmerjene prelomne cone.

Zanimivo je tudi dejstvo, da nad največjo podorno dvorano Veliko goro, ki leži nekoliko južno od Nemčjega vrha, ni vrtač.

Ostalih 25 vrtač (59,53 %) je le nad rovi sistema Postojnskih jam, ne pa tudi nad podornimi dvoranami. Nekaj manj kot polovica, in sicer 40,47 % vrtač, ki so nad rovi sistema Postojnskih jam, je tektonsko pogojena. Močnejše tektonske cone so pomembno vplivale tudi na spodaj ležeče rove, saj so nastale podorne dvorane.

Seveda pa ne moremo posploševati trditve, da so pod skoraj polovico vrtač, in sicer tudi v predelih, kjer jamski rovi niso znani, razvite podorne dvorane.

Z gotovostjo lahko trdimo le, da se vrtače, oblikovane v istih tektonsko pretrtih conah kot spo-

fault zones, and are thus genetically connected with tectonically fractured zones. Vertical percolation in the vadose zone is usually very good at such places which is also proved by chimneys on the ceilings of collapse chambers.

We can find dolines over collapse chambers above Rov brez imena, Pisani rov, the lateral passage in Lepe jame, Koncertna dvorana, Otoška jama, Martelov podor, Kraigherjeva dvorana, Črna jama and Pivka jama.

Dolines over collapse chambers do not differ morphologically from other dolines on the territory. The only connection in origin between collapse chambers and the dolines over them can be found in the regionally more strongly expressed fault zones.

In Rov brez imena (lateral passage E from Hill height 654 m) there are a collapse chamber and a doline which is 67 m above it formed in the cross-Dinaric tectonic zone 290-300/80-90. In the cave passage on the outer fault plane we observe traces of a vertical movement where the NW block sank relative to the SE one. On the surface in the doline we also find a tectonically fractured zone of the same direction as in the cave.

Above Pisani rov (N from Rov brez imena) there are two dolines over two collapse chambers. The more N collapse chamber is of smaller dimensions, as it is closed by collapse blocks. It is developed in the fault zone 140^0 which cannot be followed on the surface, as the territory lies on the SE slope of Velika Jeršanova dolina, and is morphologically quite modified.

A better example is represented by the second doline over Pisani rov, and which was formed in the Dinaric fault zone with the dip and strike 20^0. Thirty metres under the surface we can follow the same fault zone which has a somewhat different strike and dip (30/60). Along this fault zone in the cave we can define horizontal movements, i.e. left strike-slip.

Above Koncertna dvorana (S from Nemčji vrh) the distance to the surface is 30 m. Over the collapse chamber there are four dolines which are in a genetic connection with the fault zone 30-40/80-90. In the collapse chamber we can define the vertical movement where the NE block is raised relative to the SW one.

Above the collapse chambers Martelov podor and Kraigherjeva dvorana (N from jama Koliševka) four dolines are devloped on the surface their formation being, like that of collapse dolines, connected with the same Dinaric oriented fault zones.

It is an interesting fact that above the biggest collapse chamber Velika gora which lies a bit to the S from Nemčji vrh, there are no dolines.

The remaining 25 dolines (59.53%) are over the Postojnska jama Cave System passages, but not over collapse chambers. Rather less than a half, i.e. 40.47%, of dolines which are over the Postojnska jama cave system passages, are tectonically conditioned. Stronger tectonic zones also significantly influenced the lower passages, as collapse chambers formed.

daj ležeče podorne dvorane, morfološko bistveno ne razlikujejo od ostalih vrtač na terenu. Povezava med nekaterimi vrtačami in spodaj ležečimi jamskimi rovi ter predvsem podornimi dvoranami je na primeru sistema Postojnskih jam zelo očitna in predstavlja genetsko povezavo med vrtačami in podornimi dvoranami z istimi tektonsko pretrtimi conami.

But naturally we cannot generalise the statement that under almost half of dolines collapse chambers are developed, for that also in regions where the cave passages are not known.

We can assert with certainty that dolines, formed in the same tectonically fractured zones as the collapse chambers beneth, do not morphologically differ essentially from other dolines on the territory. The connection between some dolines and the cave passages below, and especially with the collapse chambers is very evident in the case of the Postojnska jama cave system, and represents the connection between dolines and collapse chambers with the same tectonically fractured zones.

8.5.2. Udornice

Šušteršič je predstavil matematični model preoblikovanja udornic, kjer je edini proces regresija pobočij. Ugotovil je, da je oblika plašča, to je živoskalnih pobočij pokopanih pod melišči, edini kazalec zgodovine udornic (Šušteršič, 1984, 109).

Nad sistemom Postojnskih jam je več udornic. Gospodarič (1976) je prikazal njihove lege glede na tloris jamskih rovov in glede na kontakt med apnencem in flišem. Pri tem je poskušal najti povezavo med smermi določenih geoloških strukturnih elementov, kot so prelomne cone, osi antiklinal in sinklinal, s potekom udornic.

Na sliki 59 je prikazana lega udornic glede na rove sistema Postojnskih jam. Ugotovili smo 16 primerov udornic. Med njimi so najbolj značilnih oblik Stara apnenica, Kafrna dolina, Velika Jeršanova dolina, Mala Jeršanova dolina, Vodni dol, Kozja jama, Pivka jama, Ruglovica, Črna jama, Magdalena jama, jama Koliševka, Drča dolina in udornica JV od Ruglovice. Poleg tega bi pravilneje kot udornice lahko 3 primere imenovali udorne doline: udorno dolino vzhodno od Magdalene jame, podolgovato udorno dolino JV od Drče doline in udorno dolino SZ od Velike Jeršanove doline. V primeru vhoda v Magdaleno jamo bi morda pravilneje kot o udornici govorili o udornem breznu.

Položaj udornic kaže močno odvisnost od poteka tektonsko pretrtih con. Oblikovanje in poglabljanje nekaterih udornic in brezen je odprlo dostop do horizontalnih jamskih rovov. Taki so primeri: Mala Jeršanova dolina je odprla dostop do Zguba jame, udornica Pivka jama do Pivka jame, udornica Črna jama do Črne jame, udornica (oziroma udorno brezno) Magdalena jama do Magdalene jame, udornica Koliševka do jame Koliševke ter udornica JV od Drče doline do Matevževega rova Črne jame.

Dno **Stare apnenice** leži na nadmorski višini 554 m, najvišji rob udornice pa na 595 m. Udornica se je oblikovala na sečišču prelomnih con št. 4 in 9 (priloga 6). Stara apnenica je ena najbolj izrazitih udornic na obravnavanem terenu. Njen nastanek je prekinil

8.5.2 Collapse Dolines

Šušteršič presented a mathematical model of collapse dolines re-forming where the only process is the regression of the surface slope. He found out that the coat form, i.e. bedrock slopes buried under screes, is the only collapse dolines history indicator (Šušteršič, 1984, 109).

Above the Postojnska jama cave system there are many collapse dolines. Gospodarič (1976) related their positions to the cave passage ground plan, and to the contact between limestone and flysch. Thereby he tried to find a connection between the defined geological structural elements directions like fault zones, anticline and syncline axes, with the collapse dolines locations.

In Figure 59 the position of collapse dolines is shown in relation to the Postojnska jama cave system passages. We found 16 examples of collapse dolines. Among them Stara apnenica, Kafrna dolina, Velika Jeršanova dolina, Mala Jeršanova dolina, Vodni dol, Kozja jama, Pivka jama, Ruglovica, Črna jama, Magdalena jama, jama Koliševka, Drča dolina and collapse doline SE from Ruglovica have the most characteristic forms. Three other examples would more correctly be called collapse valleys than collapse dolines: collapse valley E from Magdalena jama, oblong collapse valley SE from Drča dolina, and collapse valley NW from Velika Jeršanova dolina. In case of the entrance to Magdalena jama we could probably more correctly talk about a collapse shaft instead of collapse doline.

The collapse doline's position shows a strong dependence on the tectonically fractured zone's course. Formation and deepening of some collapse dolines and shafts have opened an access to the horizontal cave passages. Such examples are: Mala Jeršanova dolina has opened an access to Zguba jama, Pivka jama collapse doline to Pivka jama, Črna jama collapse doline to Črna jama, Magdalena jama collapse doline (or collapse shaft) to Magdalena jama, Koliševka collapse doline to jama Koliševka, and a collapse doline SE from Drča dolina to Matevžev rov of Črna jama.

The bottom of **Stara apnenica** lies at 554 m above sea level, and the highest edge of the collapse podzemeljsko zvezo med Otoško jamo in Zgornjim Tartarusom (Martel, 1894; Gospodarič, 1976).

Nekoliko vzhodno od Stare apnenice je **Kafrna dolina**. Oblikovala se je v prelomni coni št. 9 in je od Stare apnenice precej manjša.

Udornici Stara apnenica in Kafrna dolina sta nastali v isti prelomni coni smeri skoraj V-Z (160-190/90), ki je odločilno vplivala tudi na razvoj rova Zgornjega Tartarusa.

Na strmem severozahodnem pobočju udornice se na nadmorski višini 553 m odpira vhod v jamo **Koliševko** (kat. št. 147). Zgornji rob udornice ob cesti k Pivki jami je na nadmorski višini 570 m. Ta nekoliko manjša udornica se je razvila na sečišču Dinarske in prečno Dinarske prelomne cone. Njeno severovzhodno podorno pobočje je oblikovano po plastnatosti.

Velika Jeršanova dolina (dno v n.m.v. 535 m) nima značilne udorne oblike, zato jo je pravilneje imenovati udorna dolina. Na jugovzhodnem in vzhodnem delu ima dve morfološki zajedi, ki sta se oblikovali v zdrobljenih conah, pri tem je jugovzhodna zajeda morfološko bolj poudarjena. Severni del Pisanega rova leži v isti nadmorski višini kot dno Velike Jeršanove doline (Šebela, 1994 a).

Mala Jeršanova dolina (dno v n.m.v. 539 m) ima v J in JZ delu bolj strmo pobočje kot npr. Velika Jeršanova dolina.

