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BEDDING PLANES, MOVED BEDDING PLANES, CONNECTIVE FISSURES AND HORIZONTAL CAVE PASSAGES (EXAMPLES FROM POSTOJNSKA JAMA CAVE)

LEZIKE, ZDRSNE LEZIKE, VEZNE RAZPOKE IN HORIZONTALNI JAMSKI ROVI (PRIMERI IZ POSTOJNSKE JAME)

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Jože Čar & Stanka Šebela: Lezike, zdrsne lezike, vezne razpoke in horizontalni jamski rovi (Primeri iz Postojnske jame)

Na primeru treh odsekov rovov v Postojnski jami je bila proučevana njihova speleogeneza. Pokazalo se je, da so oblikovane po lezikah, zdrsnih lezikah in veznih razpokah.Ugodnost le nekaterih lezik in zdrsnih lezik za speleogenezo je v njihovi povezanosti v penetrativno efektivno poroznost v določenem strukturnem bloku.
Ključne besede: geologija, speleologija, lezika, zdrsna lezika, tektonika, horizontalni jamski rovi, Postojnska jama, Slovenija.

Abstract UDC 551.44(497.4)

Jože Čar & Stanka Šebela: Bedding planes, moved bedding planes, connective fissures and horizontal cave passages (Examples from Postojnska Jama cave)

In 3 examples of passage parts from Postojnska Jama their speleogenesis was studied. It was shown that they are formed along bedding planes, moved bedding planes and connective fissures. The advantage for speleogenesis of some bedding planes and moved bedding planes is represented with their connection into penetrative effective porosity in specific structural block.
Key words: geology, speleology, bedding plane, moved bedding plane, tectonics, horizontal cave passages, Postojnska Jama cave, Slovenia.

At 5th International karstological School (1997) the paper of "Moved bedding planes, connective fissures and horizontal cave passages (Examples from Postojnska Jama cave)" was presented. This article represents a supplemented and rewritten presentation.

Na 5. mednarodni krasoslovni šoli (1997) je bilo predstavljeno predavanje z naslovom "Moved bedding planes, connective fissures and horizontal cave passages (Examples from Postojnska Jama cave)". Članek, ki je pred vami, predstavlja dopolnjeno in predelano predavanje.

DEFINITION OF PROBLEM

In horizontal cave passages we find two kinds of passages regarding the principal geological structures. One follows geneticaly different *phisical discontinuities* in carbonate rocks, between them are also *bedding planes* (stratification), others are developed inside fault zones. In this article we are dealing with formation of some horizontal passages in Postojnska Jama cave which were undoubtedly formed along *bedding planes*. The passages are formed along dip direction of bedding planes or along strike direction. On the basis of direct observations we will discuss about speleogenetical role of bedding planes, mostly so-called moved bedding planes along which we can observe interbedded movements, and about connections between bedding planes with connective fissures.

PREVIOUS RESEARCHES ABOUT IMPORTANCE OF BEDDING PLANES AND MOVED BEDDING PLANES FOR KARSTIFICATION

Researches about bedding planes in speleogenesis

Bedding structures (stratification) are in numerous cave systems so clearly connected with direction and shape of the passage, that karstologists never doubted about their importance for formation of underground spaces. Numerous foreign and Slovene authors have written about that. The problematics about genetical role of bedding planes in speleogenesis is normally presented as less important part in articles, which are dedicated to other karstological problems. Interesting data about bedding planes were studied by: **Gospodarič,** 1959, 1965,1976; **Davies,** 1960; **Gams**, 1961, 1974; **Ford,** 1971; **Ford** & **Ewers**, 1978; **Čar**, 1982; **White**, 1988; **Ford** & **Williams**, 1989; **Šebela**, 1994. The authors established that bedding planes as opened discontinuities in limestones are very favourable for collection and transformation of water flow. Many times the passages are formed along strike direction or can be formed along dip direction of bedding planes. Cross sections are also formed in the same manner.

We need to mention **Lowe (**1992) and **Lowe & Gunn (**1997), they studied problematics of bedding planes and also deepened and extended the studies. According to them bedding planes are included between other "elements of carbonate sequences", which represent so called *inception horizons*. Along them first phases of speleogenesis were formed, that's so called *inception* (**Lowe & Gunn**, 1997).

In 1994 **Šušteršič** agreed with ideas of **Lowe** (1992) and with speleogentical importance of the same bedding planes and lithological contacts (dolomite-limestone) for formation of cave passages on longer distances. Šušteršič (1994) used the termin *pseudo-bedding planes* for different discontinuities in rocks.

In some regards for karstologists new interpretation about importance of bedding planes for speleogenesis was given by **Knez** (1996). He collected and critically studied facts about importance of bedding planes for speleogenesis. With sedimentological methods, especialy sedimentary petrography studies (microscopy) he try to find out the reasons for "gathering of inicial channels along small number of bedding planes", which he called *formative bedding planes*.

Researches about moved bedding planes in speleogenesis

The speleogenetical importance of moved bedding planes is for many years stressed by karstologists, but without a clear explication why some are good for karstification and others are not.

About moved bedding planes indirectly talked **Davies** (1960), when he mentioned caves in folded limestones.

About formation of interbedded movements **Gams** (Gams, 1961, 50) wrote in 1961. The same author studied Škocjanske Jame caves and he wrote: “Nice moved planes are beside Velika and Mala dolina collapse dolines visible also in watter passage of underground Reka“ (**Gams**,1974,192).

In any bedded limestone formation there are a great many bedding planes but only small propotion is used during cave formation. Very often these display some clear feature that explains their preferential selection, such as a shale parting, a discontinuous chert filling or slickensiding and minor brecciation indicative of differential slipping (**Ford & Ewers,** 1978).

Gospodarič (1983) also determined “in faults transformed bedding planes” in Škocjanske Jame caves. Many faults continue from one bedding plane to another, what we can see as moved bedding planes.

