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# KARST UNCOVERED DURING THE BIČ-KORENITKA MOTORWAY CONSTRUCTION (DOLENJSKA, SLOVENIA)

# KRAS, RAZKRIT PRI GRADNJI AVTOCESTE MED BIČEM IN KORENITKO (DOLENJSKA, SLOVENIJA)

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**Abstract** UDC: 551.44:625.7/.8(497.4)

**Martin Knez &Tadej Slabe & Stanka Šebela: Karst uncovered during the Bič- Korenitka motorway construction (Dolenjska, Slovenia)**

The most conspicuous karst formations uncovered at the bottom of morphologic depressions or uvalas along the motorway route include swallow holes and estavelles. Also uncovered during the construction were underground karrens and caves of exquisite shapes, situated at valley bottoms and often flooded by groundwater. They have a specific rock relief that, to the best of our knowledge, is now described for the first time. Old caves through which streams were once flowing testify to the lowering of the level of groundwater, which reaches the surface only in the lowest-lying valleys, and to probable tectonic dissection of the karst surface. A good part of the caves are filled with fine-grained sediment and have been transformed underneath it. The shaping of fissure caves, located predominantly along vertical fissures, can be defined as having occurred subterraneously. They exhibit features of a shallow, sediment-covered karst where groundwater is close to the surface. These features are not visible at first sight, but they become apparent at any encroachment on karst and should therefore be taken fully into account in any such activity in the future. Many karst formations, above all caves, underground karrens or stone forests, are worthy of protection and preservation.

**Key words:** covered karst, motorway construction, Dolenjska, Slovenia.

**Izvleček** UDK:551.44:625.7/.8(497.4)

**Martin Knez & Tadej Slabe & Stanka Šebela: Kras, razkrit pri gradnji avtoceste med Bičem in Korenitko (Dolenjska, Slovenija)**

Na trasi avtoceste so na dnu morfoloških depresij oziroma uval med kraškimi pojavi najbolj vidni požiralniki in estavele. Pri gradbenih delih so se razkrile tudi podtalne škraplje ter jame. Izjemnih oblik so tiste, ki so nastale v dnu podolij in ki jih podtalne vode pogosto poplavijo. Imajo povsem svojevrsten, kot vemo tokrat prvič opisani skalni relief. Stare jame, skozi katere so se nekoč pretakali vodni tokovi, pričajo o zniževanju gladine podzemeljske vode, ki površje dosega le v najnižjih podoljih ter o verjetnem tektonsko pogojenem členjenju kraškega površja. Dobršen del jam je zapolnjen z drobnozrnato naplavino in pod njo tudi preoblikovan. Oblikovanje špranjastih jam, ki so večinoma ob navpičnih razpokah, pa bi lahko opredelili kot podtalno. Razkrivajo se nam značilnosti plitkega in z naplavinami pokritega krasa, kjer je podzemeljska voda blizu površja. Te značilnosti bi bilo potrebno kar v največji meri upoštevati pri nadaljnjih poseganjih v kras, saj so nam na prvi pogled skrite, vsakršno poseganje v kras pa nam jih razkrije. Mnogi kraški pojavi predvsem jame, podtalne škraplje ali kamniti gozdovi so vredni, da jih zaščitimo in ohranimo.

**Ključne besede:** pokriti kras, gradnja avtocest, Dolenjska, Slovenija.

## INTRODUCTION

Karstologists and road builders (DARS d.d.) cooperate successfully in the planning and building of motorways in Slovenia (Knez et al. 2004, Knez & Slabe 2001, 2002; Šebela et al. 1999).

During the construction of the Bič-Korenitka motorway (Figure 1), when carbonate rocks were uncovered and present-day epikarst zone was cut into at several sites, interesting formations characteristic of that particular part of the karst were discovered. This part of the karst is predominantly covered with thicker layers of sediment and soil, groundwater in the valleys lying close beneath the surface. These formations include different kinds of karren, particularly the underground ones, some of which can be described as stone forests, karst uvalas with estavelles and swallow holes, and other caves.

## MOTORWAY ROUTE AND CHIEF CHARACTERISTICS OF THE LANDSCAPE

The Bič-Korenitka section of the motorway goes first across the low-lying eastern part of the Dob uvala, one of the many untypical depressions along the Dolenjska lowland with fluviokarst as the prevailing type of karst landscape. The bottom, and in some places also the margins of the

