

ACTA CARSOLOGICA	33/1	11	159-173	LJUBLJANA 2004
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COBISS:1.01

**THE KARST PERIODICAL LAKES OF UPPER PIVKA,
SLOVENIA**

**KRAŠKA PRESIHAJOČA JEZERA ZGORNJE PIVKE,
SLOVENIJA**

NATAŠA RAVBAR¹ & STANKA ŠEBELA¹

² Karst Research Institute, Scientific Research Centre of the Slovenian Academy of Sciences and Arts, Titov trg 2, SI-6230 POSTOJNA, SLOVENIA; natasa.ravbar@zrc-sazu.si, sebela@zrc-sazu.si

Abstract

UDC: 551.444.4(497.4)

Nataša Ravbar & Stanka Šebela: The karst periodical lakes of Upper Pivka, Slovenia

At dry season the Pivka river appears between Prestranek and Rakitnik while near Zagorje the underground karst waters are about ten meters below the valley bottom of periodical Pivka river. High waters pour over the surface and fill stream valley of the Pivka river, which runs continually from Zagorje to the ponor of Postojnska jama. When the level of the underground water increases, also shallow karst hollows – uvalas are flooded and changed into more than 15 periodical karst lakes.

Key words: karst periodical lake, uvala, Pivka, Slovenia.

Izveček

UDK: 551.444.4(497.4)

Nataša Ravbar & Stanka Šebela: Kraška presihajoča jezera Zgornje Pivke, Slovenija

Ob suši se Pivka pojavi med Prestrankom in Rakitnikom, pri Zagorju pa je podzemna kraška voda deset metrov pod dolinskim dnom presihajoče reke Pivke. Visoke vode se prelivajo na površje in napolnijo strugo reke Pivke, ki v takšnih razmerah teče površinsko od Zagorja do ponora v Postojnsko jamo. Ko se gladina podzemne vode dvigne, so poplavljenе tudi plitve kraške kotanje – uvale in pojavi se več kot 15 presihajočih jezer.

Ključne besede: kraško presihajoče jezero, uvala, Pivka, Slovenija.

INTRODUCTION

On the 11th international karstological school, which was held in July 2003 in Postojna, one of the field trips led us to karst periodical lakes of Pivka. The discussions about karst terminology related to expressions such as polje, karst valley, uvala, karst periodical lake unfolded the deficiency of geological and karstological data of periodical lakes. In recent years the discussions about Notranjska – Snežnik Park are going on. The Municipality of Pivka is working hard to establish Regional Park, which will include periodical lakes of Pivka as well. In this sense we compiled geological, hydrological and karstological data of the area and added some new facts about karst terminology of karst depressions, especially periodical lakes.

Postojna is famous for the longest karst cave in Slovenia. On the western slope of the Javorniki mountains, only 5 to 10 km south from the city, the significant karst area including periodical lakes is less known than Postojnska jama. There are 15 bigger and more frequent lakes: Jeredovci, Krajnikov dol, Petelinjsko jezero, Palško jezero, Klenško jezero, Radohovo jezero, Parsko jezero, Veliko and Malo Drskovško jezero, Veliko and Malo Zagorsko jezero, Kljunov ribnik, Laneno jezero or Jezero za gradom Kalc, Bačko jezero, Kalško jezero (Fig. 1). Several smaller lakes are just occasional and are not flooded every year. The Upper Pivka is due to karst characteristics of the landscape and due to karst periodical lakes certainly worth being visited.

The valley of the Pivka river is surrounded by numerous karst plateaus (Fig. 2). In the north Nanos and Hrušica steeply raise, in the east, southeast and south Javorniki and Snežnik are dominating, and in the west Tabor range and Slavenski ravnik, that descends into Košana valley, are situated.

Region is generally divided into Upper (Zgornja) and Lower (Spodnja) Pivka, where in the central part characteristics of karst and fluvial relief alternate due to different lithology of the basis. Upper Pivka lies south of Prestranek and is mostly built of limestone. Lower Pivka spreads north of Prestranek. It is a depression with nonpermeable flysch bottom surrounded by permeable karst rocks (limestone and dolomite) (Kranjc 1985).

The bottom of the Pivka valley is partly covered with river sediments. The alluvium covers also the bottoms of bigger karst depressions – periodical lakes in the Upper Pivka (Kranjc 1985). According to geological structure there are two types of underground water on Pivka valley: groundwater and karst water.

In this article we will focus on the Upper Pivka, where due to geological characteristics, typical karst hydrology and other karst characteristics of the Pivka river the karst periodical lakes present a typical karst form that deserves a special attention.