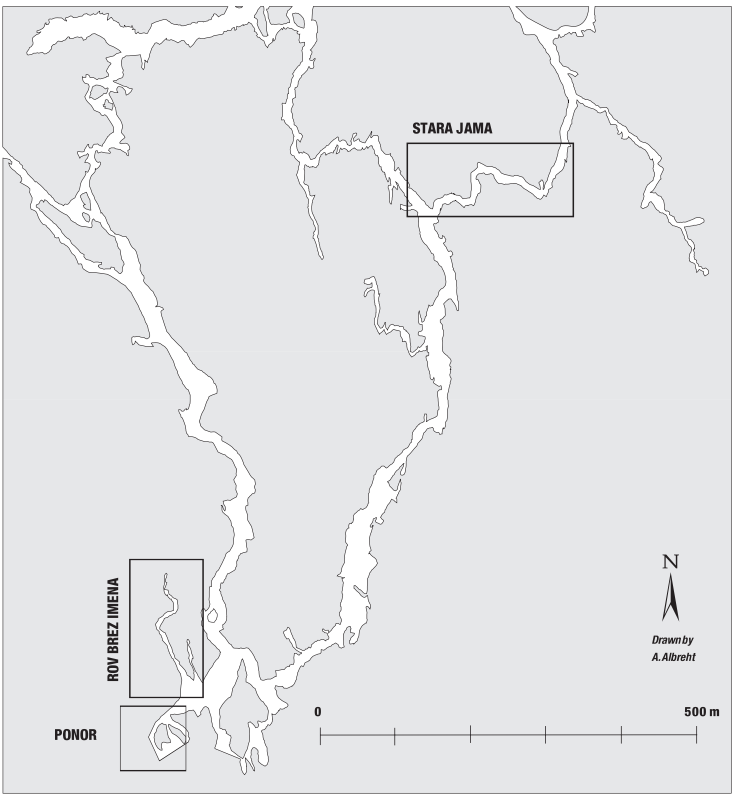

Fig. 1: Ground plan of Postojnska Jama with marked studied examples.
Sl. 1: Tloris dela Postojnske jame in označeni primeri študije.

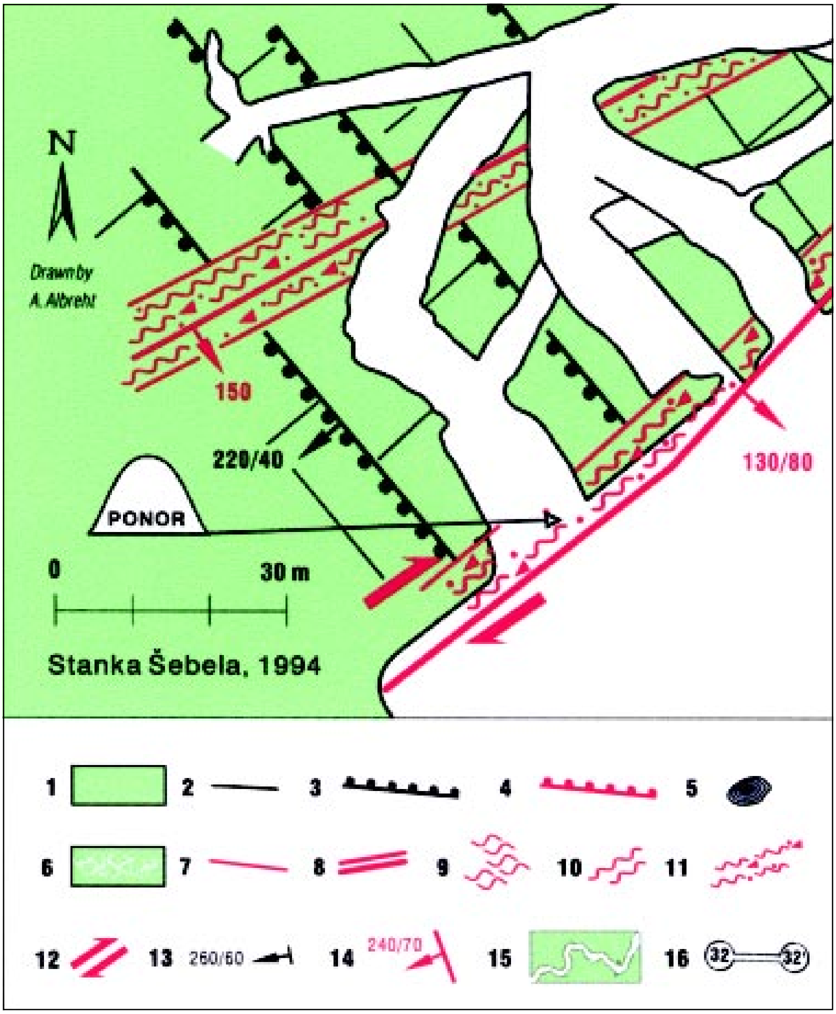

Fig. 2: Geological sketch of tectonic-lithological conditions of Pivka river ponor.
1-bedded Upper Cretaceous limestone, 2-stratification-bedding planes, 3-moved bedding plane, 4-moved connective fissure, 5-corrosional widenings, 6-calcite veins, 7-fissures, 8-fault, 9-fissured zone, 10-broken zone, 11-crushed zone, 12-relative direction of tectonic movement, 13-strike and dip of bedding, 14-strike and dip of fault plane, 15-ground plan of cave passage, 16-cross section with sign.
Sl. 2: Geološka skica tektonsko-litoloških razmer ponora Pivke.
1-plastnati zgornjekredni apnenec, 2-stratifikacija-lezike, 3-zdrsna lezika, 4-zdrsna vezna razpoka, 5-korozijske razširitve, 6-kalcitne žile, 7-razpoke, 8-prelom, 9-razpoklinska cona, 10-porušena cona, 11-zdrobljena cona, 12-relativna smer tektonskega premika, 13-slemenitev in vpad plasti, 14-slemenitev in vpad prelomne ploskve, 15-tloris jamskega rova, 16-prečni prerez z oznakami.

In development of cave passages in Postojnska Jama cave according to bedding planes the importance of interbedded movements was specially stressed (**Šebela**, 1994).

Newer investigations about importance of interbedded movements for speleogenesis were given by **Knez** (1996) in the example of Škocjanske Jame caves. He determined bedding planes marked as 400, 500 and 600 which were moved as *formative bedding planes*. Along them cave passages were formed. **Knez** (1996) also wrote: "There is a very interesting connection between formative bedding planes and interbedded movements. What interbedded movement means in speleogenetical view is still an open question."

Regarding studied literature we can conclude that all researchers agree about importance of bedding planes and interbedded movements for cave passages formation. The question why some cave passages are formed just along special bedding planes and why moved bedding planes are more convenient for speleogenesis is still not clearly answered.