Vodni dol (dno v n.m.v. 497 m) in **Kozja jama** (dno v n.m.v. 502 m) sta najbolj obširni udornici, poleg tega pa tudi najnižji, celo nižji kot je ponor Pivke (511 m), vendar višji kot odtočni sifon v Pivka jami (477 m).

Nadmorska višina vhoda v **Črno jamo** je 531 m. Vhod je razvit v udornici. Vhod v rove Pivka jame se odpira s 77 m globoko udornico **Pivka jamo** (slika 35).

Drča dolina (dno v n.m.v. 529 m) ne leži nad znanimi rovi sistema Postojnskih jam.

Nastanek in predvsem poglabljanje udornic kot Velike in Male Jeršanove doline, Vodnega dola in Kozje jame je v genetski zvezi z odmikom aktivnih vodnih rovov sistema Postojnskih jam v nižje, jugozahodne in severozahodne predele.

doline at 595 m. The collapse doline was formed at the intersection of fault zones Nos. 4 and 9 (Annex 6). Stara apnenica is one of the most expressive collapse dolines on the discussed territory. Its formation interrupted an underground connection between Otoška jama and Zgornji Tartarus (Martel, 1894; Gospodarič, 1976).

A little to the E from Stara apnenica is **Kafrna dolina**. It was formed in fault zone No. 9, and is much younger than Stara apnenica.

Stara apnenica and Kafrna dolina collapse dolines are developed in the same fault zone of the direction almost E-W (160-190/90), which also decisively influenced the development of Zgornji Tartarus passage.

On the steep NW slope of the collapse doline, at 553 m above sea level, there is an entrance to jama **Koliševka** (Cad. No. 147). The upper edge of the collapse doline along the road to Pivka jama is 570 m above sea level. This a bit smaller collapse doline was developed at the intersection of the Dinaric and cross-Dinaric fault zones. Its NE collapse slope is formed along bedding.

Velika Jeršanova dolina (bottom at 535 m a.s.l.) does not have the characteristic collapse doline form, so, it would be more correct to call it a collapse valley. In the SE and E part it has two morphological indentations which were formed in crushed zones, where the SE indentation is morphologically more emphasised. The N part of Pisani rov lies at the same height above sea level as the Velika Jeršanova dolina bottom (Šebela, 1994 a).

Mala Jeršanova dolina (bottom at 539 m a.s.l.) has a steep slope in the S and SW part than some others e.g. Velika Jeršanova dolina.

Vodni dol (bottom at 497 m a.s.l.) and **Kozja jama** (bottom at 502 m a.s.l.) are the most extensive collapse dolines, and also the lowest, even lower than the Pivka sink (511 m), but higher than the downstream sump in Pivka jama (477 m).

The **Črna jama** entrance height above sea level is 531 m. The entrance is developed in collapse doline. The entrance into the Pivka jama passages is opened by 77 m deep **Pivka jama** collapse doline (Figure 35).

Drča dolina (bottom at 529 m a.s.l.) does not lie above the known passages Postojnska jama cave system.

Development and especially deepening of collapse dolines like Velika and Mala Jeršanova dolina, Vodni dol and Kozja jama has a genetic connection with the Postojnska jama cave system active water passage lowering into SW and NW passages.

Slika 60. Slepa dolina Risovec (foto S. Šebela).
Figure 60. Risovec blind valley (photo S. Šebela).

8.5.3. Slepe doline

Slepa dolina je sestavljena kraška oblika, ki se pojavlja na prehodu nadzemeljskega hidrografskega ožilja v kraškega podzemeljskega. Že po obliki sodeč je slepa dolina prehodna stopnja med navadno rečno dolino in uvalo ter kraškim poljem (Gams, 1962, 265).

V slovenski kraški terminologiji (Gams et al., 1973, 26) je termin slepa dolina označen za dolino, ki se slepo končuje na apnencu. Pod strmimi pobočji na koncu so navadno ponori. Z morfološkim izrazom slepa dolina razume Habič (1986) kraško poglobljen del rečne doline na apnencih ob ponikalnicah z nepre-pustnega sosedstva.

Na raziskanem terenu so nekdanje slepe doline: večja dolina Risovec (slika 60), dolina vzhodno od cerkvice Sv. Andreja (n.m.v. 535 m) in morfološko slabše izražena še danes aktivna dolina na vhodu v sistem Postojnskih jam.

Morfološke značilnosti kontaktnega krasa Postojnske kotline je proučeval Mihevc (1991). Dolino Risovec imenuje fosilno slepo dolino, dolino pri ponoru Pivke in Črnega potoka, ki sta morfološko manj izraziti, pa ponorni zatrep.

8.5.3. Blind Valleys

A blind valley is a compound karst form which appeared at the transition of the surface hydrographic veins into the karst underground one. Already according to its shape a blind valley is an intermittent stage between an ordinary river valley and depression, and a karst polje (Gams, 1962, 265).

In the Slovene karst terminology (Gams et all., 1973, 26) the term blind valley is indicated as a valley which ends blindly on limestone. Under steep slopes at the lower end there are usually sinks. By the morphological expression blind valley Habič (1986) understands a karst deepened part of a river valley on limestone along underground streams of an impermeable vicinity.

On the studied territory the former blind valleys are: Risovec greater valley (Figure 60), a valley E from Sv. Andrej church (535 m a.s.l.), and a morphologically weekly expressed, still active valley in the entrance to the Postojnska jama cave system.

Morphological characteristics of the Postojna basin contact karst were studied by Mihevc (1991). Risovec valley is called a fossil blind valley, and the valleys near the Pivka river sink and Črni potok sink

Slepa dolina Risovec in manjša slepa dolina vzhodno od cerkvice Sv. Andreja sta v preteklosti odvajali velike količine vode v kraško podzemlje. Njuno hidrografsko funkcijo so prekinili podori, pozneje pa tudi flišni zasip (Gospodarič & Habič, 1966).

Čar (1982) je oblikovanje slepe doline Risovec povezal s potekom starih prelomnih con v prečno Dinarski smeri, ki jih bolj ali manj opazno sledimo vse do Planinskega polja. Gre za vzporedno tektonsko strukturo Postojnskim vratom.

Tudi ponorni zatrep, ki se je oblikoval ob aktivnem ponoru Pivke, se je prav tako kot slepa dolina Risovec oblikoval ob močnejši prelomni coni prečno Dinarske smeri, ki je na prilogi 6 označena s št. 10.

Slepa dolina Risovec in aktivni ponor Pivke sta nastala na tektonsko najbolj porušenih delih kontakta kredni apnenec - eocenski fliš, kjer se sekajo močno izražene Dinarske (priloga 6, št. 1) in prečno Dinarske prelomne cone (priloga 6, št. 8 in 10).

which are morphologically less expressed, are called sink gables.

Risovec blind valley and a smaller blind valley to the E of Sv. Andrej church drained off great quantities of water into the karst underground in the past. Their hydrographic function was interrupted by collapses, and later also by a flysch filling (Gospodarič & Habič, 1966).

Čar (1982) connected the formation of the Risovec blind valley with the old fault zones in the cross-Dinaric direction which can be more or less visibly followed even as far as Planinsko polje. It is along a parallel tectonic structure to Postojnska vrata.

Like the sink gable which was formed beside the active Pivka sink, the Risovec blind valley was equally formed along the strong cross-Dinaric direction fault zone which is indicated by No. 10 in Annex 6.

The Risovec blind valley and the Pivka active sink are developed at the tectonically most broken parts of the contact Cretaceous limestone – Eocene flysch, where there crossed strongly expressed Dinaric (Annex 6, No.1) and cross-Dinaric fault zones (Annex 6, Nos. 8 and 10).

9.0. POVEZAVA GEOLOŠKIH STRUKTURNIH ELEMENTOV MED POVRŠJEM IN JAMSKIMI ROVI

Da smo podatke podrobnega tektonsko-litološkega kartiranja jamskih rovov in površja med seboj povezali, smo uporabili vzdolžne jamske profile (priloga 1). Zajeti so: sklenjen vzdolžni profil od ponornega vhoda v sistem Postojnskih jam do Velike gore, vzdolžni profil čez Pisani rov, Male jame in Koncertno dvorano, vzdolžni profil čez Podzemeljsko Pivko (od dvorane Veliki dom do odcepa za Spodnji Tartarus) ter vzdolžni profil, ki poteka čez vhodno udornico Črne jame do odtočnega sifona v Pivki jami. Vertikalna razdalja med jamskimi rovi in površjem se spreminja od 20 metrov na ponornem vhodu v sistem Postojnskih jam ter 30 m nad severnim delom Pisanega rova do 110 m pri odcepu za Rov brez imena. Povprečna debelina apnenca iz površja do jamskih rovov je 90-100 m. Vsi vzdolžni profili imajo, prav tako kot prečni profili (priloga 1), za osnovo nadmorsko višino 529,5 m.

Potrebno je poudariti, da vzdolžni profili čez celoten teren ne potekajo v isti smeri, ampak sledijo jamskim rovom od ponora Pivke do odtočnega sifona v Pivki jami. Generalne smeri vzdolžnih profilov so označene na prilogi 1. Pomembnejše prelomne cone, ki sem jih določila v jami in na površju, so skladno označene s številkami na prilogah 1 in 6.

V dvorani Veliki dom in Kongresni dvorani se debelina stropa spreminja od 20 do 90 m. Med tektonsko pretrtimi conami je najbolj izrazita prelomna cona št. 10. V nadaljevanju jame proti Biospeleološki postaji poteka vzdolžni profil v jasno izraženih prelomnih conah 230/40 in 100-130^0.

V predelu sistema Postojnskih jam od Kongresne dvorane do odcepa za Pisani rov je debelina stropa 80 do 110 m. Pred odcepom za Male jame se na površju in v jami dobro prekrivajo porušene do razpoklinske cone z elementi vpada 70^0 in 60-80/80. Na odcepu za Rov brez imena se prelomna cona 40^0 na razdalji 110 m, kar je najdebelejši strop v vzdolžnem profilu, odlično ujema s kartiranimi razmerami na površju.