GEOLOGY OF PIVKA

According to Placer (1999) the studied area belongs to External Dinarides. Snežnik thrust sheet is overthrust over Komen thrust sheet. Between Zagorje and Knežak there is a tectonic window (Pleničar 1959), where flysch rocks lying under Paleogene limestone are visible. Pleničar (1959) described two tectonic windows, one is situated west from Zagorje, and the other is near Knežak.

Gospodarič (1989) divides Orehovec, Selce and Sajevče fault, and thrust layers along Rakulik and Gradec thrust fault. The most expressed and also the oldest is thrust dislocation (Rakulik fault) between Eocene flysch and Upper Cretaceous or Paleocene limestone between Hruševje,

Slavina and Pivka. According to Placer (1999) this dislocation represents the border between two thrust sheets (Fig. 1).

The northeast – southwest oriented faults are shorter than dinaric faults, but more numerous. They are specially concentrated in the area of Slavina, Selce and of Pivka, where they cut the thrust fault and divide carbonate layers into individual blocks and give structural basis for numerous ravines, that flow into the Pivka basin (Gospodarič 1989).

The Upper Pivka is developed in Upper Cretaceous limestone that traverses into Eocene and Paleocene limestones in the direction towards west (Fig. 1).

According to geological structure the flysch base of the Upper Pivka is close to the surface, what influences the development of shallow karst. The main characteristics of the karst water in the studied area are strong oscillations of groundwater and weak connections between particular underground water veins. This is a consequence of uneven and of too small cavity of the karst.

HYDROLOGY OF PIVKA

The watershed between the Pivka, Vipava and Reka river basins is surficial, where waters run off different ways on impermeable flysch. Underground or karstic watershed appears, where waters in karstified limestone outflow in different directions (Gospodarič 1989). In the case of changing the level of underground water the modification of the watershed extent and different surface and underground bifurcations take place.

Because part of the water from Upper Pivka flows underground to the Podstenjšek spring and onwards to the Reka river and part to the Ljubljana river basin, this is an area of bifurcation between Adriatic and Black Sea (Fig. 3). The Pivka river is an original source of the Ljubljana river. The underground water level gently lowers towards Malni springs and part of the underground water steeply flows towards the Reka river. In the Javorniki mountains area underground water level strongly oscillates in dependence from precipitation, so at low water level it is inclined towards Cerknica and Planina polje and at high water level it is inclined towards Pivka (Gospodarič 1989).

Normally the karst water level ranges between 512 and 537 meters above sea level (Kranjc 1985), which means that groundwater level is once below the bottom of the Pivka river valley (525 meters above sea level) and above it other time.

At dry season the Pivka river appears on the surface between Prestranek and Rakitnik (Pleničar 1959) while near Zagorje the underground karst waters are about ten meters below the valley bottom of periodical Pivka river. Downstream the level of the underground water lowers for more than 20 meters. Low karst waters are passing Postojna flysch valley and flow directly under the Javorniki mountains into Malni springs. This is so-called Javorniki underground flow. Unfortunately its main veins are not known yet.

When there is high groundwater level, the water appears above the surface and fills up the riverbed of the Pivka river, which then continuously flows from Zagorje until it sinks into Postojnska jama. Smaller part of the Pivka river already disappears underground into small sinkholes in its riverbed, but mainly continues its way towards Postojnska jama and then flows underground towards Planinsko polje. Small ponors in the Pivka valley are constantly draining also into the springs of the Vipava and Timavo, however, smaller amounts also into springs of the Malni and Unica on Planinsko polje (Habe 1963; Habič 1989).