GEOLOGICAL CONDITIONS IN POSTOJNSKA JAMA CAVE AND ON THE SURFACE ABOVE IT

About geological structure of Pivka basin and its surroundings by Planina and Cerknica Polje and about geological conditions in Postojnska Jama cave we have many studies. First geological

Fig. 3: Ponor of Pivka river (511 m a.s.l.) was developed along bedding planes influenced by interbedded movements (photo S. Šebela).
Sl. 3: Ponor Pivke (511 m n.m.v.) se je oblikoval ob lezikah poudarjenih z medplastnimi zdrsi (foto S. Šebela).

data were done by **Stur** (1858) and **Stache** (1859). At the beginning of 20th century the geology of Notranjska, Visoki kras and specially Postojna and Planina was studied by **Kossmat** (1897, 1905, 1909, 1913). In 1960's the lithostratigraphy of wider surroundings of Postojna and in Postojnska Jama cave was made by **Pleničar** (1961, 1970). He also contributed the data about stratigraphy of Postojnska Jama cave and first ideas about correlation between passages and bedding planes. Principal studies about geological conditions of Postojna kras and Postojnska Jama cave were contributed by **Gospodarič** (1963, 1964, 1968, 1969 a, 1969 b, 1976). Newer views on tectonic-structural questions of Postojna kras and Notranjska are opened in work of **Placer** (1981, 1996), **Čar & Gospodarič** (1984) and **Čar & Šebela** (1997). In recent time **Šribar** (1995) and **Rižnar** (1997) were dealing with lithostratigraphic development of rocks between Planina and Postojna. **Šebela** (1989, 1992, 1994) studied lithological, tectonic and speleogenetical problems of Postojna kras, especially of Postojnska Jama cave. From numerous studies we will mention just those which are important for our article.

Postojnska Jama cave system is the longest horizontal cave system in Slovenia (20 km). Postojnska Jama cave is called after southern part of cave system and is developed in Upper Cretaceous limestones (**Kossmat**, 1897; **Pleničar**, 1961; **Gospodarič**, 1976; **Rižnar**, 1997). There are light brown, gray or white coloured thin or thick bedded micritic and organogenic limestones with transitions into organogenic breccia with layers of lumacelle. Limestone can be dolomitised, in lower stratigraphic layers we find chert inclusions (**Šebela**, 1994; **Rižnar**, 1997).

Previous researches showed that Pivka basin with Postojna kras and wider surroundings is typical picture of thrust construction of W Slovenia (**Placer**, 1981, 1996). Later strike-slip faults in NW-SE and accompanying deformations complicated structural relations in studied area (**Čar**, 1982; **Čar & Gospodarič**, 1984; **Šebela**, 1994; **Čar & Šebela**, 1997). It's reasonable that rocks of Postojna kras are strongly

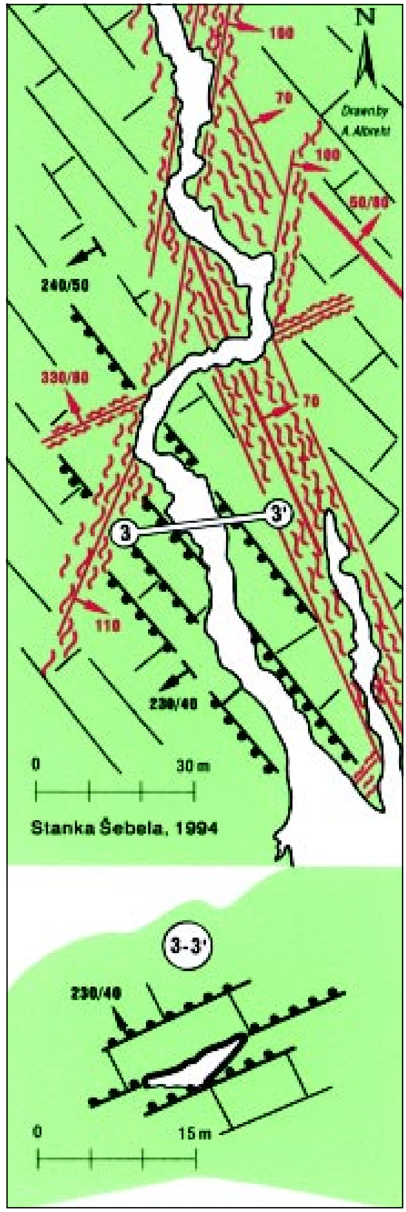

Fig. 4: Geological sketch of tectonic-lithological conditions in Rov Starih Podpisov.
Sl. 4: Geološka skica tektonsko-litoloških razmer Rova starih podpisov.

tectonically fissured. Thrusting and folding (**Gospodarič**, 1976; **Čar & Gospodarič**, 1984; **Šebela**, 1994) caused interbedded movements along numerous bedding planes in wider space. The same effects in smaller scale can be observed also along strike-slip faults.

Cave passages in Postojnska Jama cave were first mapped by **Gospodarič** (1965, 1976). Beside lithology he studied also fault planes and fissures which were not described as zones. The new tectonic-lithological mapping of Postojnska Jama was done in the scale 1:500 (**Šebela**, 1994). One of the principal conclusions represent today passages orientation compared to geological structure - bedding and fault zones. For the development of cave passages in Postojnska Jama importance of interbedded movements, which represent secondary deformations of formation of Postojna anticline in direction NW-SE is specially stressed (**Šebela**, 1994).

Postojnska Jama cave is developed in more or less bedded limestones. Bedding planes and moved bedding planes had principal role for orientation and formation of cave passages. Due to big reshaping of passages because of stronger neotectonic strike-slip faults, which crosses cave passages, today it is not possible to completely reconstruct primary stages.With studies of 93 recent cross sections in Postojnska Jama cave **Šebela** (1994) determined that 37.6 % of cross sections are shaped according to bedding. In active passage of underground Pivka cross sections formed according to bedding represent 4.6 % of all cross sections and 3.6 % represent cross sections formed along tectonic zones.

Fig. 5: Southern part of the passage Rov Starih Podpisov, is developed along moved bedding plane (photo S. Šebela).
Sl. 5: Rov starih podpisov, južni rov je razvit po lezikah poudarjenih z medplastnimi zdrsi (foto S. Šebela).

THREE EXAMPLES OF HORIZONTAL PASSAGES FROM POSTOJNSKA JAMA CAVE

With studies of genesis our observations are related to actual conditions of passage walls. First structures within which passages were formed are today not preserved any more. Studied conditions represent a good enought approximations of primary conditions, especially if we know that the thickness of removed rocks by corrosion and errosion is normally not bigger than 2-3 m.

All 3 studied examples from Postojnska Jama cave (Figure 1) are in SW part of Postojna anticline which was formed in Miocene and Pliocene when in SW Slovenia overthrusting was accompanied with folding. To that period belongs also formation of interbedded movements which activated bedding planes to communicate with water and are important factor for formation of horizontal cave passages

PONOR ENTRANCE TO POSTOJNSKA JAMA CAVE

Entrance parts of Postojnska Jama cave are developed in thicker bedded grey-brown limestone of Senonian period (K_2^3) with dip direction 30-40^0 towards SW. Active and not active entrances to

Fig. 6: Geological sketch of tectonic-lithological conditions in Stara Jama.
Sl. 6: Geološka skica tektonsko-litoloških razmer Stare jame.

the cave are developed in laterally same bedding which thickness is around 6-7 m, but are not developed in the same bedding plane. Today's ponor is at altitude of 511 m, today's not active entrances are 19 m higher.

