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LITOSTRATIGRAFSKE ZNAČILNOSTI PODROČJA PRESIHAJOČIH PIVŠKIH JEZER IN ESTAVELA MATIJEVA JAMA

LITHOSTRATIGRAPHIC CHARACTERISTICS OF THE INTERMITTENT PIVKA LAKES REGION AND MATIJEVA JAMA CAVE ESTAVELLE

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Martin Knez & Tadej Slabe: Litostratigrafske značilnosti področja presihajočih Pivških jezer in estavela Matijeva jama

V prispevku opisujeva tipične značilnosti kamnin, ki jih zasledimo na področju presihajočih Pivških jezer. V zgornjekrednih apnencih sta se oblikovali dve značilni kraški jami: Matij eva jama, ki se danes kaže kot estavela, in Trnska jama s številnimi znaki pogostega in izdatnega nihanja gladine podzemeljske vode. Predstavljava nekatere nove izsledke raziskav.

Ključne besede: Pivška jezera, geologija, skalni relief, Matijeva jama, Trnska jama, Slovenija.

Abstract

UDC: 556.538:551.435.16(497.4 Pivka)

Martin Knez & Tadej Slabe: Lithostratigraphic characteristics of the intermittent Pivka lakes region and Matijeva jama cave estavelle

This article describes the typical characteristics of rock found in the area of the intermittent Pivka lakes. Two characteristic karstic caves formed in Upper Cretaceous limestone: Matijeva jama, which appears as an estavelle today, and Trnska jama, with several old and recent signs of frequent and plentiful fluctuation in groundwater level. Several new research results are presented.

Keywords: Pivka lakes, geology, rock relief, Matijeva jama, Trnska jama, Slovenia.

UVOD

Kraško področje presihajočih Pivških jezer med Postojno in Sembijami kaže pestro geološko sestavo. V severovzhodnem delu prevladujejo kredni apnenci, v jugozahodnem pa paleogenski apnenci. Fliš leži severno od Pivke in v okolici Knežaka.

Vloga Matijeve jame (Slika 1), njeno delovanje kot občasnega izvira in ponora, torej estavele na robu presihajočega Palškega jezera na jugozahodnem vznožju Javornikov ter posebnost njene oblike in skalnega reliefa jo uvrščajo v sklop naših najbolj svojevrstnih in zanimivih, a hkrati tipičnih jam. Jama je eden izmed izvirov na robu presihajočih kraških jezer, ki se vrstijo ob vznožju Javornikov. Znanih je še več estavel na območju jezer. So pa večinoma manjše in nedostopne oziroma je dostopen le njihov vhodni del. Nizke vode se pretakajo podzemno mimo Postojne proti Malnom.

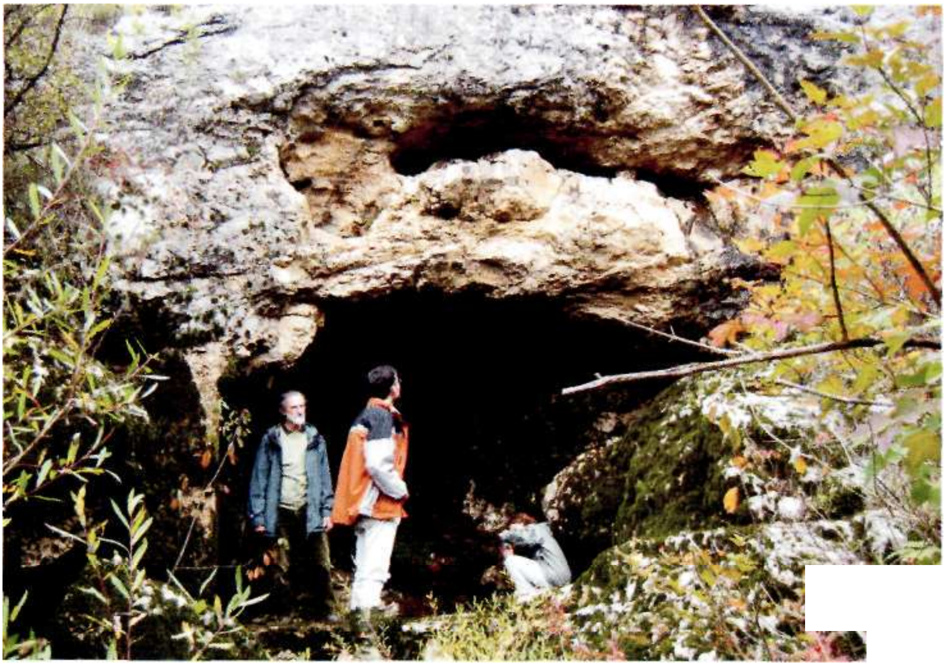
INTRODUCTION

The karst area of the intermittent Pivka Lakes between Postojna and Sembije has a varied geological composition. Cretaceous limestone predominates in the northeastern part and in the southwest Paleogene limestone. There is flysch north of Pivka and in the Knežak area.

The role of Matijeva jama cave (Figure 1), its operation as a periodic spring and sink - that is, as an estavelle on the edge of the intermittent Palško jezero lake in the southwest foothills of the Javorniki hills - and the special feature of its form and rock relief rank it as one of the most interesting, and at the same time typical, caves. The cave is one of the springs on the edge of the intermittent karstic lakes that appear in the foothills of the Javorniki hills. Additional estavelles in the area of the lakes are known. Low-flow conditions flow underground past Postojna towards Malni.

Za primerjavo in predstavo o svojevrstnem razvoju širšega zaledja je na kratko predstavljena še Tmska jama, ki pa je višje nad gladino današnjih podzemeljskih voda.

For comparison and to present the special development of the wider catchment area, there is a brief presentation of Trnska jama cave, which is higher above the level of today's groundwater.