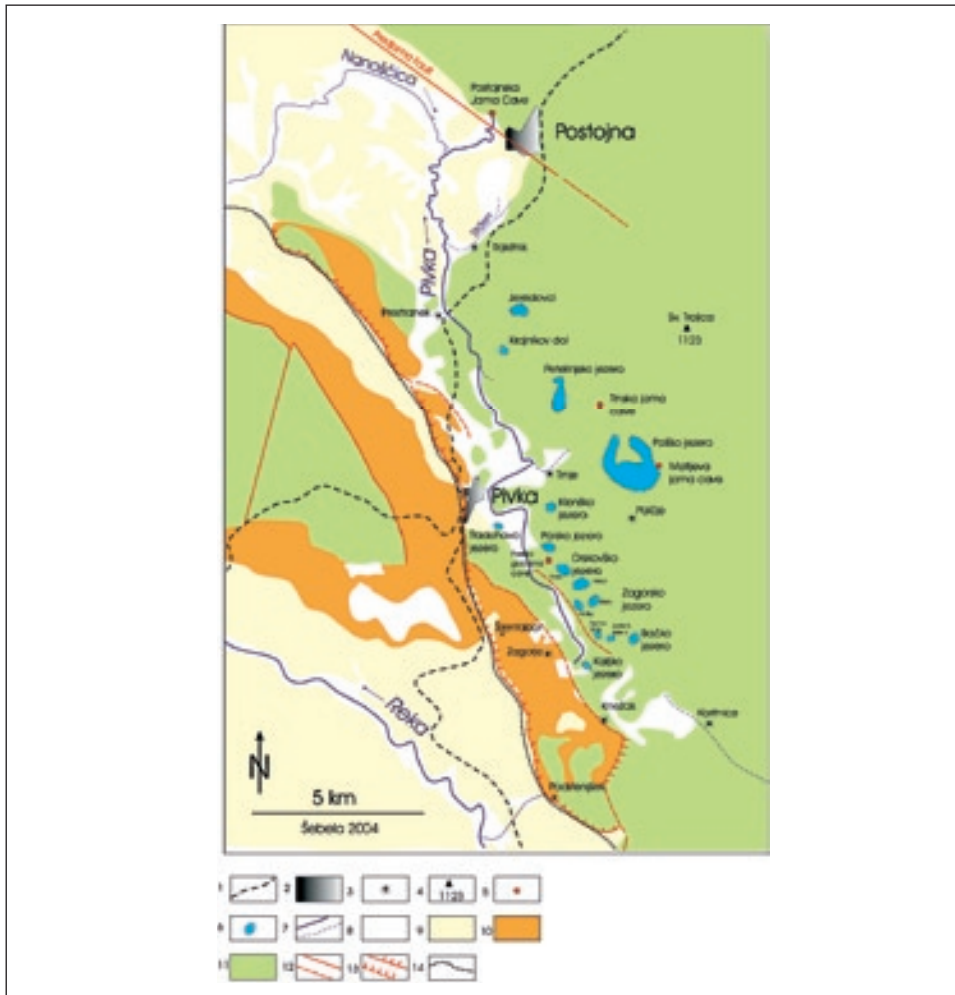


Fig. 1. Geological map of the Pivka valley with periodical lakes, compiled by S. Šebela (after Buser et al. 1967, Šikić et al. 1972, Gospodarič et al. 1970, Placer 1981).

1-railroad, 2-town, 3-smaller town, 4-hill with above sea altitude, 5-karst cave, 6-periodical lake, 7-river; periodical stream, 8-alluvium (Quaternary), 9-flysch (Eocene), 10-limestone (Paleogene), 11-limestone (Cretaceous), 12-fault: established and covered, 13-thrust fault: established and covered, 14-the border between Snežnik thrust sheet (allochton) and Komen thrust sheet (parautochton).

Sl. 1. Geološka karta Pivške kotline s presihajočimi jezeri, sestavila S. Šebela (po Buser et al. 1967, Šikić et al. 1972, Gospodarič et al. 1970, Placer 1981).

1-železnica, 2-mesto, 3-manjši kraj, 4-hrib z nadmorsko višino, 5-kraška jama, 6-presihajoče jezero, 7-reka; presihajoč potok, 8-aluvij (Kvartar), 9-fliš (Eocen), 10-apnenec (Paleogen), 11-apnenec (Kreda), 12-prelom: določen in pokrit, 13- nariv: določen in pokrit, 14-meja med Snežniško narivno grudo (alohton) in Komensko narivno grudo (parautohton).

If the water level is low, Pivka appears on the surface between Prestranek and Rakitnik, where the border between limestone and flysch is, but underground waters flow from the Pivka valley under the Javorniki mountains towards Cerkljiško polje.

Because the permeability of Javorniki mountains in the direction towards Malni springs is bounded, the high waters resurge from underground channels on the surface and fill Pivka riverbed. That is the period when in Upper Pivka numerous karst springs are active and when karst dolines, uvalas and depressions at bottom of Javorniki mountains are transformed into karst lakes (Habič 1968).

Waters of the Lokva and Belščica streams that disappear near Predjama flow into springs of Vipava (Habe 1970).

Dye injection from Poček (Fig. 3) appeared uncertainly at Žeje springs and in the Pivka river near Žeje. Main direction was into Vipava springs and Malni springs near Planina, secondary direction was into Rakov Škocjan (low water level, spring 1997). Through Malenščica and Vipava springs about 80 percent of injected dye has been detected (Kogovšek 1999).