At the ponor entrance of river Pivka to Postojnska Jama cave (Figure 2) bedding planes are expressed with interbedded movements. The displacement is just for some cm. Today's ponor is developed also at cross Dinaric fault zone with geological elements 130/80 with horizontal movement.

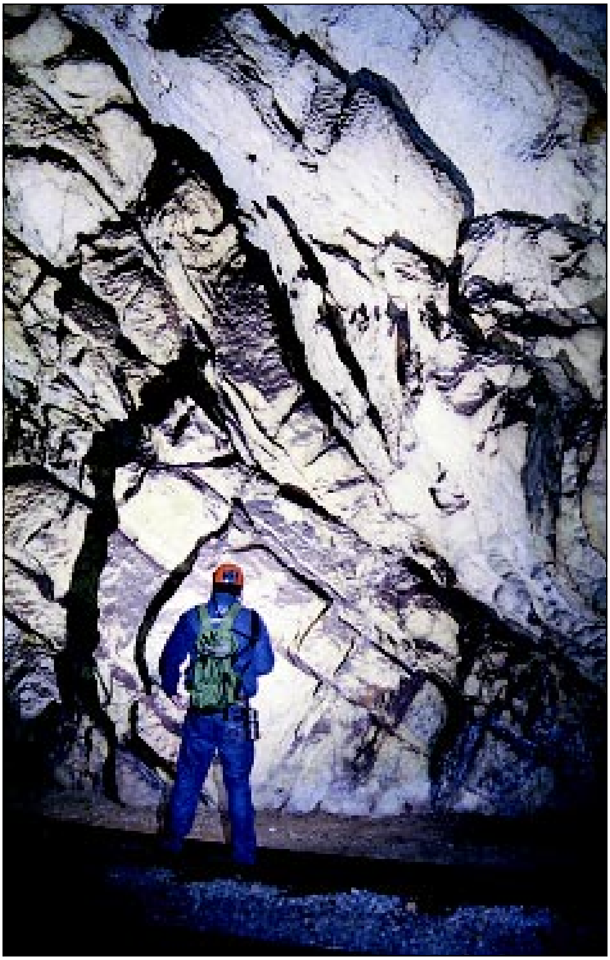

Fig. 7: Interbedded movements deformed bedding, example from Stara Jama of Postojnska Jama cave (photo S. Šebela).
Sl. 7: Medplastni zdrsi so deformirali plastnatost, primer iz Stare jame v Postojnski jami (foto S. Šebela).

In Figure 2 just some bedding planes are marked due to map scale, although all area represent many parallel moved bedding planes. The image about position of bedding planes can be seen from Figure 3.

ROV STARIH PODPISOV

The passage Rov Starih Podpisov is developed in Senonian limestone, which dips 40-50^0 towards SW. There are thicker limestone beds with 0.5-1 m. Southern part of the passage 50 m long, is developed along moved bedding plane which represents just one of numerous moved bedding planes (Figure 4), in northern part the passage follows tectonically fractured zones. Principal directions of tectonically fractured zones are NW-SE and NE-SW. The passage shows characteristic formations in phreatic zone, later formation in vadose zone is more distinctive in northern passage. Typical cross section of southern passage has the shape of lens inclined as dip direction of bedding planes (Figure 5).

STARA JAMA

A part of Postojnska Jama cave NE from Male Jame called Stara Jama (Figure 6) meanders between well expressed bedding. Beds of Upper Cretaceous Turonian limestone (K_2^2) are 0.5-1 m

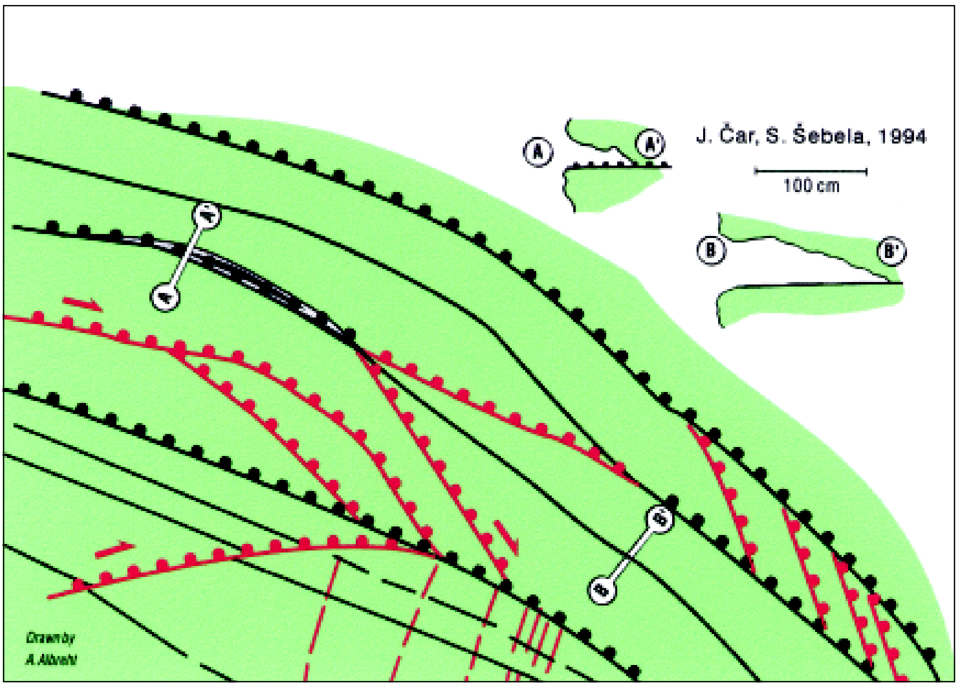

Fig. 8: Stara Jama, detail from south flank of passage.
Sl. 8: Stara jama, detajl iz južnega boka rova.

thick with dip direction towards SW for 30-50^{0}.

At the distance of 150 m the passage turns 5 times. Different parts of the passage are parallel with bedding direction, transverse to bedding direction, some parts follow tectonically fractured zones between which fissured zones in direction NW-SE prevail, less common are zones in NE-SW direction (Figure 6). From Figure 6 we can see that the passage follows moved bedding planes in 3 sections of the passage.

For better understanding the problematics also N (Figure 9) and S (Figure 8) side of passage where studied. In passage wall cross section of bedding planes and moved bedding planes in which the passage is formed are shown.