Slika 1: Vhod v Matijevo jamo (Foto: M. Knez).

Figure 1: Entrance to Matijeva jama (Photo: M. Knez).

LITOSTRATIGRAFSKE ZNAČILNOSTI PODROČJA PIVŠKIH JEZER IN OKOLICE MATIJEVE JAME

Študij litostratigrafskih enot med južnim delom Pivške kotline pri Matenji vasi na severu in Šembijami na jugu pokaže izredno pestro geološko zgradbo. V tem poglavju bodo predstavljene kamnine, ki jih tam zasledimo, tektonske značilnosti področja pa so opisane v poglavju Stanke Šebela. Zaradi lažjega razumevanja sta tu predstavljeni le dve regionalno pomembni geotektonski enoti: Jursko-kredni nariv Snežnika na SV in Brkinski terciarni bazen na JZ obravnavanega ozemlja.

LITHOSTRATIGRAPHIC CHARACTER-1STICS OF THE INTERM1TTENT PIVKA LAKES AREA AND M ATI JEVA JAMA ES-TAVELLE

A study of the lithographic units in the southern part of the Pivka basin at Matenja vas to the north and Šembije to the south reveals a varied geological structure. This section presents the rock found there, and the tectonic characteristics of the area are described in the section by Stanka Šebela. For ease of understanding, only two regionally significant geotectonic units are presented here: the Jurassic-Cretaceous thrust of Snežnik to the southeast and the Brkini Tertiary basin to the

Snežniška tektonska enota, katere JZ rob lahko s prekinitvami sledimo od Hruševja na severu do Sembij na jugu in dalje proti JV, se nad področjem Brkinskega terciarnega bazena večinoma dviguje kot strma stopnica. Meja med Snežniško grudo in Brkinskim terciarnim bazenom je zabrisana zaradi nariva Snežnika preko severovzhodnega krila sinklinale (Šikić *et al.* 1972). Na tem delu se ti dve enoti pokrivata, kar dokazujeta tektonski okni nad Knežakom in Zagorjem, kjer so pod starejšimi eocenskimi, paleocenskimi in krednimi sloji vidni flišni sedimeti, ki so mlajši od apnencev, ležijo pa pod njimi. Severovzhodno krilo Brkinskega terciarnega bazena je prevrnjeno in tvori prevrnjeno gubo, v kateri se flišni sedimenti pojavljajo tudi v tektonskem oknu med Šilentaborom in Podtaborom. Flišne plasti in plasti starejšega eocena vse do krede so v reverznem položaju. Od Ilirske Bistrice proti severozahodu (Pivka) prevrnjeno krilo postaja vse manj izraženo (Šikić & Pleničar 1975). Na začetku tvori strmo stopnico, kasneje pa se kredne plasti podrivajo pod mlajše sedimente. Jugovzhodno od Ilirske Bistrice se prevrnjeno krilo obdrži vse do meje s Hrvaško.

Podlago Brkinskega terciarnega bazena gradijo kredne karbonatne plasti. Na njih ležijo paleocenski sedimenti, med kredo inpaleocenom pa je erozijska diskordinanca (Šikić *et al.* 1972). Jedro sinklinale tvorijo flišne plasti. Celotno področje je blago valovito in nima videza večje sinklinale. Verjetno so v njej nastala sekundarna gubanja zaradi gravitacije (gravitacijske gube). Prvotno je bila sinklinala grajena simetrično, kasneje pa je bila deformirana z mlajšo tektoniko. Zaradi bočnih pritiskov so flišne plasti na več mestih zlomljene, prelome pa je težko slediti zaradi pokritosti terena. Poleg prelomov v smeri severozahod-jugovzhod in zahod-vzhod, obstajajo prelomi tudi v smeri sever-jug; slednji so pogojevali nastanek slepih dolin na jugozahodnem robu Brkinske sinklinale. Na aktivnost nekaterih prelomov kažejo številni manjši potresi, eden večjih je bil leta 1956 in je dosegel VIL stopnjo po MSK lestvici (Šikič & Pleničar 1975).

southwest of the area under consideration.

The Snežnik tectonic unit, the southwest edge of which can be traced intermittently from Hruševje on the north to Šembije on the south and further towards the southwest, is largely elevated above the area of the Brkini Tertiary basin as a steep rise. The boundarv between the soil of Snežnik and the Brkini Tertiarv basin is blurred because of the Snežnik nappe across the northeast wing of the svncline (Šikić *et al.* 1972). The two units overlap in this area, which is shown by the tectonic windows above Knežak and Zagorje, where below the older Eocene, Paleocene and Cretaceous lavers there are visible fh/sch sediments that are vounger than the limestones but lie below them. The northeast wing of the Brkini Tertiarv basin is inverted and creates an inverted fault in which flvsch sediments also appear in the tectonic window between Šilentabor and Podtabor. Flvsch lavers and older Eocene lavers ali the way to the Cretaceous are in reversed positions. From Ilirska Bistrica towards the norfhvvest (Pivka) the inverted wing becomes increasingly less distinct (Šikič & Pleničar 1975). At the beginning it creates a steep rise, and later the Cretaceous lavers are subducted beneath the younger sediments. Southeast of Ilirska Bistrica the inverted wing extends all the way to the Croatian border.