Antiklinalno upognjene plasti so v Pisanem rovu slabo izražene, tako da jih po 50-60 m na površju ni moč več zaznati. V severnem delu Pisanega rova vpadajo apnenci proti zahodu pod kotom 5-10^0. Na razdalji 30 m do površja so razmere precej spremenjene. Tanko

9.0. GEOLOGICAL STRUCTURAL ELEMENTS CONNECTION BETWEEN THE SURFACE AND THE CAVE PASSAGES

To connect the detailed cave passages and the surface tectonic-lithological mapping data we have used longitudinal cave sections (Annex 1). These include: closed longitudinal section from the Postojnska jama cave system sink entrance to Velika gora, longitudinal section over Pisani rov, Male jame and Koncertna dvorana, longitudinal section over Podzemeljska Pivka (from Veliki dom chamber to Spodnji Tartarus) and longitudinal section which runs over the Črna jama entrance collapse doline to the downstream sump in Pivka jama. The vertical distance between the cave passages and the surface changes from 20 metres at the Postojnska jama system river sink entrance, and 30 m above the N part of Pisani rov to 110 m by the Rov brez imena branch. The average limestone thickness from the surface to the cave passages is 90-100 m. All longitudinal sections, as well as cross-sections (Annex 1), have 529.5 m height above sea level for their datum.

It is necessary to stress that longitudinal sections across the entire territory do not run in the same direction, but they follow the cave passages from the Pivka sink to the downstream sump in Pivka jama. Longitudinal section general directions are indicated in Annex 1. The more important fault zones I have defined in the cave and surface are accordingly indicated by numbers in Annexes 1 and 6.

In Veliki dom and Kongresna dvorana chambers the ceiling thickness varies from 20 to 90 m. Among the tectonically fractured zones fault zone No. 10 is most expressive. Further in the cave towards Biospeleološka postaja there runs a longitudinal section in the clearly expressed fault zones 230/40 and 100-130^0.

In the part of Postojnska jama cave system from Kongresna dvorana to the Pisani rov branch the ceiling is from 80 to 110 m thick. In front of the Male jame branch, both on the surface and in the cave, there are well covered-over broken to fissured zones with the dip elements 70^0 and 60-80/80. By the Rov brez imena branch the fault zone 40^0 at the distance of 110 m below the surface, which is the thickest ceiling in the longitudinal section, perfectly matches with mapped conditions on the surface.

In Pisani rov the anticline flexible bedding planes plastnati apnenci vpadajo proti severu za $5-20^0$. Vse to kaže na širše območje osi Postojnske antiklinale.

Pri pogledu površja nad Pisanim rovom in primerjavi tlorisa rova s potekom vrtač ali udornic, smo opazili, da se projekcija tlorisa Pisanega rova izogiba vrtačam in Veliki Jeršanovi dolini. Izjema je le vrtača, ki se je oblikovala v prelomni coni 20/90. V jami, to je 45 m nižje, je v tem predelu podorna dvorana, ki je nastala ob zdrobljeni coni z elementi vpada 30/60 in 200/85.

Prelomna cona št. 7 je posebno dobro opazna na površju, kjer ustvarja morfološko zajedo v jugovzhodnem delu Velike Jeršanove doline. V jamskih rovih se na razdalji 50-ih metrov spremeni njena intenziteta, tako da je tam precej šibkejša.

Na vhodu v Pisani rov se je jamski rov oblikoval v zdrobljeni coni 10/80, ki ji na površju ustreza prelomna cona št. 6 z elementi vpada 30^0. Glede na to, da je debelina stropa nad Pisanim rovom med najtanjšimi v sistemu Postojnskih jam, lahko povzamemo, da korelacija tektonsko pretrtih con iz površja v jamo ni najboljša. Na razdalji od 30 do 70 m bi pričakovali boljšo primerljivost.

Predel vzdolžnega profila od Pisanega rova do Velike gore, poteka po jamskem rovu, medtem ko njegovo nadaljevanje proti severozahodu vključuje le dva prečna jamska profila, in sicer v Ruskem rovu in Lepih jamah.

Na Nemčjem vrhu je bel, zelo debelo plastnat apnenec, ki zvezno prehaja tudi v stene jamskih rovov. Prelomna cona št. 6 je na razdalji 70-ih metrov dobro primerljiva. Podorna dvorana Velika gora je oblikovana 55 m pod Nemčjim vrhom. Prelomna cona Dinarske smeri v kateri se je dvorana oblikovala, je v jami močneje izražena kot na površju.

Povprečna debelina stropa med površjem in jamo je v vzdolžnem profilu Podzemeljske Pivke 90-100 m. Tektonsko pretrte cone se iz površja v jamo dobro ujemajo, pri čemer je opaziti spreminjanje intenzitete in širine. Nad rovi Podzemeljske Pivke do odcepa za Spodnji Tartarus ni vrtač, pa tudi sicer gre za travnat teren brez jasnejših morfoloških značilnosti.

Na začetku Malih jam je debelina stropa do 110 m, v Koncertni dvorani pa okrog 40 m. S površja v jamske rove in obratno sta zvezno določljivi prelomni coni št. 5 in 10. Tudi močne razpoklinske do porušene cone z elementi vpada 100^0 so v jamskih stenah in na površju dobro vidne.

V vzdolžnem profilu, ki zajema Črno in Pivko jamo je dobro prikazan potek udornic glede na jamske rove in površje. Debelina stropa znaša od 20-70 m.

Vse pomembnejše prelomne cone, ki so na prilogah 1 in 6 označene s številkami, lahko določimo v jamskih rovih, seveda če naletijo nanje. Pri tem opazujemo vertikalno in horizontalno prehajanje iz ene tektonsko pretrte cone v drugo, na kar je, v raziskavah okolice Pivke in Črne jame, opozoril tudi Čar (1982, 1983). Stopnja korelacije tektonsko pretrtih con med

are badly expressed, thus they cannot be detected on the surface after vertical distance 50-60 m any more. In the N part of Pisani rov the limestone dips towards the W at an angle of $5-10^0$. At the distance of 30 m to the surface the conditions are quite changed. Thin-bedded limestone dips towards the N at $5-20^0$. All this indicates on a wider Postojna anticline axis area.

By surveying the surface over Pisani rov, and by a comparison of the passage ground plan with the dolines or collapse dolines locations we have noticed that the Pisani rov ground plan section avoids dolines and the Velika Jeršanova dolina. The only exception is a doline which was formed in the fault zone 20/90. In the cave, i.e. 45 m lower, there is a collapse chamber in this area, developed along the crushed zone with dip elements of 30/60 and 200/85.

Fault zone No. 7 is particularly well seen on the surface where it creates a morphological depression in the SE part of Velika Jeršanova dolina. In the cave passages at the distance of 50 metres below its intensity changes, and it is much weaker there.

At the entrance to Pisani rov the cave passage was formed in the crushed zone 10/80 which on the surface corresponds to fault zone No. 6 with the dip elements 30^0. As to the ceiling thickness over Pisani rov is among the thinnest in the Postojnska jama cave system, we can conclude that the correlation of the tectonically fractured zones from the surface to the cave is not the best. At a distance of from 30 to 70 m we would expect a better agreement.

The longitudinal section from Pisani rov to Velika gora runs along the cave passage, while its continuation towards the NE includes only two cave cross-sections, those in Ruski rov and in Lepe jame.

At Nemčji vrh there is white, very thick-bedded limestone on the surface which is present also at the cave passage walls. Fault zone No. 6 compares well at the distance of 70 metres between surface and cave. The Velika gora collapse chamber is formed 55 m beneath Nemčji vrh. The Dinaric direction fault zone in which the chamber was formed is more strongly expressed in the cave than on the surface.

The average ceiling thickness between the surface and the cave is 90-100 m in the Podzemeljska Pivka longitudinal section. Tectonically fractured zones from the surface to the cave agree well, whereby it is possible to notice the intensity and width modification between one and the other. Above the Podzemeljska Pivka passages to the Spodnji Tartarus branch there are no dolines, and there is grassy ground without more clear morphological characteristics.

At the beginning of Male jame the ceiling thickness is up to 110 m, and in Koncertna dvorana about 40 m. From the surface to the cave passages and vice versa there are two connectedly definable fault zones, Nos. 5 and 10. Likewise strong fissured to broken zones with the dip elements 100^0 are easily visible in the cave površjem in jamskimi prostori je, glede na geološke razmere prikazane v vzdolžnih profilih, dobra.

V jami in na površju je dobro skladna prelomna cona št. 9, ki se pojavi v Spodnjem Tartarusu, na površju pa jo sledimo čez udornico Staro apnenico.

Prelomna cona št. 10 je dobro vidna pri ponornem vhodu v sistem Postojnskih jam, kot tudi v dvorani Veliki dom. V tem primeru gre za direktno zvezo iz površja v jamo na razdalji 20-60 m.

Vzdolžni profili so povzeti po jamarskih načrtih in zato najbolje prikazujejo odnos med morfologijo površja in potekom rovov, nekoliko manj pa so primerni za prikaz geoloških razmer, saj vzdolžni profil lahko poteka nekaj časa vzporedno z določeno tektonsko pretrto cono potem pa eno in isto cono večkrat seka (priloga 1).

walls and on the surface.

In the longitudinal section which includes Črna jama and Pivka jama is well seen the collapse dolines alignment with the cave passages and the surface. The ceiling is 20-70 m thick.

All the more important fault zones which are indicated by numbers in Annexes 1 and 6 we can detect in the cave passages, if we come across them. Thereby we observe the vertical and horizontal transitions from one tectonically fractured zone to another, which was already indicated by Čar (1982, 1983) in his researches on the Pivka jama and Črna jama area. There is a good correlation of the tectonically fractured zones between the surface and cave spaces according to geological conditions presented in the longitudinal sections.

In the cave and on the surface there is a well congruent fault zone No. 9 which appears in Spodnji Tartarus, and on the surface we follow it across the Stara apnenica collapse doline.