In Stara Jama the bedding is strongly tectonically deformed. In some places bedding planes are opened, inside them we can observe 0.5 cm thick layer of secondary sparitic calcite veins. At the time of folding some bedding planes were deformed with interbedded movements. Interbedded movements can cross from one bedding plane to another. All bedding planes are not tectonically deformed, but in Stara Jama such bedding planes prevail (Figure 7 and 8).

In the layer above moved bedding plane we can observe wall potholes formed in phreatic conditions. Other wall potholes are formed along thrust bedding planes, regular bedding planes and vertical fissures which cross bedding planes (Figure 9). In speleogenesis all 3 structures are playing important role. The passage general direction is perpendicular to the strike direction of bedding planes.

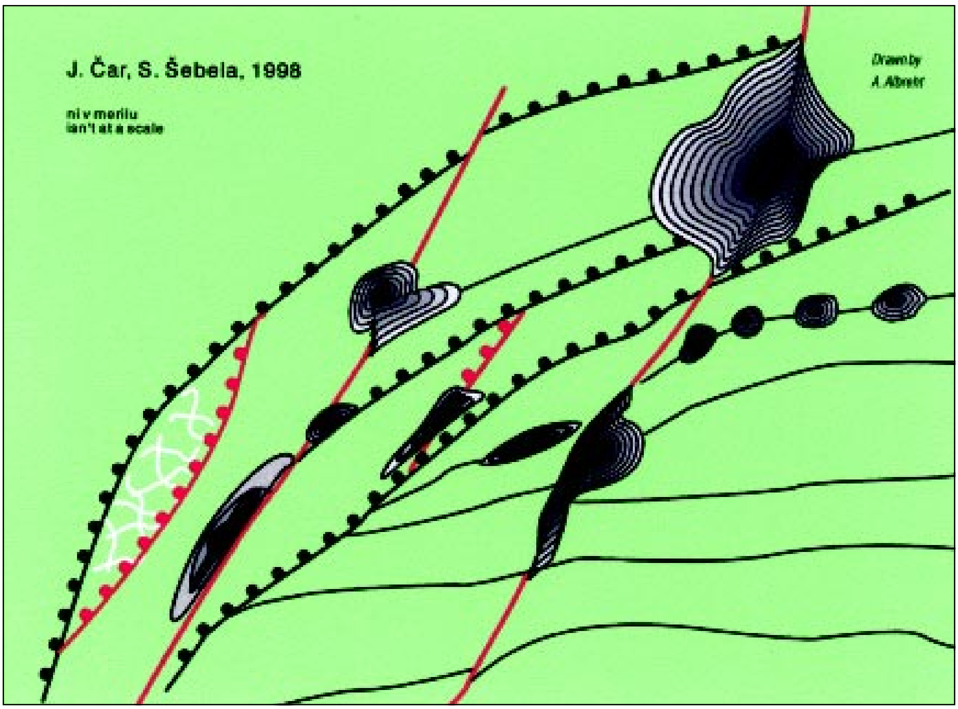

Fig. 9: Stara Jama, detail from north flank of passage.
Sl. 9: Stara jama, skica-detajl iz severnega boka rova.

BEDDING PLANES AND PERMEABILITY

Studied examples from Postojnska Jama cave prove big and in some examples principal role of bedding planes and moved bedding planes for speleogenesis.

Bedding planes form during sedimentary processes and have different causes. They represent physical discontinuities, which represent stratification in rocks, also in limestones. Because of changing of sedimentary conditions and also besause of changes which are formed during different later diagenetic processes, singular bedding planes are not endless in space. They are final discontinuities which can continue at least for a while in vertical direction, but finally terminate in all directions. Because bedding planes are opened discontinuities can be locally permeable and very capable for water flow. But that's not enought for their active role in inception processes. They are included in speleogenetical process just in case when water runs into the bedding plane and also out of it. There is probably not much of such kind of bedding planes. Speleogenetical process can start just along such bedding planes which are included in wider communication system in rocks.

Interbedded movements or so called *moved bedding planes* and *connective fissures* between bedding planes are formed during different tectonic processes. They are mostly formes during thrusting and folding, and localy also near faults especialy strike-slip faults. Because bedding planes represent already from sedimentological point of view mechanically weaker zones (tectonic preview) along them endogenic deformations in the sense of "opening" of bedding planes can be formed. Beside this also interbedded movements due to folding and near fault deformations, which can at least partly connect horizontaly and verticaly situited bedding planes, can connect bedding planes into communicative system with slipped fissures. Moved bedding planes with connective fissures can be included in speleogenetical process just if they are permeable for underground water flow. Moved bedding planes have much more importance than tectonically not disrupted bedding planes because of their bigger speleogenetical role due to wider areas of tectonic deformations and their connective role between bedding planes. If bedding planes and moved bedding planes are connected in some area into communicate system we can call this system *penetrative effective porosity*. This cause basic reason for percolation of water and formation of caves.

CONCLUSIONS

Precisely analized examples from Postojnska Jama cave and other mentioned horizontal passages show that karstification is not present along all differently opened discontinuities in carbonate rocks but just along some of them which are more favourable for karstification. Between "for karstification more favourable" opened discontinuities the "real ones" are undisturbed bedding planes, i.e. discontinuities which were formed with sedimentary processes, in our example *stratificational bedding planes*, tectonically enlarged are *moved bedding planes* as also differently formed *fissures*. The reason for favourability of some stratificational bedding planes for karstification and the others not according to our oppinion is not in some kind of special sedimentological composition. The reason cannot be find either in special tectonic mechanism. The same can be written also for genetically different fissures. The length or the shape are not important. Researched examples prove that for karstification were favourable just those opened bedding planes, moved bedding planes and fissures which were at the time of good conditions for karstification connected into system of communicational paths where water could flow easily. Such state in one area or rock block can be defined as *penetrative effective porosity.*

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LEZIKE, ZDRSNE LEZIKE, VEZNE RAZPOKE IN HORIZONTALNI JAMSKI ROVI (PRIMERI IZ POSTOJNSKE JAME)

Povzetek

PROBLEMATIKA

V horizontalnih jamskih sistemih najdemo glede na vodilne geološke strukture v splošnem dvoje vrst rovov. Eni sledijo genetsko različnim *fizičnim prekinitvam* v karbonatnih kamninah, med njimi so tudi *lezike* (stratifikacija), drugi pa so oblikovani po prelomnih conah. V tem prispevku pojasnjujemo nastanek nekaterih horizontalnih rovov v Postojnski jami, ki so nedvomno nastali ob *lezikah.* Rovi so oblikovani po njihovih vpadnicah ali vzdolž slemenitve. Na podlagi neposrednih opazovanj bomo razpravljali o speleogenetski vlogi *lezik*, predvsem takoimenovanih *zdrsnih lezik* ob katerih je prišlo do medplastnih zdrsov ter povezavah med različnimi lezikami z veznimi razpokami.