The bedrock of the Brkini Tertiary basin is formed of Cretaceous carbonate layers. Paleocene sediments lie upon these, and between the Cretaceous and Paleocene material is an erosion discordance (Šikić *et al.* 1972). The core of the syncline is created by flysch layers. The entire area is greatly undulating and does not have the appearance of a major syncline. Secondary folding probably took plače in it as a result of gravity. Originally the syncline had a symmetrical structure, and it was then deformed by later tectonic activity. Because of lateral pressures, the flysch layers were broken in several places, but the faults are difficult to trace because of the coverage of the area. In addition to northwest-southeast and west-east faults, there are also north-south faults; these

Na področju Pivških jezer zasledimo najstarejše kamnine v širši okolici Knežaka. Tam so prehodne plasti med spodnjo in zgornjo kredo apnenci, dolomitne in apnenčeve breče. Na dobro litificiranih in ploščatih apnencih se najprej pojavljajo apnenčaste breče, na njih pa še dolomitne breče. Med brečami najdemo plasti apnenca, ki se stikajo tudi laterarno. Apnenci spadajo med psevdooolitne ali oolitne kalkarenite in kalcilutite (Šikić & Pleničar 1975). Vsebnost kalcijevega karbonata je nekje med 93 in 98 odstotkov. Vmes najdemo tudi avtogeni kremen in limonitiziran pirit. Delci so v apnenčastih brečah manjši, v dolomitnih pa večji od 10 centimetrov. S fosili so te kamnine revne. Med drugim so bile najdene alge iz rodu *Thaumatoporella* in foraminifere iz rodov *Globigerina* in *Dicyclina* ter družin Miliolidae in Globigerinidae kot tudi ostrakodi. Debelina opisanih sedimentov ponekod znaša tudi do 750 metrov.

Vzhodno od Jurišč je kakšne pol kilometra širok pas menjajočih se zgornjekrednih cenomanijskih in turonijskih apnencev in dolomitov. Pas karbonatnih kamnin leži prečno na dinarsko smer. Apnenci in dolomiti so svetlosivi in rjavi ter debeloplastoviti. Količina kalcijeve karbonata v apnencih je med 93 in 97 %. Alge v apnencih so redke, nekaj več je foraminifer iz rodov *Dicvclina, Cuneolina, Nummuloculina* in druge (Sikič & Pleničar 1975). Pogosti so fosili iz rodov *Chondrodonta* in *Caprina*.

Širša okolica Petelinjskega jezera je zgrajena iz spodnjeturonijskih belih in svetlosivih apnencev in ponekod apnenčeve zoogene breče. Zelo pogosti fosili v teh plasteh so iz družin Caprinidae, Radiolitidae in drugih (Pleničar 1970). Breča je sestavljena pretežno iz zaobljenih odlomkov fosilov, ki najverjetneje kažejo na to, da so bile lupine odmrlih živali odtrgane od grebena, kjer so živele, in nato presedimentirane in sprijete v brečo oz. konglomerat.

latter created the conditions for the formation of blind valleys at the southvvest edge of the Brkini svncline. Numerous small earfhquakes indicate that some faults are active; one of the larger of these occurred in 1956 and registered VII on the MSK scale (Šikić & Pleničar 1975).

In the Pivka Lakes region, the oldest rock is found in the broader area around Knežak, where there are transitional lavers betvveen Lower and Upper Cretaceous limestone, dolomite breccia and limestone breccia. Limestone breccia appears first on well lithified and level limestone, on which there is dolomite breccia. Betvveen the breccias there are beds of limestone, which are a\so joined laterally. The limestones are pseudo-oolitic or oolitic calcarenite and calcilutite (Sikič & Pleničar 1975). The calcium carbonate content is between 93 and 98 per cent. Between these, algae of the genus *Thaumatoporella* and foraminifers of the genera *Globigerina* and *Dicyclina* and the families Miliolidae and Globigerinidae have been found, as well as ostracods. The sediments described range up to 750 metres thick in places.

East of Jurišče there is a half-kilometre wide band of alternating Upper Cretaceous Cenomanian and Turonian limestones and dolomites. This band of carbonate ročk lies transverse to the direction of the Dinaric Alps. The limestones and dolomites are light grey and brown, and thickly layered. The calcium carbonate content is betvveen 93 and 97 per cent. There are few algae in the limestones, but somewhat more foraminifers from the genera *Dicyclina, Cuneolina, Nummuloculina* and others (Sikič & Pleničar 1975). Fossils of the genera *Chondrodonta* and *Caprina* are common.

The wider surroundings of Petelinjsko jezero lake are composed of Lower Turonian white and light grey breccia and, in places, zoogenic breccia. Fossils from the families Caprinidae, Radiolitidae and others are very common in these layers (Pleničar 1970). The breccia is primarily composed of rounded

Od Šembij na jugu, preko Knežaka, Zagorja, Pivke, Palčja in Palškega jezera pa vse do južnega roba Pivške kotline ležijo neprekinjeno ali v manjših krpah turonijski in senonijski apnenci, ki jih zaradi slabe ohranjenosti fosilov večinoma niso mogli ločiti (Pleničar 1970). Med Radohovo vasjo, Trnjem in Matenjo vasjo pri Postojni so prekriti z aluvialnimi nanosi rek in potokov. Sivi apnenci so večinoma plastoviti, školjke iz rodu *Radiolites* pa so ponekod izredno številne. Kjer teh školjk v plasteh ni, je apnenec tanjše plastovit, temnejši in vsebuje rožence. Plasti apnenca v okolici Šembij in Podtabora so v prevrnjeni, inverzni legi (Buser *et al.* 1967).

Na zahodnem obrobju področja Pivških jezer zasledimo v dinarski smeri potekajoče kenozoiske kamnine, med njimi danijske apnence (kozinske plasti) ter thanetijske miliolidne in spodnjeeocenske alveolinski-numulitne apnence, ki se lateralno izklinjajo eden proti drugemu (Buser *et al.* 1967; Šikič *et al.* 1972). Plasti paleogenskih apnencev zahodno od Knežaka in Zagorja so v inverzni legi (Šikič *et al.* 1972).