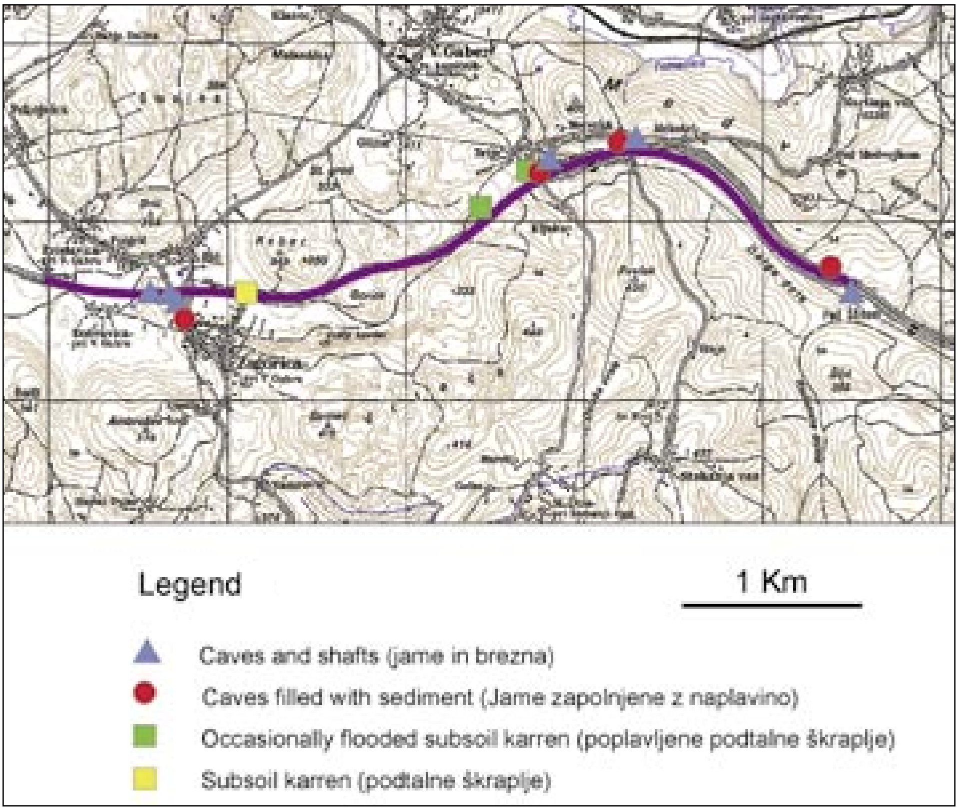


*Fig. 1: Karst features found during the construction of Bič-Korentika highway.*
*Sl. 1: Kraški pojavi odkriti pri gradnji avtoceste Bič-Korenitka.*

depression are covered with sediment strata a few metres thick.

The eastern part of the section lies on the southern slope of mount Medvedjek and has different eastward and westward dips. There is less surface water there because thinner sediment layers and