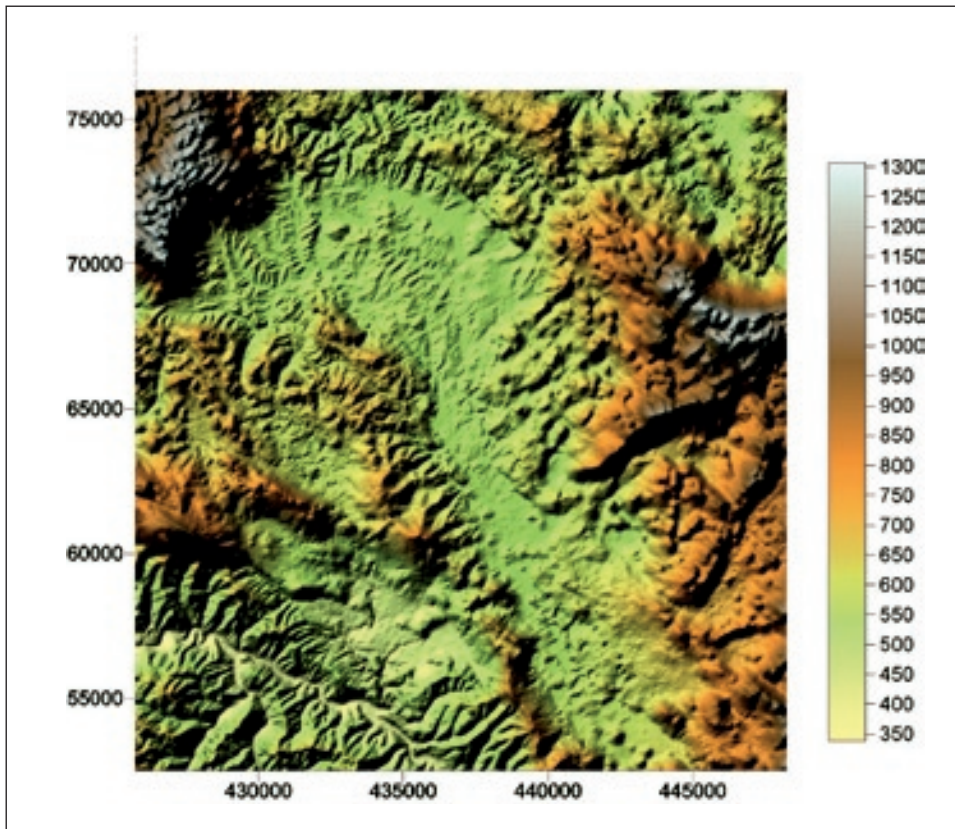


Fig. 2.: Digital Model Relief of Pivka valley.

Sl. 2.: DMR Pivške kotline.

The gradient of Pivka from springs towards the ponor at Postojnska jama is very small, just 2.5‰ (Habič 1968). So, overflow region is characteristic of landscape on Pivka, but still the riverbed could be completely dry for about half a year.

The principal Pivka spring is at the border of Eocene and Paleocene limestones near Zagorje. At high waters the discharge of springs at Pivšce is about 1500 l/s. There are additional springs Videmšce southeast of Zagorje. The underground connections with the ponors near Knežak have been proved. Those streams collect water from the flysch tectonic window (Habič 1975).