Kozinski apnenci so brakični in sladkovodni sivorjavi do črni in bitumozni, med katerimi se lahko izjemoma pojavljajo tudi svetlejši apnenci. Zanje je značilna dobra plastovitost. Pripadajo biokalkarenitom in kalkarenitom z drobnimi delci odlomkov ter biokalkarenitom z vsebnostjo alg. V plasteh lahko najdemo fosile iz rodov *Chara, Rhapydionina, Rhipidionina* in družin Miliolidae, Tekstularidae, Globigerinidae, Globorotalidae in drugih. Od mehkušcev so znani predvsem *Stomatopsis sp., Cosinia sp.* in *Cerithium sp.*

Miliolidni apnenci ležijo nad kozinskimi plastmi. Večinoma so dobro plastnati, svetlo rjavi do sivi apnenci. Pripadajo pretežno biokalkarenitom, ki poleg foraminifernih vložkov vsebujejo tudi snovi rastlinskega porekla. Količina kalcijevega karbonata znaša večinoma do 96 odstotkov. Apnenci so s fosili izredno bogati. Najpogosteje zasledimo fosile iz rodov *Operculina, Coscinolina, Alveolina,*

fragments of fossils, most likely indicating that the shells of dead animals were dislodged from the reef where they lived and then resedimented and agglutinated in breccia or conglomerate.

From Šembije to the south, through Knežak, Zagorje, Pivka, Palčje and Palško jezero lake, and ali the way to the southern edge of the Pivka basin, there are uninterrupted or smaller patches of Turonian and Senonian limestones, which are generally impossible to distinguish because of the poor preservation of fossils (Pleničar 1970). Between Radohova vas, Trnje and Matenja vas near Postojna they are covered with alluvium from rivers and streams. The grey limestones are primarily stratified and shells of the genus *Radiolites* are exceptionally numerous in places. Where these shells are not found in the layers, the limestone is more thinly stratified and contains chert. The limestone layers near Šembije and Podtabor are inverted (Buser *et al.* 1967).

On the west edge of the Pivka Lakes area there are Cenozoic rocks running in the dinaric direction. These include Danian limestones (Kozina layers) and Thanetian miliolid and Lower Eocene alveolimd-nummulite limestones that laterally wedge out against one another (Buser *et al.* 1967; Šikič *et al.* 1972). The layers of Paleogene limestones west of Knežak and Zagorje are inverted (Šikić *et al.* 1972).

The Kozina limestones are brackish and fresh-water grey-brown to black and bituminous, although lighter limestones are occasionally found. Well-defined bedding is characteristic of these limestones. They are biocalcarenite and calcarenite with small fragments and biocalcarenite with algae content. The layers include fossils from the genera *Chara, Rhapydionina* and *Rhipidionina,* and the families Miliolidae, Textularidae, Globigerinidae, Globorotalidae and others. Molluscs especially include *Stomatopsis sp., Cosinia sp.* and *Cerithium sp.*

Orbitolites in družin Miliolidae, Textulariidae in Rotalidae.

Alveolinski apnenci se pojavljajo na vseh robovih terciarnega bazena. To so pretežno sivi do sivo rjavi, slabo plastnati apnenci, ki pripadajo večinoma biokalkarenitom s prevladujočimi alveolinami. Vsebnost kalcijevega karbonata znaša med 94 in 97 odstotki.

Numulitni apnenci so bolj brečasti od alveolinskih, plastnatost pa je komaj opazna. Uvrščamo jih v biokalkarenite s prevladujočo favno iz roda *Nummulites,* vsebnost kalcijevega karbonata je enaka kot pri alveolinskih apnencih.

Najmlajše in edine nekarbonatne plasti so plasti eocenskega fliša najbolj južnega dela Pivške kotline, ki se v ozkem pasu v dinarski smeri vlečejo prav do Pivke. Druga nekoliko večja flišna izdanka sta še pri Knežaku in Zagorju. Z geotektonskim izrazoslovjem ju imenujemo tektonski okni, ki sta nastali zaradi antiklinalnega vzbočenja fliša pri upognitvi roba flišne kadunje nazaj proti jugozahodu. Flišne plasti, ki se kažejo v tektonskem oknu so torej prevrnjene, kakor tudi vse apnenčaste plasti na stopnji od krednih do eocenskih. Razmere so podobne tako pri Knežaku kot pri Zagorju, le da je pri slednjem obrobje fliša bolj prekrito s preperlino in so geološke razmere tam manj očitne kot pri Knežaku (Pleničar 1959). Kjerkoli pa je v narivni rob vrezana hudourniška grapa ali struga potoka, ki poteka pravokotno na narivni rob, sega fliš v njej visoko navgor proti severovzhodu; relativno mlajši fliš leži pod relativno starejšim apnencem.

Med kvartarnimi sedimenti so aluvialni nanosi rek in potokov v podoljih v okolici Knežaka, Zagorja, Pivke do Matenje vasi ter holocenska melišča na jugu med Taborom in Podtaborom (Buser *et al.* 1967; Šikić *et al* 1972).

Miliolid limestones lie above the Kozina lavers. They are mostly well stratified light brown to grey limestones. They are primarily biocalcarenite and, in addition to foraminifer interstices, also contain material of plant origin. The calcium carbonate content is mostly 96 per cent. The limestones are exceptionally rich in fossils. The most often found fossils are from the genera *Operculina, Coscinolina, Alveolina* and *Orbitolites* and the families Miliolidae, Textulariidae and Rotalidae.

Alveolinid limestones appear at ali edges of the Tertiary basin. These are mostly grey to grey-brown, poorly stratified limestones, which are mostly biocalcarenite predominantly containing *Alveolina.* The calcium carbonate content is between 94 and 97 per cent.

Numrnulifid limestones are more breccial than alveolinid limestones, and stratification is barely noticeable. They are categorized as biocalcarenite with fauna primarily from the genus *Nummulites,* and the calcium carbonate content is the same as for alveolinid limetones.