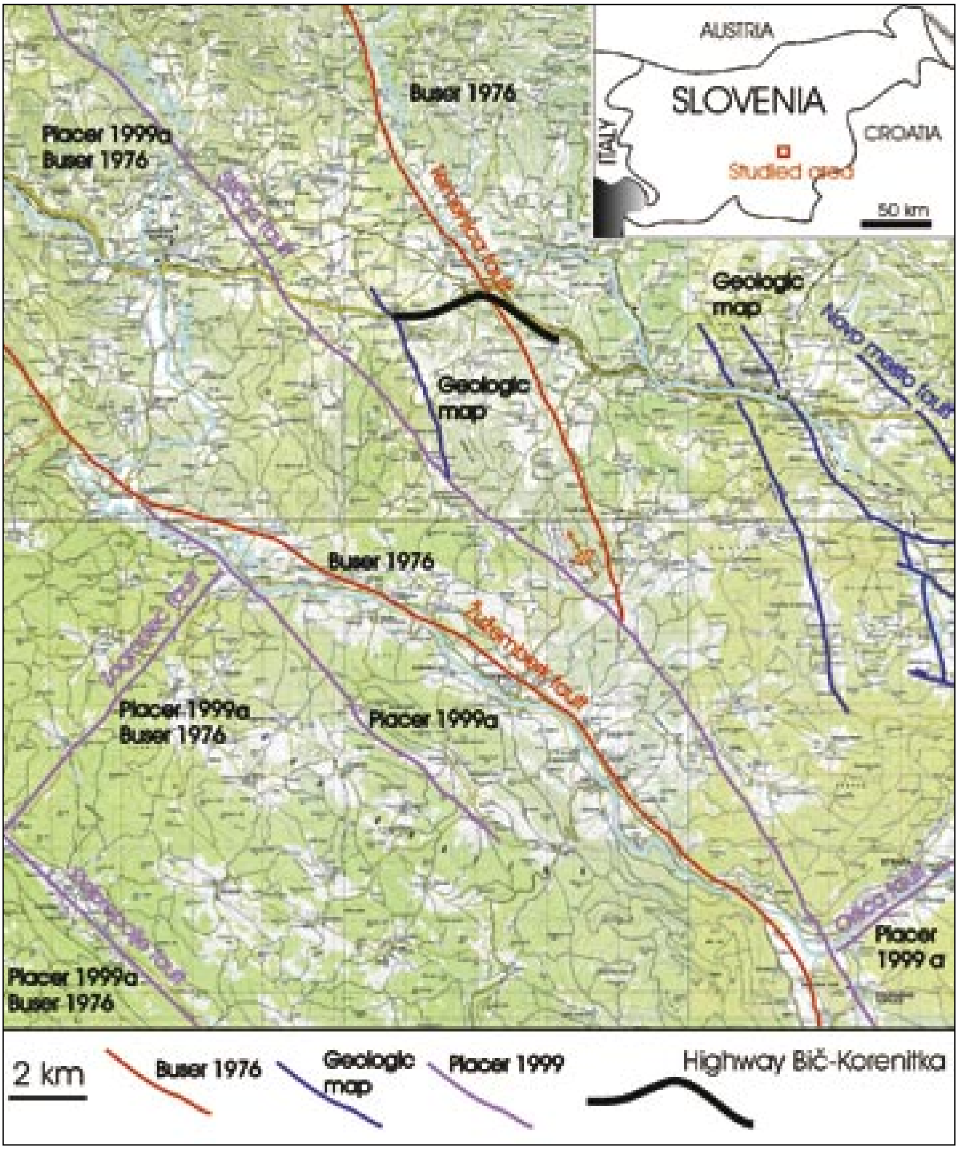


*Fig. 2: Principal faults around the Sava compressive wedge (after Placer 1999 a, Buser 1969, 1976, Pleničar & Premru, 1976).*
*Sl. 2: Glavni prelomi ob Savskem kompresijskem klinu (po Placer 1999 a, Buser 1969, 1976, Pleničar & Premru, 1976).*

unclosed weathering-product cover cause it to flow relatively rapidly underground. In many places tectonically broken rock outcrops and usually crumbles into small fragments on the surface. Here the motorway crosses several deep depressions that point to intensive karstification typical of that part of Dolenjska karst.

Surface streams (Dobovščica, Šentvid brook and Glogovnica) flowing in from dolomite sink in oolitic limestones. When heavier rainfalls occur, water also flows into the uvala from the west and east and rain-swollen smaller springs extend their flow towards its southeastern edge. Before the construction of the motorway heavier floods in this area occasionally hindered traffic on the old highway (Gams 2004). A more rapid draining of surface water, diminished flood volumes and highly permeable swallow holes all point to a broadly formed system of ground channels just below the surface. Frequent collapses and forms developed on rocks as a consequence of oscillating water levels are also an indication of this.

## KARST OF THE DOLENJSKA LOWLAND

The area circumscribed by the eastern edge of the Ljubljana marshland, Krško valley, Dobrepolje, Želimlje valley and Gorjanci belongs to what we call low, covered Dolenjska karst (Gams 2004, Kranjc 1990).

Habič (1982) points to what in lithological terms is referred to as incomplete carbonate karst, developed in the main on Triassic dolomites where cracked and porous rock absorbs a considerable amount of precipitation. Dolomites extend over surfaces of different magnitude and their position in karst also determines their karstic features. A thinly scattered river network forms on the dolomite surface and a considerable portion of drainage-basin ravines and lateral ravines are usually without permanent flows. Smaller sources of the underground waters flowing over rocks with moderately widened corrosion-provoked fissures are a frequent occurrence. Surface and underground karst formations are few and far between, but in some places they are typical of dolomite karst that can be designated as a specific type of fluviokarst.

In the Dolenjska valley there are many Plioquaternary sediments. Those in the flatland are supposed to have formed at the time when the level of underground water was closer to the surface. As the soil on Triassic dolomites is less porous than on limestones, and due to seasonal freezing in the cold Pleistocene climate was partly impermeable to water, this valley shows many signs of former tributary streams in the border limestone area (Gams 1998).

In morphological terms, an almost normal relief with valleys and a sporadic surface- river network has developed on a predominantly dolomite base (Habič 1982). The shaping of relief in different areas of this partial karst proceeds at a different pace, depending on general morphogenetic evolution. Thus dolomite ravines are deepest in the Notranjska and Dolenjska uplands, whereas the relief formed on the northern Dolenjska dolomite is much lower and gentler. Karstic features on dolomite are manifest in a mildly bumpy surface, characteristic dry valleys, infrequent dolines and shallow uvalas. Relatively smooth, un-dissected slopes of crested elevations are evidence of underground drainage. Another obvious sign of karstification are collapses opening into thicker strata of dolomitic weathering products at the bottom of valleys.

The chief hidrographic features of dolomite karst are indicated by the disposition of normal surface valleys and by the associated river network. Dolomite valleys are dry for the greater part of the year, with streams and floods appearing after heavy rainfalls. Infiltrated water feeds small but permanent springs. Flow oscillation in the springs is small, which is an indication of greater permeability and karstification. Underground water flows close to the surface, so karst having such characteristics is called "shallow karst". This is also one of the characteristics of fluviokarst. A feature of high-relief dolomite areas is abundant surface drainage of high flows. Torrent drainage influences the formation of steep and deep ravines cut predominantly into broken and crushed fault zones.