STAREJŠI PODATKI O VLOGI LEZIK IN MEDPLASTNIH ZDRSOV ZA ZAKRASEVANJE

Dela o pomenu lezik v speleogenezi

Plastnate strukture (stratifikacija) so v številnih jamskih sistemih tako jasno povezane s potekom in obliko rovov, da o njihovem odločilnem pomenu pri nastajanju podzemskih prostorov krasoslovci v resnici niso nikdar dvomili. O tem so pisali številni tuji in domači raziskovalci. Vendar pa predstavlja problematika genetske vloge lezik v speleogenezi običajno le kot manj pomemben del v razpravah, ki so sicer posvečene drugim krasoslovnim temam. Zanimive podatke o obravnavani temi so prispevali: **Gospodarič,** 1959, 1965, 1976; **Davies,**1960; **Gams**, 1961, 1974; **Ford,** 1971; **Ford** & **Ewers**, 1978; **Čar**, 1982; **White**, 1988; **Ford** & **Williams**, 1989; **Šebela**, 1994. Avtorji v splošnem ugotavljajo, da so lezike kot odprte prekinitve v apnencih izjemno ugodne za zbiranje in prevajanje vode, tako da potekajo rovi velikokrat vzdolž plasti (po slemenitvi) ali pa so nastali po njihovem vpadu. Soglasno s tem so oblikovani tudi prečni profili.

Posebej omenjamo delo **Lowe**-a (1992) in **Lowe**-a **& Gunn**-a (1997), ki sta problematiko lezik relativizirala, a hkrati poglobila in razširila. Lezike sta namreč vključila med druge "elemente karbonatnih sekvenc", ki predstavljajo takoimenovane *začetne horizonte*. Ob njih naj bi se začele odvijati najbolj zgodnje faze v speleogenezi ali *začetja* (**Lowe & Gunn**, 1997).

Šušteršič je leta 1994 razpravljal o začetju soglasno z idejami **Lowa** (1992) ter speleogenetskem pomenu istih lezik in litoloških kontaktov (dolomit-apnenec) za nastanek jamskih rovov na večji medsebojni oddaljenosti. Pri tem uvaja izraz *oblezične ploskve* za različne nezveznosti v kamnini.

Nadalnje poglobljeno in v nekaterih pogledih za krasoslovce inovativno razmišljanje o vlogi lezik pri speleogenezi je prispeval **Knez** (1996). Zbral in kritično je ocenil dosedanja spoznanja o pomenu in vlogi lezik v speleogenezi. S sedimentološkimi metodami, predvsem sedimentno petrografskimi preiskavami (mikroskopija), je poskušal ugotoviti vzroke za "zgostitev inicialnih kanalov v območju majhnega števila lezik", ki jih imenuje *nosilne lezike*.

Dela o pomenu zdrsnih lezik v speleogenezi

Tudi na speleogenetski pomen lezik ob katerih je prišlo do medplastnih zdrsov krasoslovci že dolgo časa opozarjajo, vendar brez jasnih pojasnil zakaj so nekatere ugodne za zakrasevanje druge pa ne.

Posredno govori o medplastnih zdrsih **Davies** (1960), ko omenja jame v nagubanih apnencih.

O nastanku medplastnih zdrsov je pisal leta 1961 **Gams** (Gams, 1961, 50). Isti avtor je pri opisu Škocjanskih jam zapisal: " Lepe drsne ploskve so vidne ne le v obeh udornicah, v Veliki in Mali dolini, ampak tudi v vodni jami podzemeljske Reke." (**Gams**,1974, 192).

Po mnenju **Ford**-a in **Ewers**-a (1978) je le nekaj lezik v plastnatih apnencih ugodnih za oblikovanje jamskih rovov. Vzroke za to moramo iskati v glinastih vložkih, prisotnosti rožencev ter različnih tektonskih zdrsnih strijah in brečah.

Gospodarič (1983) je pri opisu Škocjanskih jam omenjal "v prelome spremenjene lezike".

Kot je poudarila **Šebela** (1994), imajo velik pomen za razvoj rovov Postojnske jame tudi lezike ob katerih so jasno izraženi medplastni zdrsi.

Najnovejša razmišljanja o pomenu medplastnih zdrsov za speleogenezo je na primeru Škocjanskih jam podal **Knez** (1996). Ugotovil je, da so lezike z oznakami 400, 500 in 600, ob katerih je prišlo do medplastnih zdrsov, takoimenovane *nosilne lezike.* Ob njih so nastali jamski rovi. V nadaljevanju je **Knez** (1996) zapisal, da kaže "na zanimivo skladnjo nosilnih lezik in medplastnih zdrsov", v zaključku pa dodaja "kaj pomeni medplastni zdrs v speleogenetskem pogledu, je še odprto vprašanje."

Glede na dosedanje literarne podatke torej lahko povzamemo, da so vsi raziskovalci soglasni o velikem pomenu lezik in lezik z medplastnimi zdrsi za speleogenezo. Na vprašanje zakaj se oblikujejo jamski rovi samo ob določenih lezikah in zakaj so zdrsne lezike v splošnem ugodnejše za speleogenezo pa raziskovalcem doslej še ni uspelo v celoti in nedvoumno odgovoriti.

ORIS GEOLOŠKIH RAZMER V POSTOJNSKI JAMI IN NAD NJO

O geološki zgradbi Pivške kotline, njene širše okolice tja do Planinskega in Cerkniškega polja ter geoloških razmerah v Postojnski jami imamo obilico razprav. Prve geološke podatke sta prispevala sredi prejšnjega stoletja **Stur** (1858) in **Stache** (1859). Na začetku 20.stoletja je geologijo Notranjske, Visokega krasa in še posebno ozemlja med Postojno in Planino podrobneje raziskoval **Kossmat** (1897, 1905, 1909, 1913). V šestdesetih letih se je z litostratigrafskimi problemi v širši okolici Postojne in Postojnski jami ukvarjal **Pleničar** (1961, 1970). Prispeval je tudi pomembne podatke o stratigrafiji Postojnske jame in prve zamisli o soodvisnosti poteka rovov in plastnatosti.