Fault zone No. 10 is clearly seen by the Postojnska jama cave system sink entrance, as well as in the Veliki dom chamber. In this case there is a direct connection from the surface to the cave at a distance of 20-60 m.

Longitudinal sections are taken from the caving plans, and so, they best present the relation between the surface morphology and the passage direction, but they are somehow less convenient to present geological conditions, for a longitudinal section can run for some way parallel to a particular tectonically fractured zone, and then it crosses the same zone several times (Annex 1).

10.0. ZAKLJUČKI

Osnovno razumevanje oblikovanja jamskih rovov kraških jam predstavlja dobro poznavanje geološke zgradbe, za kar je poleg litoloških, stratigrafskih in tektonskih raziskav potrebno tudi razumevanje kraške hidrogeologije.

Površje nad jamskimi rovi sistema Postojnskih jam sem podrobno tektonsko litološko kartirala v merilu 1:2.500. Jamske rove sem kartirala v merilu 1:500. S prečnimi profili sem prikazala morfologijo rovov in odvisnost oblikovanja rovov od geoloških zakonitosti. Geološke strukturne elemente površja in jamskih rovov sem sprva proučevala ločeno, kasneje pri korelaciji geoloških razmer v vzdolžnih profilih med površjem in jamo pa sem prikazala tudi povezave in razlike na razdalji 20 -110 m. Z vzdolžnimi profili sem geološke podatke prostorsko predstavila.

Glavni rezultati dela so naslednji:

1. Na območju sistema Postojnskih jam, ločimo starejše deformacije narivanja in gubanja ter mlajše prelomne deformacije. K deformacijam gubanja je Gospodarič (1965) prišteval Postojnsko antiklinalo.

Njena osna ravnina je na površju najbolj določljiva nekoliko južno od vrha Magdalene gore in na severnem pobočju Nemčjega vrha, kjer se dobro ujema z razmerami v jamskih rovih (priloga 1). Na površju nad sistemom Postojnskih jam vpadajo plasti zgornje krednega apnenca na severovzhodnem krilu za 5-30^0 na jugozahodnem krilu pa za 10-60^0. Glede na rezultate podrobnega tektonsko-litološkega kartiranja površja in podzemlja je osna ravnina antiklinale nagnjena proti jugozahodu za 7-14^0.

V temenu Postojnske antiklinale se na površju javljajo ene najstarejših kamnin kartiranega terena, ki ne izdanjajo v zveznem pasu, temveč v posameznih poljih na Magdaleni gori, Nemčjem vrhu in nekoliko jugovzhodno od Nemčjega vrha. To vodi k zaključku, da je osna ravnina povita v horizontalni in vertikalni smeri. V predelu med Magdaleno goro in Nemčjim vrhom je os antiklinale globje v prostoru kot na Nemčjem vrhu.

Če ekstrapoliramo ocenjene vertikalne premike ob močni prelomni coni iz severnega dela podorne dvorane Velike gore, kjer se je severni blok dvignil in južni spustil, na površje, lahko povzamemo, da se je blok

10.0. CONCLUSIONS

A basic understanding of the karst cave passage formation is obtained by a good knowledge of the geological structure. Therefore, besides lithological, stratigraphical and tectonic researches, it is also necessary to comprehend the karst hydrogeology.

Tectonically and lithologically I mapped in detail the surface over the Postojnska jama cave system passages at a scale of 1:2,500. I mapped the cave passages at a scale of 1:500. By cross-sections I presented the passage morphology and the dependance of the passage formation on the geological properties. At first I studied the surface and the cave passages geological structural elements separately. Later I also presented connections and differences between them at their distance apart of 20-110 m, by correlating the geological conditions in longitudinal sections between the surface and the cave. I presented geological data of the area by longitudinal sections.

The main results of the work are as follows:

1. In the Postojnska jama cave system area we distinguish older overthrusting and folding deformations, and younger fault deformations. Gospodarič (1965) added the Postojna anticline to the folding deformations.

The Postojna anticline axis plane on the surface is most clearly traced a little S from the top of Magdalena gora, and on the Nemčji vrh N slope where it agrees well with conditions in the cave passages (Annex 1). On the surface above the Postojnska jama cave system the Upper Cretaceous limestone beds dip on the NE flank at 5-30^0, and on the SW flank for 10-60^0. According to the results of detailed tectonic-lithological surface and underground mapping the anticline axis plane is inclined towards the SW for 7-14^0.

In the Postojna anticline crest we found the oldest rocks of the mapped area on the surface. They are in particular isolated areas at Magdalena gora, Nemčji vrh, and a little SE from Nemčji vrh. This leads to conclusion that the axis plane is wrapped up in the horizontal and vertical direction. In the area between Magdalena gora and Nemčji vrh the anticline axis is deeper in the space as at Nemčji vrh.

If we extrapolate the estimated vertical move-severno od Nemčjega vrha dvignil, južnejši pa spustil. Velikost vertikalnega premika ob prelomni ploskvi vidni v jami na Veliki gori ne presega 3-eh m. Ker so na severnem bloku razkrite najstarejše kamnine, na južnem pa nekoliko mlajše, sklepamo na erozijo senonijskih plasti, ki v tem delu manjkajo.

Postojnska antiklinala ne deluje kot zapora, saj jo podzemeljski rovi prečkajo, prav tako kot prečkajo prelomne cone. To dokazujeta Črna in Pivka jama, ki sta oblikovani v severovzhodnem krilu antiklinale z manjšimi vmesnimi podornimi dvoranami in sifonskimi prekinitvami.

2. Na OGK list Postojna je morfološki rob zgornje kredni apnenec - eocenski fliš označen kot erozijska meja (Pleničar, 1970). Ker je vhod v sistem Postojnskih jam razvit prav na tem stiku, zgoraj omenjena razlaga pri razumevanju oblikovanja jame ni bila zadostna.

Gospodarič (1965, 44) zagovarja, da je med krednim apnencem in eocenskim flišem erozijska diskordanca ter se sedimentacija fliša začne s transgresijsko bazalno brečo in konglomeratom.

S podrobnim tektonskim kartiranjem bližnje okolice sistema Postojnskih jam sem na kontaktu kredni apnenec - eocenski fliš zajela do 50 m široko prelomno cono, v kateri so na prelomnih ploskvah vidni sledovi vertikalnega in horizontalnega premikanja. Gre za Dinarsko (SZ-JV) usmerjeno prelomno cono, ki jo štejemo k širši coni Predjamskega preloma. Geološki stik kredni apnenec - eocenski fliš je torej deformiran s prelomno cono (priloga 6, št. 1), ki jo po genetski klasifikaciji (Čar & Gospodarič, 1984) uvrščamo v 4., to je najmlajšo, generacijo.

3. Za razvoj rovov sistema Postojnskih jam so pomembni medplastni zdrsi. Njihov nastanek povezujemo z deformacijami gubanja. Ob kasnejši zmični tektoniki je prišlo do reaktiviranja medplastnih zdrsov.

Lezike poudarjene z medplastnimi zdrsi so dobro izražene v jamskih rovih. Na prilogi 1 so medplastni zdrsi označeni v prečnih profilih.

V sistemu Postojnskih jam je nekaj izrednih primerov, ki dokazujejo razvoj inicialnih rovov po zdrsnih lezikah. Medplastni zdrsi vzpostavijo lezike za komuniciranje z vodnim tokom ter tako za nastanek in oblikovanje vodoravnih jamskih rovov. V začetnih fazah razvoja jamskih rovov je voda izrabljala tudi odprte tektonsko pretrte cone, ki so še posebno ugodne točke na stiku s plastnatostjo. Pri tem je širila jamski rov navzgor in navzdol v tektonsko pretrti coni, lahko pa tudi po leziki.

Red velikosti medplastnih zmikov je lahko le nekaj cm, lahko pa premika tudi ni, ampak gre samo za odprtje oziroma nastanek razpoke po leziki. Nekatere odprte razpoke so zapolnjene s sekundarnimi kalcitnimi žilicami. Številni so primeri vmesnih razpok, ki povezujejo zdrsne lezike med seboj. Vodoravni jamski rov vzhodno od odcepa za Male jame vijuga med tektonsko porušeno do razpoklinsko cono in kaže očiten razvoj in

ments along a strong fault zone from the N part of the Velika gora collapse chamber, where the N block rose and the S one sank, to the surface, we may conclude that the block N from Nemčji vrh also rose, and the more S one sank. The vertical movement along the fault plane visible in Velika gora does not exceed 3 m. Since the oldest rocks are found on the N block, and the younger ones on the S, we conclude about the erosion of Senonian beds which are absent in this part.

The Postojna anticline does not function as an obstacle, because the underground passages cross it just as they cross the fault zones. This is proved by Črna jama and Pivka jama which are formed in the NE anticline flank with smaller intermediate collapse chambers and sump interruptions.

2. On the Basic Geological Map Postojna Sheet the morphological edge, Upper Cretaceous limestone – Eocene flysch, is indicated as an erosional limit (Pleničar, 1970). Since the Postojnska jama cave system entrance is developed exactly at this contact, this explanation for understanding of the cave formation was not sufficient.

Gospodarič (1965, 44) argues that between the Cretaceous limestone and Eocene flysch there is an erosional discordance, and the flysch sedimentation begins with the transgression basal breccia and conglomerate.

By a detailed tectonic mapping of the Postojnska jama cave system and its surface area I included the position of the contact of the Cretaceous limestone – Eocene flysch at a fault zone which is up to 50 m wide. Inside the fault zone traces of the vertical and horizontal movements on the fault planes are seen. It is a Dinaric (NW-SE) oriented fault zone which belongs to the wider area of the Predjama fault zone. The geological contact, Cretaceous limestone – Eocene flysch, is thus deformed by the fault zone (Annex 6, No. 1) which is according to the genetic classification (Čar and Gospodarič, 1984) ranged in the 4th, i.e. the youngest generation.

3. Interbedded movements are important for the development of the Postojnska jama cave system passages. We connect their formation with the folding deformation. By the later strike-slip tectonics the interbedded movements were reactivated.

Bedding planes broken by interbedded movements are well expressed in the cave passages. In Annex 1 the interbedded movements are indicated in cross-sections.