## GEOLOGY

According to the Basic Geologic Map, sheet Ribnica (Buser 1969), Upper Triassic limestone lying in the north and Lower Jurassic limestone lying in the south come in contact south of mount Medvedjek. Triassic limestones are strongly recrystallized and contain numerous coloured insertions of sedimentary breccia. According to the Basic Geologic Map, what is involved is a normal passage from the Triassic to the Jurassic evolving south of the hills Mali Medvedjek (409.1 m) and Veliki Medvedjek (417.3 m). The general direction of the Triassic and Jurassic limestone is NNW-SSE. The layers of massive, brecciated, Triassic limestone are subvertical. Jurassic limestone dips towards NW and SE at an angle of 20-50$^{0}$. South of the Mali Medvedjek we find darker oolitic Jurassic limestones dipping towards the SW at an angle of 20-40°. Slightly more to the west, south of the Veliki Gaber locality, the Jurassic limestones contain Megalodontidae sp. remains. The limestones here decline in the NE direction at an angle of 30-50$^{0}$. This means that in the Jurassic limestones there is a syncline with a general NE-SW direction of the axis. Along the bedding-planes of Jurassic limestone we also detect slips with traces of vertical displacements.

According to Buser (1976) the studied area belongs to »western Dolenjska mesozoic blocks«. The Temenica fault runs through Temenica river valley, passes Veliki gaber and Dobrava near Dobrnič. The Stična fault can be followed through the valley of Stiški potok stream, passing Rdeči kal, Šumberk and Dobrava near Dobrnič. Buser (1976) determined the position of Žužemberk fault differently to Placer (1999a) (Figure 2). According to Buser (1976) it runs between Lipoglav, Zagradec, Žužemberk and Dvor.

A part of the fault in cross-Dinaric orientation called Orlica fault (Placer 1999b) was by Premru (1976) named Straža fault. It is also called Krško fault (Pleničar & Premru, 1977). Straža tectonic depression is filled with pleistocene sediments. The vertical displacement along the Straža fault is 350 m on its southern side (Premru 1976).

The studied area is part of the triangular segment between the Idrija and Mid-Hungarian tectonic zones called the Sava kompressive wedge. A field of N-S directed increased normal tensions was formed that resulted into the folding of the W-E oriented Sava folds. Owing to folding the compressive wedge shortened in the N-S direction for about 20 km which led to the shift of the Periadriatric tectonic zone to the south, and its narrowing (Placer 1999a).

The begining of intense folding of Sava folds could not be more precisely determined as being younger than Miocene, or presumingly Pliocene. The process of compression was at work also in the Quaternary and could be hypothetically active even at present (Placer 1999a).

The reason for the formation of the Sava compressive wedge we see in the development of the Idrija – Mid-Hungarian transsection zone in which the dominant shear direction cannot be established. This means that the compressive wedge came into being in a period of stagnation of intensive shear movements in the inner part of the Idrija and in the Mid-Hungarian tectonic zones (Placer 1999a).

*Fig. 3: Subsoil karren.*
*Sl. 3: Podtalne škraplje.*

*Fig. 4: The cave filled with fine-grained sediment and flowstone.*
*Sl. 4: Jama zapolnjena z drobnozrnatimi naplavinami in sigo.*

*Fig. 5:. Fissure cave that formed along tectonic structures and is filled with fine-grained sediment and flowstone.*
*Sl. 5: Špranjasta jama, ki je nastala ob tektonskih strukturah in je zapolnjena z drobnozrnatimi naplavinami in sigo.*

*Fig. 6: The cave formed in crushed rock.*
*Sl. 6: Jama oblikovana v pretrti kamnini.*

The genessis of the Sava folds is due to the formation of the Idrija – Mid-Hungarian transsection zone and also due to reorientation of tension conditions from the dextral shear character, over transpressive to normal ones oriented perpendicular to the Periadriatic tectonic zone in the direction N-S, in probable connection with a rotation of wider dimensions (Placer 1999a).

In the Basic Geologic Map, sheet Ribnica (Buser 1969), the contact between Upper Triassic limestone and Lower Jurassic limestone is shown as a normal lithologic contact running south of Medvedjek along Dolge Dole valley, but tectonic mapping indicates that the morphology of that valley is also tectonically determined by a powerful NW-SE (230/60) fault zone. Parallel zones also extend toward the west where we have measured a 220/80 right-shear fracture and a 10-40/70-90 left-shear fracture. We believe that the NW-SE fracture involves at least two phases of horizontal tectonic movement (right and left shears). The Basic Geologic Map, sheet Ribnica (Buser 1969), also shows that in this area there is a strong fault with dip direction $60^0$ which comes from the river Temenica valley in the north, runs east of the Veliki Gaber locality, crosses the western margin of Mali Medvedjek and continues SW of Dobrnič. Buser termed this fault in 1976 the Temenica fault (Figure 2). The fault running through Dolge Dole is the NE fracture concomitant with the Temenica fault.

We include the fault zone before Korenitka with its 310/70 dip direction among the fault zones with tectonically powerfully crushed rock. It is probably an older, some 4 metre-wide fault zone traversed by the NW-SE fault zone that runs along the Dolge Dole valley. We presume that the oldest tectonic deformations of the zone are those in the NE-SW direction, followed by NW-SW zones (horizontal movement, right and left shear) and E-W zone as the youngest (horizontal movement, right shear). Thrust deformations probably also belong to older deformations.