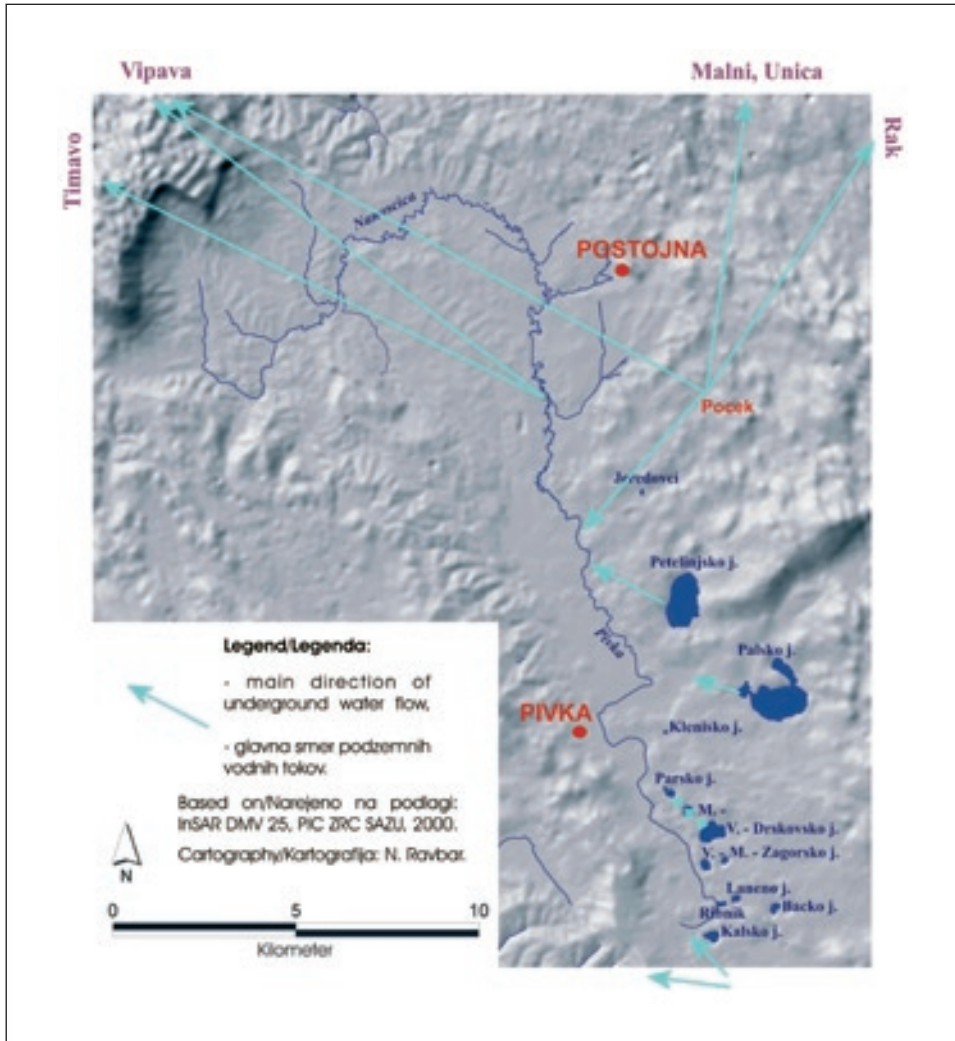


Fig. 3.: Hydrology of Pivka valley (after Habič 1968, 1975, 1989, Kogovšek 1999).

Sl. 3.: Hidrologija Pivške kotline (po Habič 1968, 1975, 1989, Kogovšek 1999).

At high waters more than 3500 l/s of water can spring near Zagorje and additional Kalški izviri springs near Kljunov ribnik lake appear. The temperature and water hardness of karst springs Kalški izviri are different from Pivka springs, that is why we are assuming they have different hydrographical recharge area. At high waters Kalški izviri springs have the discharge about 2000 l/s. At the same time Bačko jezero lake, Laneno jezero lake and Čičko polje on the east side are filled with water (Habič 1975).

Whenever the bed of the Pivka river is full of water, northwards also Malo and Veliko Zagorsko jezero lakes grow full. Only at extremely high waters Malo and Veliko Drskovško jezero lakes are flooded. From these two lakes water flow underground into Parsko jezero lake. Otherwise the connection is not yet proved, however we deduce it because of similar temperatures and hardness of water in both lakes. Northwards is Klenško jezero lake (Habič 1975).

North of Palčje village the biggest lake in the Upper Pivka valley Palško jezero is situated. It exceeds more than 1 km² and could contain more than 1,5 million m³ of water. Dye tracings have proved the underground connection to the karst springs near Trnje, which water pours into the Pivka river. Another relatively big periodical lake is Petelinjsko jezero, which has the underground connection with the karst springs near Žeje. Jeredovci and Krajnikov dol lakes appear only occasionally (Habič 1975).

The duration of surficial Pivka flow through Prestranek is in accordance with average floods duration on Petelinjsko and Palško jezero lakes, what is 3-6 months per year (Kranjc 1985). The longest floods are in Petelinjsko jezero lake (half of the year), which is situated at the lowest altitude. Consequently also the springs near Žeje are active only half of the year. Palško jezero lake is three quarters per year dry; but other karst depressions are filled with water just in very wet periods (Habič 1968). The highest waters are in autumn, when the strong rains appear and in spring, when besides rainy weather also the snow from the mountains melt.

Matijeva Jama cave, situated at Palško jezero, (Fig. 4) is a typical estavelle with a considerable oscillation of water level and till now the only larger water cave in which we can reach the karstic waters under the Javorniki mountains in drought periods. It has been carefully observed in the sixties, when there has been an option, that the waters from the cave could be used for drinking water supply of the area. After heavy falls of rain it emits up to 6 m³/s, while the decreasing waters are swallowed by it, and the water level in the cave sinks beneath the altitude of the Pivka riverbed, from which we infer that the waters of Matijeva Jama also flow directly towards the springs of Malni near Planina. The lowest water level in Matijeva Jama is almost 40 m bellow surface. *Proteus anguinus*, found in the cave, evidences clean and qualitative water (Habič 1968). The cave is 36 m deep and 50 m long. In November 2000, the period of extremely high waters appeared. At that time the entrance of the cave was eight meters below the lake's surface.