The youngest and the only noncarbonate layers are the layers of Eocene flysch from the southernmost part of the Pivka basin, which extend all the way to Pivka in a narrow band in the dinaric direction. There are other somewhat larger flysch outcrops at Knežak and Zagorje. In geotectonic terminology these are referred to as tectonic windows, which were formed because of anticline raised flysch in the curved edge of the fiysch basin back towards the southwest. The flysch layers seen in the tectonic window are thus inverted, as well as ali the limestone layers at the level from the Cretaceous to the Eocene. The conditions are similar at both Knežak and Zagorje, except that in the latter case the edge of the flysch is more covered with weathered stone, and the geological conditions there are less obvious than at Knežak (Pleničar 1959). Wherever a torrent ravine or a stream channel running perpendicular to the thrust edge has cut into the thrust edge, the flysch extends into it upwards towards the northeast;

OBLIKA MATIJEVE JAME IN NJEN SKALNI RELIEF

Na dnu vhodnega, 30 m globokega brezna se za ožino, ki vodi proti vzhodu, odpre prostornej ša dvorana s stalnim sifonskim jezerom. Jamsko jezero je v času nizkih voda globoko 3 m, nadaljuje pa se v podvodni rov. Ob dežju bruha iz jame 6 m^3/s, ob upadanju vodne gladine pa teče vanjo močan tok. Najnižja gladina vode je na nadmorski višini 518 m, najvišja, izmerjena na površju pa na 556 m (Habič 1968).

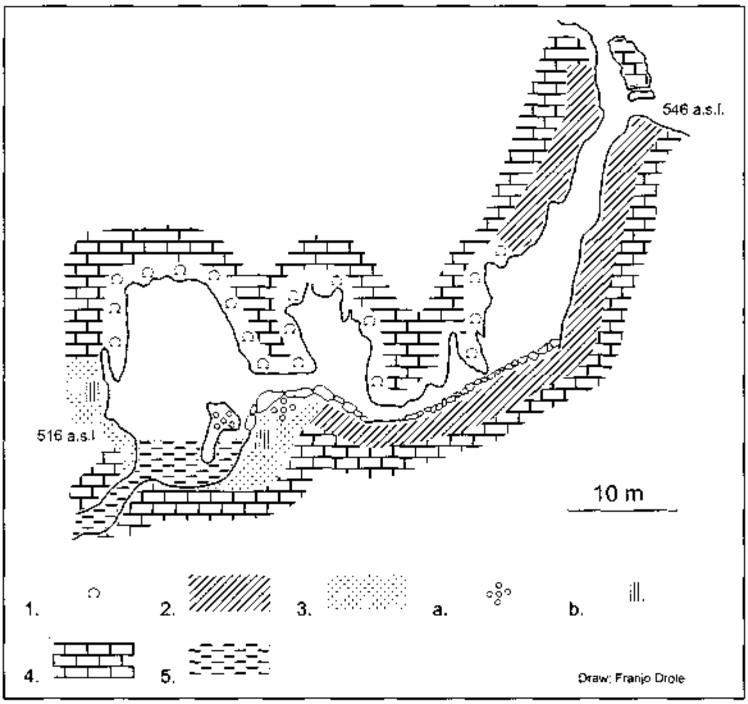
Skalne oblike nam pogosto razkrijejo značilnosti oblikovanja kraških jam, najbolj pomembne dejavnike in procese dolbljenja skale ter razmere, v katerih se jame razvijajo.

relatively younger flysch lies below relatively older limestone.

Among the Quaternary sediments are alluvium from rivers and streams in the valleys near Knežak, Zagorje and Pivka as far as Matenja vas and Holocene scree to the south between Tabor and Podtabor (Buser *et al.* 1967; *Šikičetal.* 1972).

THE FORM OF MATIJEVA JAMA AND ITS ROČK RELIEF

At the floor of the eastern, 30-m-deep shaft behind a narrowing that leads towards the east, a larger room opens up with a permanent siphon



Slika 2: Skalni relief v Matijevi jami (1. stropne kotlice, 2. erozijsko zglajeni del rova, 3. podsedimentni skalni relief, 4. apnenec, 5. voda, a. podsedimentne vdolbinice, b. podsedimentni žlebovi).

Figure 2: Rock relief of Matijeva jama (1. ceiling pockets, 2. erosionally polished passage, 3. below-sediment rocky relief, 4. limestone, 5. water, a. below-sediment pits, b. below-sediment channels).

Skalni relief, ki povezuje skalne oblike, pa nam lahko razkrije razvoj jame, njegova najbolj značilna obdobja in zaporedja. Tudi v Matijevi jami (Slika 2) nam skalne oblike pomagajo razložiti njeno oblikovanje ter vlogo v kraškem vodonosniku. So pa vse oblike sled današnjega, raznovrstnega oblikovanja jame. Tovrsten skalni relief lahko opredelimo kot značilen za estavelo.

Na obodu spodnjega dela jame so najbolj značilne skalne oblike **stropne kotlice** (Slika 3). So polkroglastih oblik, nekatere so ob razpokah nekoliko podaljšane v elipsaste prečne prereze, tudi slednje pa imajo polkrožne vrhove. Njihov premer meri 40 - 50 mm. Na drobno razpokani skali so ena ob drugi, med njimi so le ostri robovi, kar kaže na njihov nastanek s korozijo. Ob izrazitih razpokah so bolj izrazito podaljšanje, skozi dele kamnine, ki štrli iz stropa, voda izdolbe cevi.

lake. During low flow conditions the cave lake has a depth of 3 m and it continues into an undenvater passage. During rains, water is discharged from the cave at a rate of 6 m^3/s, and with a fall in water level there is a strong inflow. The lowest water level is at 518 m above sea level and the highest, measured at the surface, is at 556 m (Habič 1968).