## UNCOVERED KARST FORMATIONS

### Karst uvalas with swallow holes and estavelles

South of Bič, at the bottom of a morphologic reminiscent of a periodically flooded polje, there are many estavelles and swallow holes. The entrances are opened in the sediment. The Dob uvala, on which the western part of the research route runs, is one of many untypical depressions along Dolenjska lowland, with fluviokarst the predominating landscape type. It lies at the contact of Upper Triassic dolomite on the northern side of the valley and Jurassic oolite limestone on the southern side. Because of its diversified geologic composition we can expect locally differing water permeability, or poorer water permeability in general. The uvala is the lowest part of the Šentvid environment. Given the dimensions of its bottom, the depression could be defined as polje. However, because of the absence of a larger sedimentary flatland at the bottom, and because most of the rim has not been closed and therefore does not have the form of a typical Dinaric polje, the depression is termed uvala (Gams 1987).

Among other morphologic depressions-uvalas found along the motorway route are Kljuka and Žurmanca. The Kljuka uvala is tectonically positioned in the east-west direction in which the fault zones are also spreading.

The Dolge Dole morphologic depression has developed at the lithologic and tectonic contact.

### Karrens

Underground Karrens in this area can be divided into two types. The first have formed by the steady vertical penetration of water through the more or less thick layer of soil covering broken carbonate rock. Under the thicker layer of sediment and soil are wider or narrower V-shape fissures formed on crushed rock. They resemble underground teeth developed in a heavily crushed rock. In places where fissures are more thinly scattered and the rock is more corrosion resistant, genuine stone teeth with pointed or bladed tops, and sometimes even smaller stone forests, have developed (Knez et al. 2003). They are dissected by subsoil channels. Their surface is corroded subcutaneously in a characteristic fashion - it is relatively smooth on the uniformly grained and small-grained rock and rough on diversely composed or crushed rock. Before the removal of the soil only smaller karrens or pieces of rock were sticking out on the surface. The surface was covered with vegetation and often with moss as well, and there were also subsoil cups and partly reshaped subsoil forms, channels and notches (Slabe 1999). The latter are indications of slow erosion of the soil.

The other type of underground karrens was discovered during archaeological excavations at the bottom of the valley near Bič. They were formed entirely subcutaneously (Figure 3). In some places the layer of sediment and soil is relatively thick, and in other places karrens almost reach the surface. They have sharpened tops and an interesting rock relief that speaks volumes. A relatively smooth rock, characteristic of formation beneath the soil and small-grained sediment, prevails in the upper part. In the lower part of the karrens the most expressive feature are underground notches. Larger and horizontal notches reach one metre in diameter, and smaller ones are placed on top of each other. Semi-cylindrical notches represent the ends of vertical underground channels formed along the most conductive ways. Some of the tops of underground teeth located above the most expressive notches are mushroom like. The underground grooves on these karrens can be divided into vertical and horizontal ones. The former are the conduits of oscillating waterflow along the most conductive ways. The latter crisscross more gently sloping rocks, including larger ones, and are co-shaped with moisture, which stays in them the longest, even after the level of underground water decreases. Formed along flaws in the rock that occur mostly as small fissures are underground solution cups which can develop into pipes. Between solution cups and channels, then, are the underground tubes that crisscross the rock at different inclinations.

Similar formation of underground karrens was illustrated by an experiment in which we covered gypsum columns with soil and then exposed them to artificial rain. The water drained from the model at the bottom. The upper part of the columns was formed by water penetrating the soil dispersively, and the lower part formed in the locally watered zone. The drainage was too slow and that explains why the water filled the bottom of the model.

To sum up, two prevailing ways of karren formation can be inferred from their shape and their rock relief. The shapes of rock, which are the traces of frequent oscillations in the level of underground water that floods karrens from underneath, give them a special character. During low levels of underground streams, karrens are formed by water flowing slowly and dispersively from the surface through the soil and gliding over the rock downwards. It stays longer in underground solution cups and gently sloping channels as well as along less permeable interfaces between rock and the surrounding sediment.

**Caves**

There are few larger caves in the explored area. A few more are found on the higher-lying margins of depressions. As long as the karst water level was closer to the surface, thick Plioquaternary sediments undoubtedly hindered karstification deep below the surface (Gams 2004). Because the level of underground water in the explored valley was high and erosion was modest thick layers of weathering material, which in the geologic past covered a large part of Slovenian karst, remained preserved.

On the 5 km long section of Bič-Korenitka motorway we discovered 10 new karst caves. Off the motorway route several swallow holes had been discovered before the construction: Dobravska Jama swallow hole between Dobravica pri Velikem Gabru and Bič; Špaja Jama (cad. no. 3464), a pothole 68 m long and 44 m deep of a stepped form, east of Bič; Kovačeva Rupa and Volčji Kevder (7 m deep) swallow holes east of Zagorica pri Velikem Gabru.