In the Postojnska jama cave system there are some exceptional examples which prove the development of initial passages along the slipped bedding planes. The interbedded movements make bedding planes favorable for communication with the water flow, and thus for creation and formation of horizontal cave passages. In the initial phases of cave passage development the water used also the tectonically opened fractured zones, which are particularly favourable points at the contact with the bedding. Water flow enlarged a oblikovanje po deformacijah zdrsnih lezik.

V določenem obdobju razvoja jamskih rovov so se podori oblikovali po lezikah, medplastnih zdrsih in tektonsko pretrtih conah, in sicer v predelih največje nestabilnosti v jami, ki je vezana na močne Dinarske prelomne cone. Voda je ponekod podorni material lahko sproti odnašala, nekaj se ga je kopičilo v podorni nasip, ki ga podzemeljska reka ni več zajela, saj se je umaknila v nižji severnozahodni in jugozahodni del jame.

4. Rovi sistema Postojnskih jam so značilno oblikovani po tektonsko pretrtih conah izmed katerih so najmočneje izražene Dinarske (SZ-JV), ki jih lahko zvezno povezujemo na velike razdalje. Prečno Dinarske prelomne cone (št. 10 na prilogi 6) je v prostoru težje povezovati, saj jih Dinarske sekajo in zamikajo. Vendar je potrebno poudariti, da imajo pri razumevanju regionalnega razvoja jamskih rovov in odtekanja podzemeljskih voda le-te eno pomembnejših vlog. Ponor reke Pivke v sistem Postojnskih jam se nahaja prav ob prelomni coni prečno Dinarske smeri. Tudi nekdanja slepa dolina Risovec in vodni rov Podzemeljske Pivke in Pivke jame, potekajo skladno s prečno Dinarsko prelomno cono.

5. Kjer je bilo možno, sem predvsem v jamskih rovih določila tudi glavne premike ob prelomnih ploskvah.

Ob eni najbolj izrazitih zdrobljenih con, ki poteka po severnem robu Velike gore in se proti severozahodu nadaljuje v Lepe jame in Perkov rov ter proti jugovzhodu v Pisani rov, so dobro opazne smeri premikov. Pri tem je potrebno poudariti, da so v notranji prelomni coni določljive različne smeri premikov ob prelomnih ploskvah. V Lepih jamah (slika 31) je ob severni prelomni ploskvi, ki omejuje notranjo prelomno cono, horizontalen premik, in sicer desni zmik. Ob južni prelomni ploskvi kažejo tektonske drse vertikalno premikanje, pri čemer se je severni blok spustil in južni dvignil.

Ob prelomni ploskvi na Veliki gori se je južni blok spustil, severni pa dvignil. V Pisanem rovu, je ob prelomni ploskvi 30/60, ki pripada isti prelomni coni, prišlo do levega zmika.

Čez Koncertno dvorano poteka druga pomembnejša prelomna cona (na prilogi 1, št. 5), ki je vzporedna zgoraj omenjeni prelomni coni. Tektonske drse kažejo na vertikalno in horizontalno premikanje. V JV stranskem rovu pri železniških tirih lahko še najbolj zanesljivo določimo vertikalno premikanje, kjer se je severni blok dvignil, južni pa spustil, tako kot ob vzporednem prelomu čez Veliko goro.

Različne smeri vertikalnega ali horizontalnega premikanja ob istih tektonskih ploskvah, potrjujejo večfaznost tektonskih procesov.

6. V jamskih rovih sem posebno pozornost namenila oblikovanosti jamskih rovov. Z natančno določitvijo oblike in položaja jamskih rovov (s pomočjo 96 prečnih profilov) v odvisnosti od geoloških strukturnih

cave passage up and down in the tectonically fractured zone, and possibly also along the bedding plane.

The size of interbedded movements can be only some centimetres, there might even not be any displacement at all, but only an opening or a fissure along the bedding plane. Some opened fissures are filled by small secondary calcite veins. There are several examples of fissures which connect slipped bedding planes between them. The horizontal cave passage E from the Male jame branch winds between the tectonically broken to the fissured zone, and shows an evident development and formation along the slipped bedding planes deformations.

In a certain cave passage development period the collapses were formed along bedding planes, interbedded movements and tectonically fractured zone, usually in the areas of the greatest instability in a cave which is related to strong Dinaric fault zones. In some places the collapse material could be simultaneously carried away by water, but elsewhere some of it was accumulated into a collapse cone, because it was not removed by the underground river, which had retreated to the lower NW and SW part of the cave.

4. The Postojnska jama cave system passages are characteristically formed along the tectonically fractured zones, among which the Dinaric zones (NW-SE) are most strongly expressed, and which can be continuously traced over long distances. The cross- Dinaric fault zones (No. 10 in Annex 6) are more difficult to follow, as they are crossed and strike-slipped by the Dinaric zones. But it is necessary to stress that in understanding the cave passage regional development and the underground waters outflow they have one of the more important roles. The Pivka river sink into the Postojnska jama cave system is located exactly by the cross-Dinaric direction fault zone. Also the former Risovec blind valley and the water passages of Podzemeljska Pivka and Pivka jama, run parallel to the cross-Dinaric fault zone.

5. Wherever it was possible, and mainly in the cave passages I also defined the main movements along the fault planes.

Along one of the most expressive crushed zones which runs by the N edge of Velika gora, and continues in the NW into Lepe jame and Perkov rov and in the SE to Pisani rov, the movements are well determined. So it is necessary to stress that inside the inner fault zone the different movement directions on fault planes are defined. In Lepe jame (Figure 31) by the N fault plane which is the limit of the inner fault zone there is a horizontal movement, that is the right strike-slip. By the S fault plane the tectonic striae show vertical movement, where the N block sank and the S one rose.

By the fault zone at Velika gora the S block sank, and the N one rose. In Pisani rov, by the fault plane 30/60 which belongs to the same fault zone, we observe the left strike-slip movement.

Across Koncertna dvorana there goes another elementov, sem določila recentno stanje v oblikovanju jamskih rovov. Kjer je bilo možno, sem iz sedanje oblike sklepala tudi na inicialne zasnove razvoja jamskih rovov v odvisnosti od geoloških strukturnih parametrov.

Izmed vseh prečnih profilov sem izbrala 17 primerov (priloga 3), zaradi posebno zanimivih oblik. V nekaterih izbranih primerih se je prvotna oblika le malo spremenila. Ti profili predstavljajo nekakšne standarde za vseh ostalih 96 prečnih profilov. Tako so nekateri jamski rovi prikazani tudi z genetskega vidika.

Kot je poudaril že Šušteršič (1979 a), moramo pri opisovanju prečnih jamskih profilov upoštevati dve stališči, in sicer lahko prikazujemo današnje in inicialno stanje. Opisi vseh 96-ih prečnih profilov temeljijo na današnjem stanju, od tega 17 profilov (priloga 3) upošteva tudi nekdanje stanje do meje, kjer ga je bilo mogoče določiti.

7. Na podlagi terenskega geološkega kartiranja jamskih rovov, oblike prečnih jamskih profilov ter speleomorfoloških značilnosti rovov sem v celotnem sistemu Postojnskih jam izvrednotila danes neaktivne in aktivne rove. Pri tem sem ločevala oblikovanje v tektonsko pretrtih conah in plastnatosti.

S pomočjo geoloških in morfoloških razmer jamskih rovov sem na prilogi 4 ovrednotila njihovo oblikovanje v štirih osnovnih primerih:

- danes aktiven ali neaktiven rov oblikovan v tektonsko pretrtih conah
- danes aktiven ali neaktiven rov oblikovan v leziki
- rovi preoblikovani s podorom v tektonsko pretrtih conah
- rovi preoblikovani s podorom ob leziki.

S pomočjo analize morfoloških razmer v jami lahko z gotovostjo ločimo le glavne razvojne faze v sistemu Postojnskih jam, in sicer:

- danes neaktivni vodni rovi so se razvili v freatični coni in kasneje prešli v cono nihanja vodne gladine.
- podorni rovi so vezani na cono nihanja vodne gladine. V jugozahodnem delu takšnih rovov, je voda odnašala podorni material in jamske sedimente.
- danes aktivni vodni rov Podzemeljske Pivke je nekdanji freatični rov, ki predstavlja cono nihanja vodne gladine.

Od danes neaktivnih rovov sistema Postojnskih jam (slika 47) jih je 16% oblikovanih po tektonsko pretrtih conah in 6% po plastnatosti. Danes aktivni vodni rovi so v enakem razmerju oblikovani po tektonsko pretrtih conah (12%) kot po plastnatosti (12%). Izmed podorno preoblikovanih neaktivnih rovov jih je 9% oblikovanih po tektonsko pretrtih conah in 7% po plastnatosti. V aktivnih rovih je manjši delež podorno preoblikovanih rovov, in sicer le 3% po tektonskih conah in 2% po plastnatosti. Izmed vseh rovov sistema Postojnskih jam je kar 33% geološko neopredeljenih (slika 47), kar pomeni, da predstavljajo neprehodne sifone ali z jamskimi sedimenti preoblikovane rove, v primeru katerih

more important fault zone (in Annex 1, No. 5) which is parallel to the above-mentioned fault zone. Tectonic striae indicate vertical and horizontal movements. In the SE side passage near the railway tracks we can most reliably define the vertical movement, where the N block rose, and the S one sank, with the same movement characteristics as on the parallel fault from Velika gora.

Various vertical or horizontal movement directions along the same tectonic plane confirm the multi-phase tectonic processes.

6. I paid special attention to the cave passage development. By a precise cave passage form and position definition (by means of 96 cross-sections), dependent on geological structural elements I defined the recent state in the cave passage formation. Where it was possible from the present form I also drew a conclusion regarding the initial scheme of the cave passages development in dependence on geological structural parameters.

From all the cross-sections I chose 17 examples (Annex 3) because of their specially interesting forms. In some examples the primary form has only slightly changed. These sections represent certain standards for all the other 96 cross-sections. Some cave passages are also presented from the genetic point of view.