The rock forms often reveal the characteristics of the formation of karstic caves, the most important factors and processes in carving out the rock, and the conditions in which the caves develop. The rock relief that connects the rock forms can also provide information about the development of a cave, its most significant periods and their sequence. The rock forms at Matijeva jama (Figure 2) also help explain its formation as well as its role in the karstic aquifer. AU of the forms are the result of various cave formation processes going on today. This type of roček relief may be considered characteristic for an estavelle.

Slika 3: Stropne kotlice v Matijevi jami (Foto: T. Slabe).

Figure 3: Ceiling pockets in Matijeva jama (Photo: T. Slabe).

Stropne kotlice dolbe vodni tok, ki se pod močnim pritiskom pretaka navzgor. Ali nastanej o le zaradi vrtinčenja vode in raztapljanja skale ob mestih šibkosti ali pa so delo tudi drugih procesov kot so kavitacija, delovanje kondenzirane vlage v zračnih mehurjih ujetih pod stropom ali pa so sled povečanega pritiska $C0_2$ v ujetih mehurjih zraka pod stropom (Lismonde 2000) ali sled še neznanega načina oblikovanja skale, še ni moč zaključiti. So pa svojevrstne velikosti, stropne kotlice so praviloma večje, in posebne oblike ter značilno drobno hrapave površine. Torej. Odpirajo se zanimiva vprašanja, ki jih bo potrebno še razrešiti. Odgovori pa nam bodo pomagali razjasniti razmere oblikovanja tovrstnih jam in njihovega skalnega oboda.

The most significant rock forms at the periphery of the lower portion of the cave are **ceiling pockets** (Figure 3). These have a semicircular shape; at fissures some are somewhat elongated in an elliptical transverse profile, and these also have semicircular tops. They range from 40 to 50 mm in diameter. With slighfly fissured rock they appear one alongside the other with sharp margins between, which points to their origin through corrosion. Alongside distinct fissures they are more clearly elongated, and the water carves out channels through the parts of the stone that project from the ceiling.

Slika 4: Drobne vdolbinice v erozijsko zglajeni kamnini (Foto: T. Slabe).
Figure 4: Small cups and rock polished by erosion (Photo: T. Slabe).

Draslje (Slabe 1995) **in erozijsko zglajena površina skale** (Slika 4) sta značilnosti jamskih tal in v ožjih delih jame celega oboda.

The ceiling pockets are carved out by water flow that decants upwards under strong pressure. It is stili not possible to determine whether they arise only because of the whirling of water and dissolving of rock at weak points, or whether they are the work of other processes as well, such as cavitation, the operation of condensed moisture in air bubbles trapped beneath the ceiling or the result of excess CO_2 pressure in air

Polkrogelne draslje so manjših premerov (do 10 cm). Oblikuje jih močan vodni tok, ki v svoje vrtinčenje vključuje prod in pesek ter gladi stene med njimi.

Podnaplavinske skalne oblike (Slabe 1992) prevladujejo v skalnem reliefu spodnjega dela jame. Podnaplavinske, polkroglaste vdolbinice, ki dosegajo do 5 cm premera, nastajajo zaradi korozije pod naplavino, ki se odlaga na vboklih delih kamnine, na bolj ali manj položnih površinah skalnega oboda. Najprej se valjasto poglabljajo, ko pa so dovolj velike, se na njihovem dnu odloži več naplavine, ki se ne obnavlja in vodi preprečuje stik s kamnino. Voda se po umiku visokih voda zadrži nad napavino- Korozija zato prevladuje na robovih vdolbinic- Gosto razporejene vdolbinice se začno združevati in med njimi ostanejo le posamezne štrline. Takšna je skala ob robujamskega jezera. Na strmejših odsekih pod naplavino nastajajo podnaplavinski žlebiči. Njihovo oblikovanje smo si pomagali razložiti tudi z laboratorijskimi poskusi (Slabe 1992). Podnaplavinske skalne oblike so sled pogostega, manjšega nihanja gladine podzemeljske vode, iz katere se odlaga manjša količina drobnozrnate naplavine.

Kot **sestavljeno skalno obliko,** torej oblike pri katerih oblikovanju izmenjujoč deluje več različnih procesov, lahko izdvojimo majhne in ozke (nekaj cm premera) ter razmeroma globoke vdolbinice z navpičnimi stenami. Nastale so kot splet korozije pod drobnozrnato naplavino, ki jo odlagajo nižje vode in jamo deloma poplavijo in erozije pod peskom, ki ga vrtinci vodni tok, ko bruha iz jame.

Tudi **površina skalnih oblik** nam razkriva proces oblikovanja jame (Slabe 1994). Stropne kotlice imajo drobno hrapavo površino. Nastajajo zaradi raztapljanja skale z vodnim tokom. Skalni obod spodnjih delov rovov in ponekod cel obod ožjih delov jame je erozijsko zglajen. Takšne površine imajo dokaj ravne osnovne ploskve. Pod veliki povečavami elektronskega vrstičnega mikroskopa pa je moč razbrati drobno erozijsko hrapavost z razami,

bubbles trapped beneath the ceiling (Lismonde 2000), or the result of a stili unknown manner of ročk formation. There are unique sizes, and the ceiling pockets are generally large, with a special shape and a characteristically slightly coarse surface. They therefore pose interesting questions that remain to be answered. These answers will help clarify the conditions under which such caves and their rock peripheries are formed.

Potholes (Slabe 1995) **and erosion-polished rock surfaces** (Figure 4) are characteristic of cave floors and in narrower parts of the entire cave periphery. Semicircular potholes have smaller diameters (up to 10 cm). They are formed by strong water fiow that contains gravel and sand as it swirls and smoothes the walls between them.