During the main work relatively few caves (Figure 4) were uncovered, the largest number being found in a deep cutting across southern part of the Mali Medvedjek hill. Most of the caves were filled with fine-grained sediment and only some potholes were empty. The diameter of the largest passage whose walls were covered with an abundance of speleothems was 5 m and other passages were one or two metres in diameter. The rocky circumference of the passages was transformed at the contacts with the sediment. The brokenness of the rock is most often reflected in the position and form of passages. A special type of cave is the fissure cave (Figure 5) formed along more perceptible upright fissures and fractures and at intersections of bedding-planes and tectonic deformations. In cross section they are more or less vertical and sometimes meandering too. In all cases they conform to the lithotectonic state in the rock. The width and volume of filled spaces in the rock correspond to the local brokenness of the rock. Such caves often follow narrower fault zones from which the interior fault-zone material was transported underground and replaced with superficial sediment. On the walls of some caves whose width does not exceed one metre traces of the last movement of rock blocks are still visible. Vertical circulation of water did not take place at one point alone, but alongside the entire spread of the fracture or alongside the equivalent brokenness of the rock. That is why these caves display a somewhat specific evolution pattern and present-day appearance. Did they form as sub-sedimentary caves? Smaller caves also developed in a markedly broken, atomised and sometimes brecciated rock (Figure 6), which explains why their circumference is very rough.

## CONCLUSION

It is a fact that limestone along Bič-Korenitka motorway route is tectonically powerfully deformed and broken into broad demolished and crushed zones where limestones are often broken to the degree of tectonic breccia. This is understandable, for the explored terrain is part of the Sava compressive wedge (Placer 1999a), which has gone through several phases of tectonic processes. Unlike karst in south-western Slovenia where cretaceous limestones prevail, this karst developed in Triassic and Jurassic limestones and dolomites which are covered with thicker sediment than in south-western Slovenia. The most conspicuous karst formations are swallow holes and estavelles at the bottom of morphologic depressions or uvalas. During the work underground karrens and caves were uncovered. Those that developed at the bottom of valleys and are often flooded by underground streams are of exquisite shapes and have specific rock relief which, as far as we know, is now described for the first time. Old caves through which streams were once flowing testify to the lowering of the level of groundwater, which reaches the surface only in the lowest-lying valleys, and to probable tectonic dissection of the karst surface. A good part of the caves are filled with fine-grained sediment and have been transformed underneath the sediment. The shaping of fissure caves, located predominantly along vertical cracks, can be defined as having occurred subterraneously. Water widened cracks into fissure caves and at the same time filled them with small-grained sediment. The characteristics of a shallow (underground water is close to the surface), sediment-covered, specific type of Slovenian karst are brought to light. These characteristics should be fully taken into consideration in future encroachments upon karst. They are not visible at first sight, but each encroachment on karst reveals them, many of which (caves, underground karrens or stone forests) are worth protecting and preserving.

## REFERENCES


Buser, S., 1969: Osnovna geološka karta SFRJ 1:100000, list Ribnica. Zvezni geološki zavod, Beograd.

Buser, S., 1976: Tektonska zgradba južnozahodne Slovenije.- 8.jugoslovanski geološki kongres Bled 1.-5. oktober 1974, 3, 45-58, Ljubljana.

Gams, I, 1987, Razvoj reliefa na zahodnem Dolenjskem (s posebnim ozirom na poplave).- Geografski zbornik, 63-96, Ljubljana.

Gams, I , 1998, Kras. Eds: Gams, I. & Vrišer, I. (In.), Geografija Slovenije.-Slovenska matica, 55-90, Ljubljana.

Gams, I, 2004, Kras v Sloveniji v prostoru in času.- Založba ZRC, 515 p, Ljubljana.

Habič, P. 1982, Pregledna speleološka karta Slovenije.- Acta carsologica 10, 5-22, Ljubljana.

Knez, M. & Slabe, T. 2001: Karstology and expressway construction.- Proceedings 14th IRF Road World Congress, Paris.

Knez, M. & Slabe, T. 2002: Unroofed caves are an important feature of karst surface: examples from the Classical Karst.- Z. Geomorphol., 46,2, 181-191, Stuttgart.

Knez, M., Otoničar, B. & Slabe, T. 2003: Subcutaneous stone forest (Trebnje, Central Slovenia).- Acta carsologica 32/1, 29-38, Ljubljana.

Knez, M. Slabe, T. & Šebela, S. 2004: Karstification of the aquifer discovered during the construction of the expressway between Klanec and Črni Kal, Classical Karst.- Acta carsologica 33/1, 205-217, Ljubljana.

Kranjc, A. 1990, Dolenjski kraški svet.- Dolenjska založba, 240 p., Novo mesto.

Placer, L., 1999a: Structural meaning of the Sava folds.- Geologija 41, 191-221 (1998), Ljubljana.

Placer, L., 1999b: Contribution to the macrotectonic subdivision of the border region between Southern Alps and External Dinarides.- Geologija 41, 223-255 (1998), Ljubljana.

Pleničar, M. & Premru, U., 1976: Osnovna geološka karta SFRJ 1:100000, list Novo mesto. Zvezni geološki zavod, Beograd.