Odločilne podatke o geoloških razmerah na Postojnskem krasu in Postojnskem jamskem sistemu je prispeval **Gospodarič** (1963, 1964, 1968, 1969 a, 1969 b, 1976). Nove poglede na tektonsko-strukturna vprašanja Postojnskega krasa in Notranjske odpirajo razprave **Placerja** (1981, 1996), **Čarja & Gospodariča** (1984) ter **Čarja & Šebele** (1997). V najnovejšem času sta se z litostratigrafskim razvojem kamnin med Planino in Postojno ukvarjala **Šribar** (1995) in **Rižnar** (1997), **Šebela** (1989, 1992, 1994) pa z litološkimi, tektonskimi in speleogenetskimi problemi Postojnskega krasa in predvsem Postojnske jame. Iz obilice podatkov iz naštetih razprav, bomo omenjali le tiste, ki so pomembni za naše nadaljnje razpravljanje.

Postojnski jamski sistem je najdaljši jamski splet v sloveniji (20 km). Postojnska jama, ki predstavlja njegov jugozahodni del, je nastala v zgornjekrednih apnencih (**Kossmat**, 1897; **Pleničar**, 1961; **Gospodarič**, 1976; **Rižnar**, 1997). Menjavajo se svetlo rjavi, sivi ali beli tanko do debelo plastnati mikritni in organogeni apnenci s prehodi v organogeno brečo in vložki lumakel. Apnenec je ponekod dolomitiziran, v nižjih stratigrafskih nivojih najdemo tudi vložke roženca (**Šebela**, 1994; **Rižnar**, 1997).

Dosedanje raziskave so pokazale, da je Pivška kotlina s Postojnskim krasom in širšo okolico izsek iz značilne narivne zgradbe zahodne Slovenije (**Placer**, 1981, 1996). Kasnejši zamiki v smeri SZ-JV s spremljajočimi deformacijami so dodatno zapletli strukturne odnose na obravnavanem ozemlju (**Čar**, 1982; **Čar & Gospodarič**, 1984; **Šebela**, 1994; **Čar & Šebela**, 1997). Razumljivo je torej, da so kamnine Postojnskega krasa močno tektonsko pretrte. Narivanje in s tem povezano gubanje (**Gospodarič**, 1976; **Čar & Gospodarič**, 1984; **Šebela**, 1994) je povzročilo medplastne zdrse ob številnih lezikah v širšem prostoru. Enake efekte v manjšem obsegu pa opazujemo tudi ob zmikih.

Jamske prostore v Postojnski jami je prvi kartiral **Gospodarič** (1965, 1976). Poleg litologije je izvrednotil tudi posamezne prelomne ploskve in razpoke, ki jih pa ni združeval v sisteme. Novo kartiranje Postojnske jame je potekalo v merilu 1:500 in je bilo tektonsko-litološkega značaja (**Šebela**, 1994). Eden bistvenih zaključkov je ugotovitev današnjega poteka rovov v odvisnosti od geoloških struktur - plastnatosti in prelomnih con. Za razvoj rovov v Postojnski jami je posebej poudarjen pomen medplastnih zdrsov, ki predstavljajo sekundarne deformacije pri nastajanju Postojnske antiklinale s smerjo SZ-JV (**Šebela**, 1994).

Postojnska jama je v celoti razvita v bolj ali manj izrazito plastnatih apnencih. Lezike in zdrsne lezike so zato vsekakor imele odločilno vlogo pri usmerjanju in oblikovanju njenih rovov. Zaradi obsežnega preoblikovanja rovov ob številnih tudi močnih neotektonskih zmikih, ki sekajo jamski sistem, seveda danes ni več mogoče v celoti rekonstruirati prvotnih razmer. **Šebela** (1994), ki je analizirala 93 recentnih prečnih profilov v Postojnski jami, je ugotovila, da je kar 37,6 % analiziranih profilov oblikovanih po plastnatosti. V aktivnem delu podzemeljske Pivke predstavljajo prečni profili oblikovani po plastnatosti večji delež, in sicer 4,6 % vseh prečnih profilov, medtem ko se je v tektonskih conah oblikovalo 3,6 %.

TRIJE PRIMERI HORIZONTALNIH ROVOV IZ POSTOJNSKE JAME

Pri študiju geneze se naslanjamo na opazovanja razmer na današnjih stenah rovov. Pri tem je seveda treba upoštevati, da prvotne strukture, ob katerih se je raziskovani odsek rova neposredno začel razvijati, niso več ohranjene. Vendar pa so običajno strukturne razmere v posameznih manjših tektonskih blokih penetrativne. Zato predstavljajo opazovane razmere dobre približke prvotnih pogojev, posebno še, če upoštevamo, da debelina korozijsko-erozijsko odstranjenih kamnin običajno ni večja od 2 do 3 m.

Vsi trije opisani primeri iz Postojnske jame (Slika 1) se nahajajo v JZ krilu Postojnske antiklinale, ki se je oblikovala v miocenu in pliocenu, ko je bila JZ Slovenija izpostavljena narivanju in gubanju. V to obdobje uvrščamo tudi nastanek medplastnih zdrsov, ki so aktivirali lezike za komuniciranje z vodo in so pomemben faktor za oblikovanje horizontalnih jamskih rovov.

PONORNI VHOD V POSTOJNSKO JAMO

Vhodni deli Postojnske jame so razviti v debelo plastnatem, sivo rjavem apnencu senonijske starosti (K_2^3) z vpadom od 30-40^0 proti jugozahodu. Aktivni in neaktivni vhodi v jamo so razviti v lateralno istih plasteh, debeline okrog 6-7 m, pri čemer je treba omeniti, da se niso razvili v isti leziki. Današnji ponor je v nadmorski višini 511 m, danes neaktivni vhodi pa so 19 m višje.

Na ponornem vhodu reke Pivke v Postojnsko jamo (slika 2) so lezike poudarjene z medplastnimi zdrsi. Velikost premika ob zdrsih znaša le nekaj cm. Današnji ponor pa je oblikovan tudi ob prečno dinarski prelomni coni z geološkimi elementi 130/80 ob kateri je prišlo do horizontalnih premikov.

Na sliki 2 je zaradi merila skice prikazano le nekaj zdrsnih lezik sicer pa celotno območje predstavlja snop zdrsnih lezik. Predstavo o položaju lezik lahko dobimo iz fotografije (Slika 3).

ROV STARIH PODPISOV

Tudi Rov starih podpisov je oblikovan v senonijskem apnencu, ki vpada za 40-50^0 proti JZ. Gre za debelejše plastnat apnenec z debelino plasti od 0,5 do 1 m. Južni del rova do dolžine 50 m poteka po zdrsni leziki, ki predstavlja le eno izmed številnih zdrsnih lezik (Slika 4), v severnem delu pa rov sledi predvsem tektonsko pretrtim conam. Glavni smeri tektonsko pretrtih con sta SZ-JV in SV-JZ. Rov kaže značilnosti oblikovanja v freatični coni, kasnejše oblikovanje v vadozni coni je bolj izrazito v severnem delu rova. Značilen prečni profil južnega dela rova ima obliko leče nagnjene po vpadnici plasti apnenca (Slika 5).