Below-sediment rock forms (Slabe 1992) predominate in the rock relief of the lower part of the cave. Below-sediment semicircular cups that reach up to 5 cm in diameter are formed as a result of corrosion beneath the sediment that is deposited on the concave areas of rock on more or less gently sloping surfaces of the rock periphery. At first they deepen in a wavy pattern and, when they are large enough, significant sediment is deposited on their bottoms and is not replaced, and prevents the water from coming in contact with the rock. Following high-flow conditions, water remains above the sediment. Corrosion therefore primarily occurs on the edges of the cups. Densely arranged cups begin to join and only individual protuberances remain betvveen them. This is how the rock appears at the edge of the cave lake. On steeper sections beneath the sediment, below-sediment flutes appear. We have also been able to explain their formation through laboratory tests (Slabe 1992). Below-sediment rock forms are the result of frequent minor fluctuations in groundwater levels, which deposits small quantities of fine-grained sediment.

Small and narrow (a few cm in diameter) and relatively deep cups with vertical walls

Slika 5: Rov s stenskimi zajedami (Foto: T. Slabe).

Figure 5: Passage with wall notches (Photo: T. Slabe).

Slika 6: Stropne kotlice v Trnski jami (Foto: T. Slabe).

Figure 6: Ceiling pocket in Trnska jama (Photo: T. Slabe).

ki so posledica trenja prodnikov in peska ob skalo. Takšen je tudi obod manjših draselj. Najbolj izpostavljeni deli so pogosto obtolčeni in prepoznavni že s prostim očesom.

Podnaplavinske skalne oblike imajo drobno hrapavo površino, sled enakomernega raztapljanja zrnate kamnine.

TRNSKAJAMA

Na vznožju Javornikov, nad Petelinskim jezerom je večja in večinoma stara jama. Njena oblika, skalni relief in vsebina s sigo ter drobnozrnato naplavino nam razkriva v primerjavi z Matijevo jamo drugačen razvoj in razmere, v katerih se je oblikovala. Prostorni rovi z visokimi dvoranami so sledi najbolj izrazitega obdobja njenega oblikovanja. Jama je bila v dobršni meri oblikovana ali vsaj preoblikovana na stiku z drobnozrnato naplavino, ki je jamo bolj ali manj zapolnjevala. Voda, ki je v jamo nanašala naplavino, je nihala in značilno oblikovala jamski skalni obod. Ob naplavini so nastali nadnaplavinski žlebovi, stenski žlebovi, ki so sled pretakanje vode ob ali nad naplavino in vzdolžne zajede, ki pričajo o dolgotrajnejšem nivoju naplavine ter večje obsedimentne niše (Slika 5). Slednje nastanejo zaradi dolgotrajnega zatekanja vode navzdol ob širši stik naplavine s skalo po znižanju gladine podzemeljske vode. Takšnemu oblikovanju jame smo priča še danes v njenem spodnjem delu v nivoju jezerca, katerega gladina niha. Težko je opredeliti, če so stropne kotlice (Slika 6), ki pričajo o počasnem vrtinčenju vode v njej, nastale pred zapolnjevanjemjame z naplavinami ali so sled vrtinčenja vode nad njo.

Kot kaže, se je jama oblikovala in se še deloma v njenem spodnjem delu v območju pogostega in izdatnega nihanja gladine podzemeljske vode (Slika 7) in izrazitega zapolnjevanja vodonosnika z naplavino, torej v stranskem zaledju glavnih vodnih poti ali pa s poplavljanjem od zunaj. Dosegale so jo torej najvišje poplavne vode.

can be excluded as **combined rock forms,** or forms in the formation of which various processes operate in alternation. They arose as a combination of corrosion from fine-grained sediment deposited by low-flow water that partially floods the cave and erosion from sand swirled by the flow of water discharged from the cave.

The **surface of rock forms** also reveals the process of cave formation (Slabe 1994). Ceiling pockets have a slightly coarse surface. They form as a result of the flow of water dissolving the rock. Erosion has smoothed the peripheral rock in the lower parts of the shaft and, in places, the entire periphery of the narrower parts of the cave. These surfaces have rather level base surfaces. Under extreme magnification with a scanning electron microscope it is possible to make out slight erosion roughness with abrasions that are the result of the friction of pebbles and sand along the rock. The periphery of small potholes also has this character. The most exposed parts are often battered and recognizable with the naked eye.

Below-sediment rock forms have a slightly rough surface, which is the result of uniform dissolving of granular rock.

TRNSKAJAMA

At the foothills of the Javomiki hills, above Petelinjsko jezero lake, there is a large and generalby older cave. Its form, rock relief and calcareous sinter content, as well as fine-grained sediment, show a different development and conditions of formation in comparison to Matijeva jama. Its large shafts with high galleries are a result of the most distinctive period of its formation. The cave was shaped, or at least reshaped, to a substantial degree by contact with fine-grained sediment that more or less filled the cave. The water that carried the sediment into the cave fluctuated and significantly shaped the cave's rock periphery. Along with the sediment, above-sediment

Slika 7: Sledovi nihanja vode (Foto: M. Knez).

Figure 7: Trace of vvater oscilation (Photo: M. Knez).

Vhodne dele jame, kamor seže svetloba, preoblikuje biokorozija pod algami in lišaji. Poraščeni so le deli skale, na katere pada svetloba. Prenikajoča voda v nekaterih delih jame dolbe žlebiče in na previsnih površinah stropne konice. Ponekod, zlasti na ožjih prehodih med jamskimi rovi, je skalni obod preoblikovan z vodo, ki se kondenzira iz zračnega toka in raztaplja tudi staro sigo ter dolbe vdolbinice (Slika 8) v raznovrstno sestavljeni skali.

channels and wall channels formed, which are the result of decanting of water along or above the sediment and longitudinal notches that indicate a long-standing level of sediment and larger niches along the sediment (Figure 5). These appear because of long-term decanting of vvater dovvnvvards along broader contact of the sediment vvith the roček follovving a decrease in groundwater level. Such cave formation is stili occurring today in the cave's lower part at the level of the pond with a fluctuating level. It is difficult to determine vvhether the ceiling pockets (Figure 6), vvhich indicate a slovv svvirling of vvater, formed before the cave was filled with sediment or are the result of the swirling of vvater above it.