Pleničar, M. & Premru, U., 1977: Tolmač za list Novo mesto.- 61, Zvezni geološki zavod, Beograd.

Premru, U., 1976: Neotectonic Evolution of Eastern Slovenia.- Geologija 19, 211-249, Ljubljana.

Slabe, T., 1999: Subcutaneous rock forms.- Acta Carsologica 28/2, 255-269, Ljubljana.

Šebela, S., Mihevc, A. & Slabe, T. 1999: The vulnerability map of karst along highways in Slovenia.- In. Beck B.F., A.J. Pettit, J.G. Herring (eds). Hydrogeology and engineering geology of dolines and karst – 1999. Proceedings of the Seventh Multidisciplinary Conference on Dolines and the Engineering and Environmental Impacts on Karst. A.A. Balkema, Rotterdam, 419-422.

# KRAS, RAZKRIT PRI GRADNJI AVTOCESTE MED BIČEM IN KORENITKO (DOLENJSKA, SLOVENIJA)

## Povzetek

Krasoslovci z graditelji (DARS d.d.) uspešno sodelujemo pri načrtovanju in gradnji avtocest v Sloveniji (Knez et al. 2004, Knez & Slabe 2001, 2002, Šebela et al. 1999).

Pri gradnji avtoceste Bič-Korenitka (Sliki 1, 2), ko so bile razgaljene karbonatne kamnine in z useki na več mestih presekana današnja epikraška cona, so se razkrili zanimivi in za ta del krasa, ki je pretežno prekrit z debelejšimi plastmi naplavin in prsti, talna voda pa v podoljih plitko pod površjem, značilni kraški pojavi. To so različne vrste škrapelj, zlasti podtalne (Slika 3), o nekaterih lahko govorimo kot o podtalnih kamnitih gozdovih, kraške uvale z estavelami in požiralniki ter druge jame.

Odsek ceste med Bičem in Korenitko poteka v prvem delu po ravninskem vzhodnem delu Dobske uvale, ki je ena izmed mnogih netipičnih kotanj vzdolž dolenjskega podolja s prevladujočim fluviokrasom. Dno in ponekod robovi depresije so prekriti z več metrov debelimi plastmi naplavin.

Vzhodni del odseka leži na južnem pobočju hriba Medvedjek in ima različne naklone proti vzhodu oz. zahodu. Površinske vode je tam manj, saj zaradi tanjših plasti naplavin in nesklenjenosti preperinskega pokrova, relativno hitro odteče v podzemlje. Marsikje tektonsko izredno pretrta kamnina izdanja na površino, kjer večinoma razpada v drobne fragmente. V tem delu cesta prečka več globokih kotanj, katere kažejo na intenzivno in hkrati za ta del dolenjskega krasa tipično zakrasevanje.

Površinski tokovi (Dobovščica, Šentviški potok in Glogovnica), ki površinsko pritečejo iz dolomita poniknejo v oolitnih apnencih. Ob močnejših padavinah priteka voda v uvalo tudi iz zahoda in vzhoda. Manjši izviri ob višjih vodah zelo narastejo in si podaljšujejo površinski vodni tok proti jugovzhodnemu robu uvale. Pred izgradnjo hitre ceste so obsežnejše poplave na tem področju občasno ovirale promet na stari magistralni cesti (Gams 2004). Hitrejši odtok površinske vode in manjši obseg poplav ob dobro propustnih požiralnikih kaže na široko izoblikovan pozemski splet kanalov plitvo pod površjem. Na to kažejo tudi pogosti grezi in zaradi nihajoče vode nastale oblike na skali.

Habič (1982) iz litološkega vidika posebej izpostavlja t.i. nepopolni karbonatni kras, ki je razvit pretežno na triasnih dolomitih, kjer razpokana in porozna kamnina vpije znaten del padavin. Po obsegu zavzemajo dolomiti različne površine, od njihovega položaja sredi krasa pa so odvisne tudi njihove kraške značilnosti. Na dolomitnem površju se oblikuje redka rečna mreža, znaten del povirnih ter stranskih grap pa navadno nima stalnih tokov. Pogosti so manjši izviri podzemljskih vod, ki se pretakajo po posameznih korozijsko večinoma skromno razširjenih razpokah v kamnini. Površinski in podzemeljski kraški pojavi so redki, vendar ponekod prav značilni za dolomitni kras, ki ga lahko označimo tudi kot poseben tip fluviokrasa.

Po dolenjskem podolju je veliko pliokvartarnih naplavin. Na ravnini naj bi nastale še v času, ko je bila gladina podzemne vode bližje površja. Ker so tla (prst) na triasnih dolomitih bolj sklenjena kot na apnencih in so bila v pleistocenski hladni klimi zaradi sezonske zamrznjenosti vodno delno nepropustna, je v tem podolju več znakov nekdanjih pritokov voda na robni apnenec (Gams 1998).