STARA JAMA

Del Postojnske jame SV od Malih jam, ki se imenuje Stara jama (Slika 6) meandrira med dobro izraženo plastnatostjo. Zgornje kredni, turonijski apnenec (K_2^2) debeline 0,5-1 m vpada proti JZ za 30-50^0. Med plastmi opazujemo medplastne zdrse.

Na razdalji 150 m rov 5 krat zavije. Različni deli rova potekajo vzporedno s slemenitvijo plasti, deli rova prečno na slemenitev plasti, nekateri predeli pa sledijo tektonsko pretrtim conam, izmed katerih prevladujejo razpoklinske cone v smeri SZ-JV, manj pa so zastopane cone smeri SV-JZ (Slika 6). Iz priložene slike 6 vidimo, da rov poteka v treh odsekih po svojih zdrsnih lezikah.

Za lažje razumevanje problematike smo prikazali še severni (Slika 9) in južni bok (Slika 8), kjer se v steni rova pokaže prečni presek lezik in zdrsnih lezik po katerih je oblikovan rov.

V Stari jami je plastnatost močno tektonsko deformirana. Ponekod so plasti odprte, znotraj lahko opazujemo 0,5 cm debelo plast sekundarnih žilic. Ob gubanju terena so bile nekatere lezike deformirane z medplastnimi zdrsi. Medplastni zdrs lahko prehaja tudi iz ene lezike v drugo. Vse lezike niso tektonsko deformirane, vendar pa v Stari jami prevladujejo tektonsko deformirane lezike (Slika 7 in 8).

V plasti nad leziko poudarjeno z medplastnim zdrsom opazujemo kotlice oblikovane v freatičnih pogojih. Druge stenske kotlice so oblikovane po narivnih in navadnih lezikah ter navpičnih razpokah, ki sekajo plasti (Slika 9). Pri speleogenezi vse tri strukture igrajo pomembno vlogo. Celoten rov poteka pravokotno na slemenitev plasti.

LEZIKE IN PREPUSTNOST

Obravnavani primeri iz Postojnske jame potrjujejo veliko v nekaterih primerih odločilno vlogo lezik in zdrsnih lezik za speleogenezo.

Lezike nastajajo ob različnih sedimentacijskih procesih in so različno pogojene. Predstavljajo fizične prekinitve, ki nam določajo stratifikacijo v kamninah, tudi v apnencih. Zaradi spreminjanja sedimentacijskih pogojev kakor tudi sprememb, ki nastajajo v različnih kasnejših diagenetskih procesih, posamezne lezike niso prostorsko neomejene. So končne prekinitve, ki se lahko po vertikali vsaj delno premikajo, vendar se v vseh smereh izklinjajo. Ker so lezike "odprte" stratifikacijske prekinitve, so seveda lokalno (znotraj sebe) prepustne in izjemno ugodne za pretakanje vode. Vendar pa to še ne zadostuje za njihovo aktivno vlogo v procesih začetja. V speleogenetski proces se vključijo le v primeru, da voda lahko priteče do lezike in da se iz nje tudi izteka. Tovrstnih primarnih lezik pa je verjetno sorazmerno malo. Iz tega seveda izhaja sklep, da se začne speleogenetski proces le ob tistih lezikah, ki so vključene v širši prepustnosti (komunikacijski) sistem v kamnini.

Zdrsi ob lezikah oziroma takoimenovane *zdrsne lezike* in *vezne razpoke* med lezikami se oblikujejo pri različnih tektonskih procesih. V večjem obsegu nastajajo ob narivanju in gubanju, lokalno pa tudi ob različnih prelomih, predvsem zmikih. Ker predstavljajo lezike že sedimentološko oblikovane mehansko šibke mejne površine (tektonski predris) pride ob njih do endogenih deformacij v obliki "odpiranja" lezik in medplastnih zdrsov zaradi gubanja in obprelomnih deformacij, ki lahko vsaj del lateralno in vertikalno ležečih sosednjih lezik povežejo v prepustnostni (komunikacijski) sistem z drsnimi razpokami. Tudi v tem primeru velja, da se zdrsne lezike z veznimi razpokami vključijo v speleogenetski proces le, če se skozi njih lahko pretaka podzemna voda. Seveda pa prav iz prostorsko širšega značaja tektonskih deformacij in njihove povezovalne vloge med lezikami izhaja bistveno večja speleogenetska vloga zdrsnih lezik, kot pa jih imajo tektonsko "neprizadete" lezike. Če se lezike in zdrsne lezike z veznimi razpokami združijo na nekem območju v prežemajoči komunikacijski sistem, ki bi ga lahko označili kot *penetrativno efektivno poroznost*, so seveda dani temeljni pogoji za pretakanje vode in s tem nastajanje jam.

SKLEPI

Podrobno analizirani primer iz Postojnske jame in drugi omenjeni horizontalni rovi kažejo, da zakrasevanje ne poteka ob vseh različnih odprtih prekinitvah v karbonatnih kamninah, pač pa le ob nekaterih, ki so očitno za zakrasevanje ugodnejše od drugih. Med "za zakrasevanje ugodnejšimi" odprtimi prekinitvami so "prave" nepoškodovane lezike, torej prekinitve, ki so nastale že pri sedimentacijskih procesih, v našem primeru *stratifikacijske lezike*, tektonsko razširjene *zdrsne lezike* kot tudi različno nastale *razpoke*. Vzrok za ugodnost le nekaterih stratifikacijskih lezik za zakrasevanje drugih pa ne, po našem mnenju ni morda v neki prav posebni sedimentološki zgradbi. Prav tako ne tiči vzrok za primernost enih zdrsnih lezik za zakrasevanje drugih pa ne v morda posebnem tektonskem mehanizmu. Podobno lahko zapišemo tudi za genetsko sicer različne razpoke. Ni pomembna dolžina ali pa morda oblika. Raziskani primeri dokazujejo, da so bile za zakrasevanje ugodne oziroma primerne le tiste odprte lezike, zdrsne lezike in razpoke, ki so bile v času, ko so bili ustvarjeni ostali potrebni pogoji za zakrasevanj, združene v splet povezanih komunikacijskih poti, po katerih se je voda lahko nemoteno pretakala. Tako stanje v nekem območju ali kamninskem bloku bi lahko označili kot *penetrativno efektivno poroznost.*