It appears that the cave was shaped in an area of frequent and substantial fluctuation of groundvvater level (Figure 7) and pronounced filling of the aquifer vvith sediment; that is, in the lateral catchment area of main vvater routes or with flooding from the outside. It was therefore the highest floodwaters that achieved this.

The entry areas of the cave, where light penetrates, are shaped by biocorrosion by algae and lichens. The only overgrown areas of the cave are where light falls. Trickling water in certain parts of the cave carves out flutes and small ceiling pendants on overhanging surfaces. In places, especially on the narrow transitions between the cave passages, the rock periphery is shaped by water that condenses from air pressure and also dissolves old calcareous sinter and carves out net of cups (Figure 8) in rocks of various composition.

Slika 8: Vpliv kondenzne korozije na kamnino (Foto: T. Slabe).

Figure 8: Rock etched by condense corrosion (Photo: T. Slabe).

SKLEP

Področje Pivških jezer karakterizirajo plasti od spodnje krede do kvartarja. Kredni apnenci, še posebno turonijske in senonijske starosti so zaradi debelih plasti, visoke vsebnosti CaCCh in močne razpokanosti zelo zakraseli. V teh apnencih sta se oblikovali tudi Matijeva in Trnska jama. Paieogenski apnenci na zahodnem robu področja so manj zakraseli. Stiki propustnih apnencev in nepropustnega fliša kažejo značilnosti kontaktnega krasa.

Skalni relief Matijeve jame lahko opredelimo kot tipičen za estavelo. Gre za jamo, ki se razvija v epifreatičnih razmerah, torej ob gladini nihajoče podzemeljske vode. Pretok skozi jamo je ob visokih vodah hiter. Dobršen del z erozijo oblikovanega skalnega oboda vhodnih delov jame namreč priča o moči vodnega toka, ki se pretaka skozi jamo in vrtinči tudi prod in pesek. Na stenah ni faset, najbolj značilnih korozijskih sledi vodnih tokov, saj prevladujoča erozija onemogoča njihov nastanek. Tla in položne stene spodnjih delov jame prekrivajo podnaplavinske vdolbinice. Jamski skalni relief jasno izpričuje menjavanje občasnih izbruhov vode iz jame in vodnega toka, ki teče v jamo, s pogostimi manjšimi nihanji vodne gladine v spodnjem delu jame. Primerjava s Trnsko jamo nam razkrije svojevrsten razvoj prevotljenosti tega dela krasa.

CONCLUSION

The Pivka Lakes area is characterized by lavers from the Lower Cretaceous to the Quaternary. Because of their thick lavers, high $CaCO_3$ content and extensive fissuring, Cretaceous limestone, especially from the Turonian and Senonian periods, is heavily karstified. Matijeva jama and Trnska jama also formed in these limestones. Paleogene limestones at the western edge of the region are less karstified. Contacts between permeable limestones and impermeable flysch show the characteristics of contact karst.

The rock relief of Matijeva jama can be defined as typical for an estavelle. It is a cave that is developing in epiphreatic conditions, that is, at the level of fluctuating groundwater. Flow through the cave is faster in high-flow conditions; namely, a substantial part with erosion of the shaped rock periphery of the entry parts of the cave point to the strength of the water flow, which flows through the cave and also swirls gravel and sand. There are no facets on the walls, which are the most characteristic corrosion traces of water flows, because the predominant erosion prevents them from forming. The floor and gently sloping walls of the lower parts of the cave are covered with below-sediment cups. The cave's rock relief clearly indicates the alternation of occasional discharges of water from the cave and water flow that flows into the cave, with frequent small fluctuations in water level in the lower part of the cave. A comparison with Trnska jama reveals the unique development of the perforation of this part of the karst area.

LITERATURA-REFERENCES

Buser, S. Grad, K. & M. Pleničar, 1967: Osnovna geološka karta SFRJ, list Postojna 1:100.000.- Zvezni geološki zavod Beograd, Beograd.

Habič, P, 1968: Javorniški podzemeljski tok in oskrba Postojne z vodo.- Naše jame 10, 47-54, Ljubljana.

Lismonde, B., 2000: Corrosion des coupoles de plafond par les fluctuations de pression de l'air emprisonne.- Karstologia 35, 39-46.

Pleničar, M., 1959: Tektonski okni pri Knežaku.- Geologija, razprave in poročila, 5, Geološki zavod Ljubljana, Ljubljana.

Pleničar, M., 1970: Tolmač lista Postojna. Osnovna geološka karta SFRJ 1 : 100.000.- Zvezni geološki zavod Beograd, 62 pp., Beograd.

Slabe, L, 1992: Naravni in poskusni obnaplavinski jamski skalni relief-Acta carsologica 21, 7-34, Ljubljana.

Slabe, T, 1994: Dejavniki oblikovanja jamske skalne površine.- Acta carsologica 23, 369-398, Ljubljana.

Slabe, T., 1995: Cave Rocky Relief- Zbirka ZRC 10, ZRC SAZU, 128 pp., Ljubljana.

Šikič, D. & M. Pleničar, 1975: Tolmač lista Ilirska Bistrica. Osnovna geološka karta SFRJ 1 : 100.000,- Zvezni geološki zavod Beograd, 51 str., Beograd.

Šikič, D., M. Pleničar & M. Šparica, 1972: Osnovna geološka karta SFRJ Ilirska Bistrica 1 : 100.000.- Zvezni geološki zavod Beograd, Beograd.