Pivka has special hydrological characteristics that are similar to water conditions on Cerknica polje. The similarities and differences between hydrology of Pivka and Cerknica polje are influenced by geological structure and development of karst. Habič (1975) has written, that Pivka polje once spreaded from Koritnice to Ravbarkomanda and from Palčje to Bukovje.

If we compare the morphology of Cerknica (550 meters above sea level) and Pivka polje (565-535 meters above sea level), there is an obvious difference. Cerknica polje is wide and the elevations do not vary greatly. Upper Pivka is narrow depression, stretching north from the thrust fault. Its bottom is not flat, but is dissected by numerous smaller depressions and conical hills. The bottoms of the hollows are not on the same elevation level – their elevations descend northwards with the

Pivka water flow gradient. The hollows that are on southern parts are smaller and more numerous than those on the north.

We believe that Cerknica polje is in older stage of development than Pivka polje. They both developed by the vertical drainage of the underground water outflow. Because of the corrosion on the primary undulating surface dolines, hollows, uvalas and other depressions started to develop. Dolines incise vertically through the vadose zone. Depressions deepen relatively quicker in comparison to the lowering of the hills until the bottoms of depressions reach the underground water level. In this stage is the Upper Pivka now. Afterward karstification only continues on the hills, while their edges are modified by erosion, where the water table is. So they reduce by parallel slope retreat and undercutting pretty quick like the ice cubs resulting a flat morphological feature like is

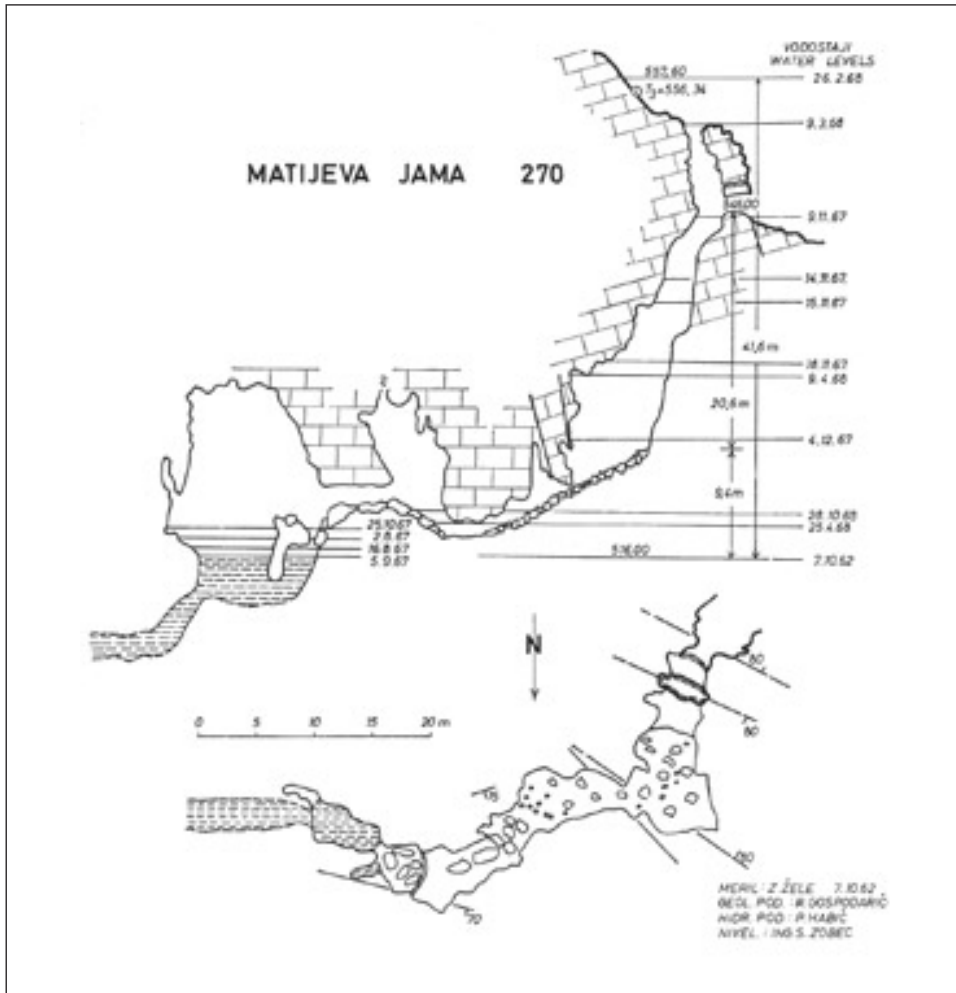


Fig. 4.: The plan of Matijeva Jama cave (Habič 1968).