As Šušteršič has already stressed (1979 a) we should pay regard to two aspects in describing cave cross-sections, i.e. we should describe the present and the initial state. All 96 cross-sections descriptions are based on the present state, and 17 of them (Annex 3) can apply to a former state so far as it can be defined.

7. On the basis of the cave passage geological mapping, of the cave cross-section forms, and of the passage speleomorphological characteristics, I evaluated the now inactive and active passages of the entire Postojnska jama cave system. Thereby I distinguished between the formation in the tectonically fractured zones and in bedding.

By means of the cave passage geological and morphological conditions I evaluated in Annex 4 their formation in four basic categories:

- now active or inactive passage formed in tectonically fractured zones
- now active or inactive passage formed in bedding planes
- passages re-formed by a collapse in tecto-nically fractured zones
- passages re-formed by a collapse along bedding planes

By means of the analysis of morphological characteristics in the cave we can with certainty distinguish only the main developing phases in the Postojnska jama cave system, as follows:

- now inactive water passages were developed in the phreatic zone, and later they came into the water table oscillation zone.
- collapse passages are connected with the water

ni bilo možno zanesljivo določiti njihovega oblikovanja po geoloških strukturnih elementih.

Statistično opredeljeni rezultati geološke analize jamskih rovov nakazujejo, da predstavljajo razmere v danes neaktivnih rovih sistema Postojnskih jam drugačno podobo kot v aktivnem rovu, kjer resnično lahko opazujemo še aktivno oblikovanje jamskih rovov z vodnim tokom.

8. Z vzdolžnimi profili (priloga 1) so prikazane povezave geoloških razmer iz površja v podzemlje in obratno. Korelacija geoloških strukturnih elementov iz jame na površje na različni debelini (20-110 m) je v primeru sistema Postojnskih jam dobra. Zanesljivost morfoloških znakov na površju iz katerih bi sklepali na podzemeljske kraške rove je majhna.

9. Večletna študija odvisnosti oblikovanja jamskih rovov od geoloških strukturnih elementov je zajela konkreten primer sistema Postojnskih jam, ki je z 20 km dolžine najdaljši jamski sistem v Sloveniji.

Z geološkim kartiranjem smo dokazali odvisnost poteka jamskih rovov od geološke zgradbe terena, pri čemer se kot najpomembnejše vodilne geološke strukture kažejo: lezike poudarjene z medplastnimi zdrsi ter tektonsko pretrte cone.

Oblikovanje jamskih sistemov je v grobem lahko matematični model, ki pa v posemeznih delih seveda odstopa in ima lastne značilnosti, ki se včasih ne ujemajo s celoto oziroma le v manjšem deležu. Le zavedanje in raziskovanje podobnosti in različnosti nas pripelje do temeljnih ugotovitev.

table oscillation zone. In the SW part of such passages, water carried away the collapse material and cave sediments.

- the now active Podzemeljska Pivka water passage is a former phreatic passage which represents the water table oscillation zone.

Out of the now inactive Postojnska jama cave system passages (Figure 47) 16% of them are formed along the tectonically fractured zones, and 6% of them along the bedding. The now active water passages are equally formed along the tectonically fractured zones (12%) and along bedding (12%). Out of the collapse re-formed inactive passages 9% of them are formed along the tectonically fractured zones, and 7% of them along bedding. In the active passages there is a smaller share of the collapse re-formed passages, i.e. only 3% along tectonic zones and 2% along bedding. Out of all the Postojnska jama cave system passages there is 33% of them geologically undefined (Figure 47), which means that they represent impassable sumps, or passages re-formed by cave sediments, in which case it was not possible reliably to define their formation along geological structural elements.

Statistically defined cave passage geological analysis indicates that the conditions in the now inactive Postojnska jama cave system passages represent different features to those in an active passage where we can truly observe the still active formation of the water table cave passages.

8. The geological condition connections from the surface to the underground and vice versa are presented by longitudinal sections (Annex 1). The geological structural element correlation from the cave to the surface through different thickness of rock (20-110 m) is good in the Postojnska jama cave system sample. The reliability of morphological characteristics on the surface from which we could assume to the underground karst passages is small.

9. This several years long study of geological structural elements influence on cave passages formation used Postojnska jama cave system which is with its 20 km length the longest cave system in Slovenia, as a case study.

By geological mapping we have proved the cave passages direction dependence on the geological structure where the most important leading geological structures are bedding planes broken by interbedded movements and tectonically fractured zones.

The cave system formation can roughly be a mathematical model which naturally deviates in particular parts, and has its own characteristics which sometimes do not agree entirely, or only in a small part. Only awareness and study of similarities and differences lead us to basic statements.

11.0. UPORABLJENA LITERATURA

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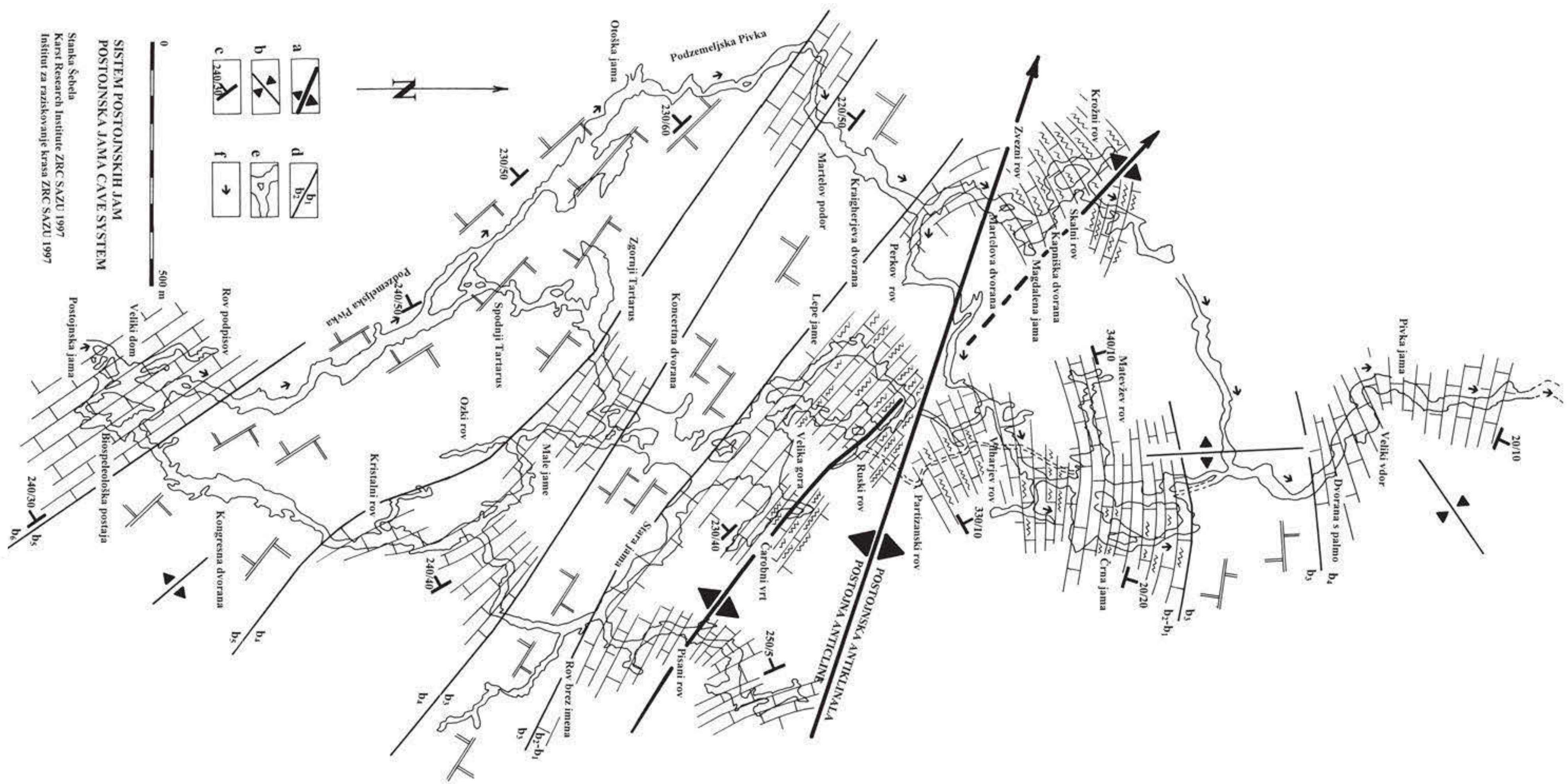
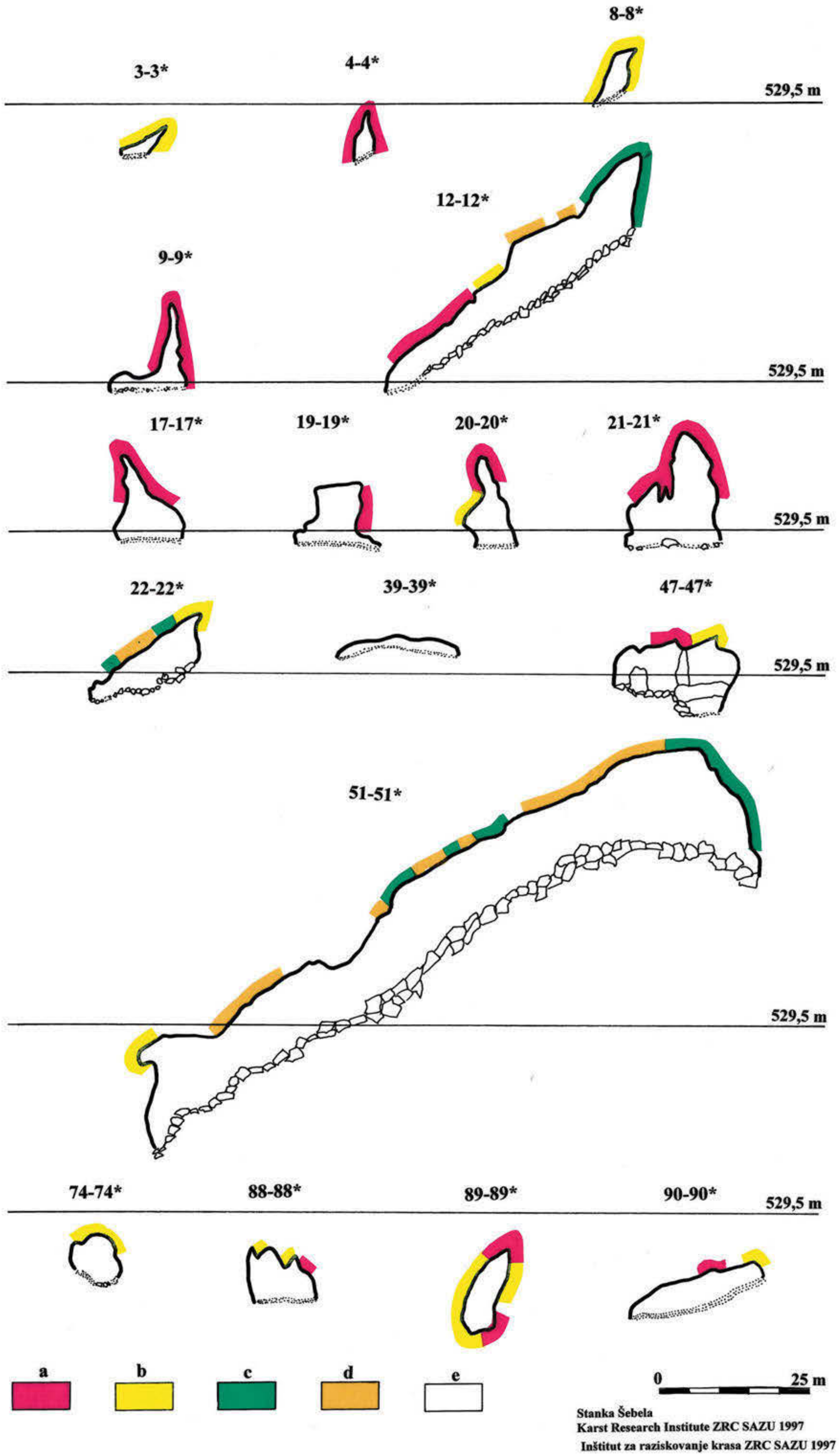


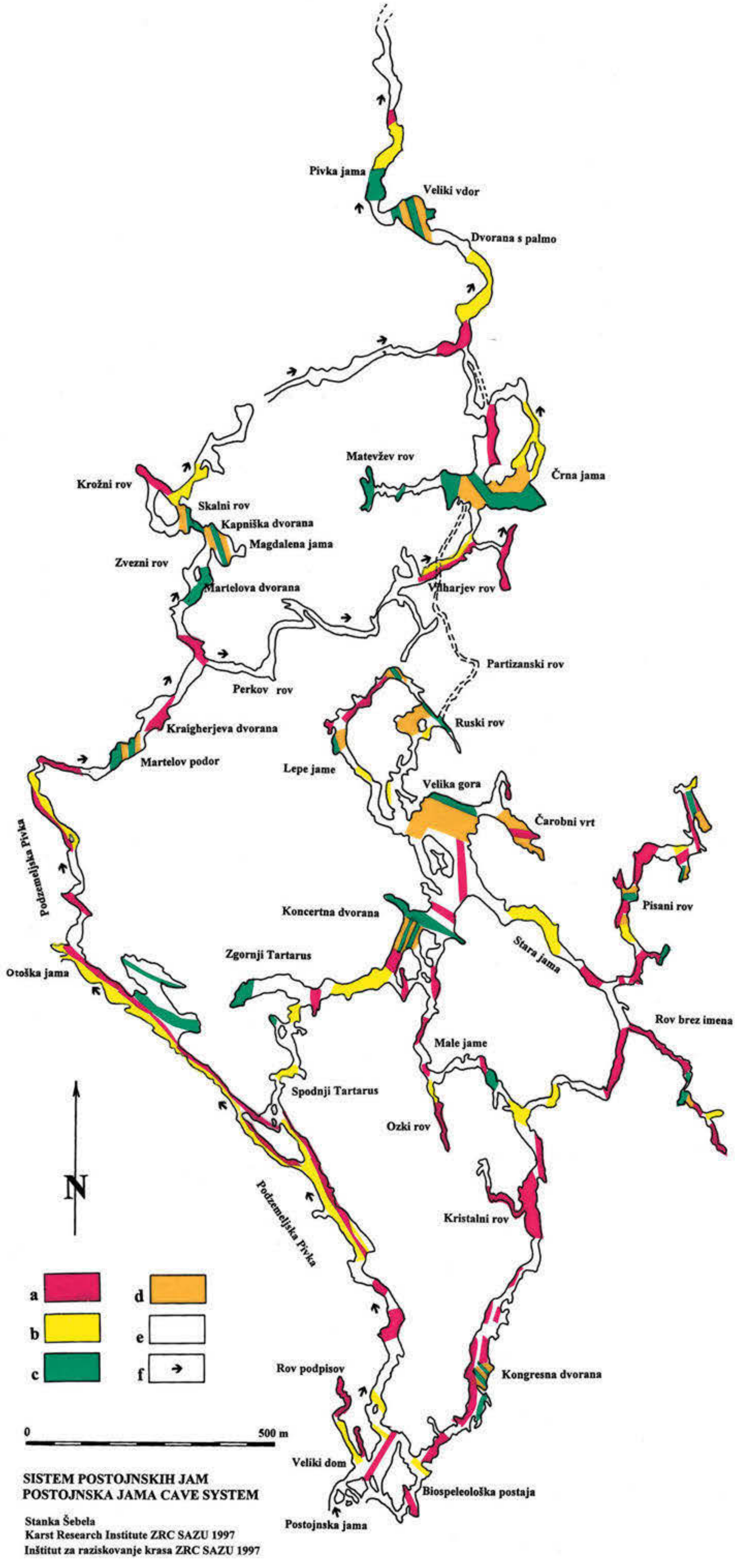
Priloga 2. Osnovna geološka karta sistema Postojnskih jam. **a** antiklinala, **b** sinklinala, **c** vpad plasti zgornje krednega apnenca, **d** litološka meja (razlaga simbolov je na sliki 2), **e** tloris jamskih rovov, **f** smer toka podzemeljske Pivke.

Annex 2. Postojnska jama cave system basic geological map. **a** anticline, **b** syncline, **c** Upper Createceous limestone bedding plane dip and strike, **d** lithological boundary (explanation of symbols is in Fig.2.), **e** cave passages ground plan, **f** underground Pivka flow direction.



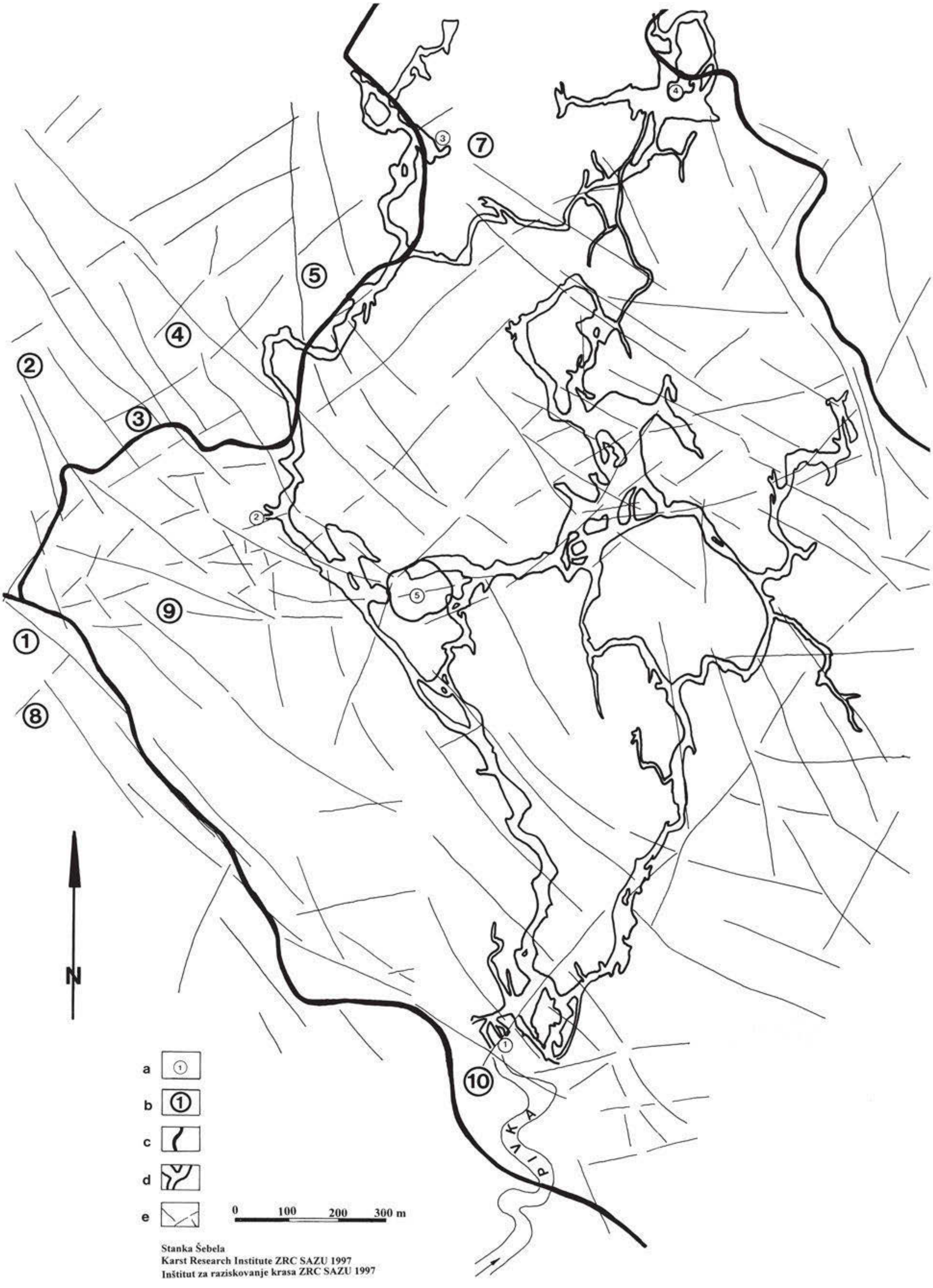
Priloga 3. Speleomorfološke razmere v 17 izbranih prečnih profilih. **a** danes aktivni ali neaktivni vodni rov oblikovan po tektonsko pretrtih conah (freatične oblike prečnih profilov), **b** danes aktivni ali neaktivni vodni rov oblikovan po plastnatosti (freatične oblike prečnih profilov), **c** izsutje iz tektonske cone (podor), **d** odlom po plastnatosti (podor), **e** nedoločljivi rovi

Annex 3. Speleomorphological conditions in 17 selected cross-sections. **a** now active or inactive water passage formed along tectonically fractured zones (cross-sections phreatic forms), **b** now active or inactive water passage formed along bedding (cross-sections phreatic forms), **c** spill out from a tectonic zone (collapse), **d** break off along bedding (collapse), **e** indefinable passages.