Sl. 4.: Načrt Matijeve jame (Habič 1968).

the case of Cerknica polje.

Surficial Pivka had probably once risen in Žlebovi near Koritnice. The biggest part of that water today flows underground into Podstenjšek spring near Šembije (Habič 1975). Another proof for the former flow of the Pivka river is the Parska golobina cave. The cave is situated about ten meters above the actual Pivka river. Srečko Brodar described that the cave was part of primarily underground Pivka channels (Habič 1975). In Parska golobina cave the remains of ice age humans were found.

KARST PERIODICAL LAKES OF UPPER PIVKA

The total number of karst periodical lakes of Upper Pivka is at least 15 with some additional lakes that appear only at higher floods and can be dry for years (Fig. 5 and 6). Below is a list (Table 1) of most frequent periodical lakes.

Name of the periodical lake	Height above sea level (in m)	The surface of a lake (in m ²)
Jeredovci	537-538	5,299
Petelinjsko jezero	532-545	736,721
Palško jezero	543-557	1.027,396
Klenško jezero	544-545	3,648
Parsko jezero	538-540	29,658
Malo Drskovško jezero	539-540	41,007
Veliko Drskovško jezero	542-545	186,436
Malo Zagorsko jezero	549-550	16,495
Veliko Zagorsko jezero	544-548	39,785
Jezero za gradom Kalc or Laneno jezero	553-558	23,314
Bačko jezero	561-563	32,831
Kalško jezero	554-555	55,937

Table 1.: The list of Pivka periodical lakes with water levels and surface in their normal extent.

DISCUSSION

Gams (1973) is affirming, that karst polje is a huge karst depression with a narrow bottom and karst outflow. It usually has a sinking river and very steep slopes (Gams 1973). Other definition also asserts, that polje is a large flat-floored closed depression, with sharp slope, that breaks between commonly alleviated floor and the marginal limestone. The form of some poljes is related to the geological structure, but others are purely the products of lateral dissolution and plantation (Lowe & Waltham, 1995).

Even though some researchers (Habič 1975) discussed Pivka valley being a Pivka polje, it is obvious that Upper Pivka is a different karst form than Cerknica polje. The famous periodical lake of Cerknica spreads on 36 km² at the most and has a relatively flat bottom. On the contrary Upper



Fig. 5.: Water erupting out of the borehole in Kljunov ribnik lake (5th January 2004).

Sl. 5.: Bruhanje vode iz vrtine v Kljunovemu ribniku (5. januar 2004).



Fig. 6.: Dry Palško jezero lake (1st April 2003).

Sl. 6.: Suho Palško jezero (1. april 2003).



Fig. 7.: Flooded Palško jezero lake (2nd December 2003).

Sl. 7.: Poplavljeno Palško jezero (2. december 2003).



Fig. 8.: Dry Petelinjsko jezero lake (2nd July 2003).

Sl. 8.: Suho Petelinjsko jezero (2. julij 2003).

Pivka is dissected by numerous small depressions and conical hills.

According to Gams (1973) uvala is a dish-shaped depression that is usually smaller than karst polje and bigger than doline (Gams 1973). Periodical lakes of Upper Pivka are in fact karst depressions – uvalas periodically filled with water. According to Lowe & Waltham (1995) the uvala is a multi-coned closed depression. The term was introduced to describe features assumed to be the second step in a three-stage process of polje development, in which dolines were supposed to coalesce into uvalas. Thus the evolution of the science broth to abandoning of this certain term, while this mechanism is no longer accepted. The term uvala has fallen into discusses and is expressing needs to redefine it (Lowe & Waltham 1995).

Occasionally flooded uvalas or small depressions are special habitats with mainly wet bottom over the year and adequate vegetation and animals (Gams 2003, 293).

CONCLUSION

Upper Pivka valley represents an interesting karst area built on a sequence of limestone and alluvium, that are overlaying flysch. Numerous karst springs fed the surficial Pivka river that flows about half of the year, depending on water conditions. Fifteen periodical lakes (Jeredovci, Krajnikov dol, Petelinjsko jezero, Palško jezero, Klenško jezero, Radohovo jezero, Parsko jezero, Veliko and Malo Drskovško jezero, Veliko and Malo Zagorsko jezero, Kljunov ribnik, Laneno jezero or Jezero za gradom Kalc, Bačko jezero, Kalško jezero) are spreading in the area of 50 km². Palško jezero (1.027,396 m²) is the biggest lake and Petelinjsko jezero holds the water for the longest period. Periodical lakes belong to Snežnik thrust sheet that is thrust over Komen thrust sheet. The periodical lakes are developed in the distance of 1-5 km far from the thrust fault that divides two tectonic units. Upper Pivka is not karst polje in the sense as it is Cerknica polje. The periodical lake of Cerknica polje is developed inside northwest-southeast oriented Idrija fault and the Upper Pivka is developed north from the thrust fault.

Periodical lakes of Upper Pivka are karst depressions periodically filled with water and the Cerknica periodical lake is karst polje periodically filled with water as well. In karst terminology the expression periodical lake is mostly related to a flooded karst polje. The type of periodical lakes as is the case of Upper Pivka could be a new karst term. Upper Pivka periodical lakes are very impressive karst features that should awaken more attention in wider population.

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KRAŠKA PRESIHajoČA JEZERA ZGORNJE PIVKE

Povzetek

Na enajsti mednarodni krasoslovni šoli, ki je potekala junija 2003 v Postojni, nas je ena od strokovnih ekskurzij vodila na Zgornjo Pivko. Udeležencem smo predstavili presihajoča jezera ter geološke in hidrološke razmere na Pivškem (Sl. 1 in 2). Razpravljali smo o izrazih presihajoče jezero, kraško polje, uvala, estavela (Sl. 4), depresija, bifurkacija ter o tem, ali je pokrajina, ki smo jo obiskali dolina Pivke, Pivška kotlina ali kraško polje.

Pokrajina Pivke je kotanja, z vseh strani obdana s kraškimi planotami. Na severu se strmo dvigata Nanos in Hrušica, na vzhodu, jugovzhodu in jugu Javorniki in Snežniški masiv, na zahodu pa Taborski hrbet in Slavinski ravniki, ki se spuščata v Košansko dolino.

Pokrajino delimo na Spodnjo in Zgornjo Pivko, kjer se zaradi različnih litoloških značilnosti v osrednjem dolinskem delu prepletajo značilnosti kraškega in rečnega reliefa. Spodnja Pivka, severno od Prestranka, je iz flišnih kamnin in deloma prekrita z rečnimi naplavinami. Tu prevladuje razvejan površinski pretok.

Kamninska podlaga v Zgornji Pivki, ki sega južno od Prestranka, je iz apnencev. Tok Pivke je v tem delu občasen, vendar ob visokih vodah pogosto poplavlja. Ko se gladina podzemne vode po obilnejših padavinah dvigne, zalije vrsto plitvih kraških globeli, ki se spremenijo v občasna kraška jezera.

Navadno nastane 15 kraških jezer (Jeredovci, Krajnikov dol, Petelinjsko jezero, Palško jezero, Klenško jezero, Radohovo jezero, Parsko jezero, Veliko in Malo Drskovško jezero, Veliko in Malo Zagorsko jezero, Kljunov ribnik, Laneno jezero ali Jezero za gradom Kalc, Bačko jezero, Kalško jezero), toda nekaj manjših jezer se pojavi le izjemoma ob visokih vodah.

Obravnavano območje je območje podzemeljske kraške bifurkacije med Jadranskim in Črnim morjem (Sl. 3). Vode se razlivajo v različne smeri; visoke se prelivajo na površje in napolnijo strugo Pivke, ki sklenjeno teče od Zagorja do ponorov v Postojnsko jamo. Del Pivke ponika v kraški svet že v manjše požiralnike v strugi, večinoma pa nadaljuje svojo pot proti Postojnski jami in potem podzemsko proti Planinskemu polju. Ob nizkem vodostaju se podzemne vode pretakajo pod Javornike proti Cerkniskemu polju. Del podzemeljskih voda s Pivke med Prestrankom in Rakitnikom ob zahodnem obrobju Javornikov stalno odteka v izvire Vipave in Timava, del pa v izvire Unice na Planinskem polju (Habe 1963; Habič 1989). Vode Lokve in Belščice, ki ponikajo pri Predjami, pa odtekajo v izvire Vipave (Habe 1970).

Presihajoča jezera Zgornje Pivke so kraške depresije, občasno zapolnjene z vodo (Sl. 5 in 6). Cerkniško polje pa je pravo kraško polje, ki ga občasno napolnejo visoke vode. V mednarodni kraški literaturi je izraz kraško polje večinoma vezano na večje občasno poplavljenе kraške kotanje z ravnim dnom, ponikalnico in strmim obodom (Gams 1973, Lowe & Waltham 1995).