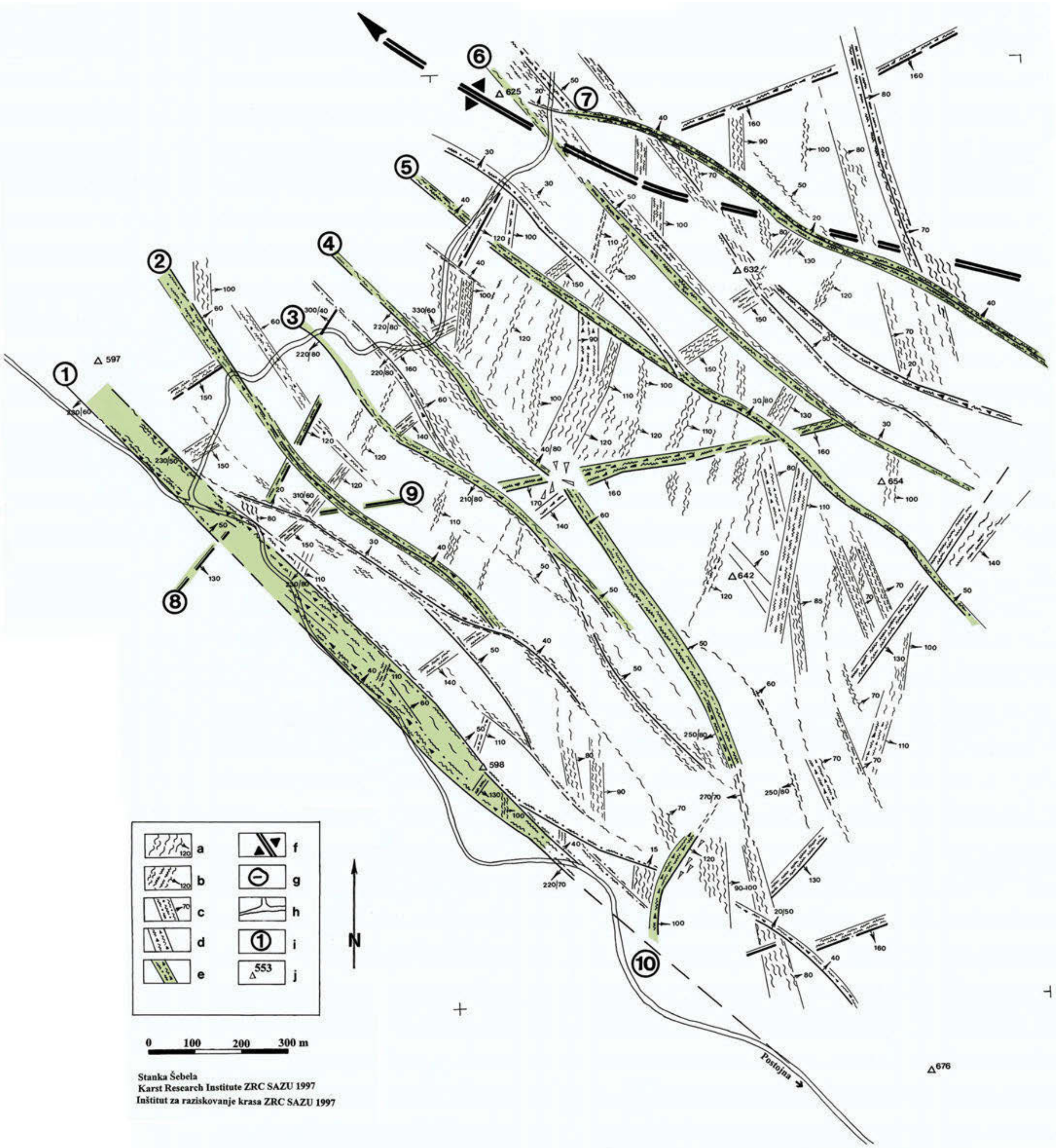
Priloga 4. Razdelitev rovov sistema Postojnskih jam glede na njihovo oblikovanje. **a** danes aktivni in neaktivni vodni rov oblikovan po tektonsko pretrtih conah, **b** danes aktivni in neaktivni vodni rov oblikovan po plastnatosti, **c** podor po tektonsko pretrtih conah, **d** podor po plastnatosti, **e** nedoločljivi rovi, **f** smer toka podzemeljske Pivke.

Annex 4. Postojnska jama cave system passages classification according to their formation. **a** now active or inactive water passage formed along tectonically fractured zones, **b** now active or inactive water passage formed along bedding, **c** collapse along tectonically fractured zones, **d** collapse along bedding, **e** indefinable passages, **f** underground Pivka flow direction.



Priloga 5. Interpretacija letalskih posnetkov nad sistemom Postojnskih jam. **a** *(**1** vhod v Postojnsko jamo **2** vhod v Otoško jamo; **3** vhod v Magdaleno jamo; **4** vhod v Črno jamo; **5** udornica Stara apnenica)*, **b** oznaka pomembnejših prelomnih con, **c** cesta, **d** tloris jamskih rovov, **e** tektonske linije.

Annex 5. Aerial photograph interpretation over the Postojnska jama cave system. **a** *(**1** entrance to Postojnska jama; **2** entrance to Otoška jama; **3** entrance to Magdalena jama; **4** entrance to Črna jama; **5** Stara apnenica collapse doline)*, **b** more important fault zones indication, **c** road, **d** cave passages ground plan, **e** tectonic lines.



Priloga 6. Tektonska karta površja nad sistemom Postojnskih jam. **a** razpoklinska cona z geološkimi elementi, **b** porušena cona z geološkimi elementi, **c** zdrobljena cona z geološkimi elementi, **d** tektonska breča, **e** pomembnejša prelomna cona, **f** antiklinala, **g** vrtača, **h** tloris jamskih rovov, **i** oznaka pomembnejše prelomne cone, **j** oznaka n.m. v. hriba v metrih.

Annex 6. Tectonic map of the surface over the Postojnska jama cave system. **a** fissured zone with geological elements, **b** broken zone with geological elements, **c** crushed zone with geological elements, **d** tectonic breccia, **e** more important fault zone, **f** anticline, **g** doline, **h** cave passages ground plan, **i** more important fault zone indication, **j** above sea level of hill in metres.

IZVLEČEK

Tektonska zgradba sistema Postojnskih jam

Nedvomna je povezava med geološko zgradbo terena in oblikovanjem kraških rovov. Sistem Postojnskih jam predstavlja združbo starih, danes suhih, vodoravnih jamskih rovov, aktivnega rova reke Pivke in brezen oziroma udornic, ki omogočajo povezavo površja z nekaterimi jamskimi rovi. Današnji vhod v jamo predstavlja ponor reke Pivke, ki je oblikovan na kontaktu med neprepustnim eocenskim flišem Postojnske kotline in zgornje krednim apnencem. Že razlaga oblikovanja aktivnega jamskega vhoda je sinteza oblikovanja večine jamskih rovov. Ponorni vhod reke Pivke je namreč v horizontalni smeri oblikovan po medplastnih zdrsih, v vertikalni smeri pa leži v močni tektonsko prelomni coni smeri severovzhod-jugozahod. Metoda podrobnega tektonsko-litološkega kartiranja je pokazala, da so se jamski rovi oblikovali v tektonskih deformacijah nastalih pri formiranju Postojnske antiklinale, kot so medplastni zdrsi ter v kasnejših prelomnih deformacijah, pri čemer so glavne smeri tektonsko prelomnih con Dinarske severozahod-jugovzhod in prečno Dinarske severovzhod-ju gozahod. Poleg dveh glavnih prelomnih smeri so ugodne tudi spremljajoče porušene in razpoklinske cone, ki so rezultat prelomne Dinarske tektonike.

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ABSTRACT

Tectonic Structure of Postojnska jama Cave System

Connection between the geological structure and karst cave passages formation is undoubted. The Postojnska jama cave system represents a union of old, now dry, horizontal cave passages, the Pivka river active passage, and shafts or collapse dolines, which enable surface connection with some cave passages. The present entrance to the cave represents the Pivka river sink which is formed at the contact between the Postojna basin impermeable Eocene flysch and the Upper Cretaceous limestone. The active cave passage formation explanation is a formation synthesis of most of the cave passages. The Pivka river sink entrance is formed along interbedded movements in the horizontal direction, and in the vertical direction it lies in a strong tectonic fault zone of NE-SW direction. The detailed tectonic-lithological mapping method has shown that the cave passages are formed in tectonic deformations which developed by the formation of the Postojna anticline, as there are interbedded movements, and in later fault deformations, where the main tectonic fault zones directions are the Dinaric NW-SE and cross-Dinaric NE-SW. Besides two main fault directions, the accompanying broken and fissured zones which are the result of the fault Dinaric tectonics are also favourable to cave formation.

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