Na prevladujoči dolomitni podlagi je iz morfološkega pogleda razvit skoraj normalen relief z dolinami ter ponekod s površinsko rečno mrežo (Habič 1982). Oblikovanje reliefa je v posameznih

predelih tega delnega krasa različno hitro, odvisno je od splošnega morfogenetskega razvoja. Tako so dolomitne grape najgloblje zarezane v območju visoke Notranjske in Dolenjske. Precej nižji in blažji relief pa je izoblikovan na dolomitu severne Dolenjske. Kraške značilnosti dolomita se odražajo v drobnem grbinastem površju, v značilnih suhih dolinah in redkih vrtačah ter plitvih uvalah. Na podzemeljsko drenažo opozarjajo razmeroma gladka nerazčlenjena pobočja slemenastih vzpetin. Očiten znak zakrasevanja pa so tudi grezi, ki se odpirajo v debelejše plasti dolomitne preperine v dnu globeli.

Glavne hidrografske značilnosti dolomitnega krasa so nakazane z razporeditvijo normalnih površinskih dolin in s pripadajočo rečno mrežo. Doline v dolomitu so večji del leta suhe, po nalivih pa se v njih pojavijo potoki in poplave. Infiltrirana voda napaja majhne a stalne izvire. Nihanje pretokov v izvirih je majhno, redko pa bolj izdatno, kar je odraz večje propustnosti in prevotljenosti. Podzemno pretakanje vode je plitvo pod površjem, zato kras s takšnimi značilnostmi imenujemo tudi »plitvi kras«. Tudi to je ena od značilnosti fluviokrasa. Za dolomitne predele z večjo reliefno intenzivnostjo je značilen tudi izdaten površinski odtok visokih voda. Hudourniški odtok vpliva na oblikovanje strmih in globokih grap, ki so večinoma zarezane v bolj pretrte in zdrobljene prelomne cone.

Večjih jam je na raziskanem področju malo. Nekoliko več jih je na višje ležečih obrobjih depresij. Dokler je bila kraška vodna gladina bližje površja, so debeli pliokvartarni sedimenti nedvomno zavirali globinsko zakrasevanje (Gams 2004). Na obravnavanem podolju so se namreč zaradi visoke gladine podzemne vode in skromne erozije ohranile debele plasti preperine, ki je v geološki preteklosti prekrivala velik del slovenskega krasa.

Na 5 km dolgem odseku avtoceste Bič-Korenitka smo odkrili 10 novih kraških jam.

Izven trase avtoceste je bilo že pred gradnjo znanih več požiralnikov. Med Dobravico pri Velikem Gabru in Bičem se nahaja požiralnik Dobravska jama. Vzhodno od Biča najdemo Špajo jamo (Kat. št. 3464) stopnjasto brezno dolžine 68 m in globine 44 m. Vzhodno od Zagorice pri Velikem Gabru sta požiralnika Kovačeva rupa in Volčji kevder (globina 7 m).

Pri zemeljskih delih se je odkrilo razmeroma majhno število jam (Slika 4). Še največ jih je bilo v globljem useku, ki je prerezal južni del hriba Mali Medvedjek. Večina jam je bila zapolnjena z drobnozrnato naplavino, le posamezna brezna so bila votla. Premer največjega rova, katerega stene so bile prekrite s kopo sige, je meril 5 m, premer ostalih pa je dosegal meter ali dva. Skalni obod rovov je bil obnaplavinsko preoblikovan. V njihovem položaju in obliki se največkrat odslikava pretrtost kamnine. Posebna vrsta so špranjaste jame (Slika 5), ki so nastale ob izrazitejših pokončnih razpokah in prelomih ter sečiščih plasti in tektonskih deformacij. V preseku so bolj ali manj navpične, ponekod tudi vijugaste. V vseh primerih sledijo litotektonskemu stanju v kamnini. Širina in volumen zapolnjenih prostorov v kamnini sledi lokalni pretrtosti kamnine. Takšne jame pogosto sledijo ožjim prelomnim conam iz katerih je material iz notranje prelomne cone odnesen v podzemlje in nadomeščen s površinskim sedimentom. Na stenah nekaterih od teh jam, ki niso širše od metra ali dveh, so še vidne sledi zadnjega premikanja blokov kamnine. Navpično pretakanje ni potekalo samo na eni točki temveč vzdolž celotne razširitve preloma oziroma vzdolž enake pretrtosti kamnine. Zato opisane jame kažejo nekoliko specifičen razvoj in današnji izgled. So se oblikovale kot podnaplavinske votline? Manjše votline so nastale tudi v izrazito, v drobne kose, pretrti (Slika 6) in ponekod v brečo sprijeti kamnini. Njihov obod je zato grobo hrapav.

Dejstvo je, da je apnenec vzdolž trase Bič-Korenitka močno tektonsko deformiran in pretrt v široke porušene in zdrobljene cone, kjer so apnenci večkrat pretrti do stopnje tektonske breče. To je razumljivo, saj je obravnavan teren del Savskega kompresijskega klina (Placer 1999 a), ki je pretrpel več faz tektonskih procesov. Najbolj vidni kraški pojavi so požiralniki in estavele na dnu morfoloških depresij oziroma na dnu uval. Pri gradbenih delih pa so se razkrile tudi podtalne škraplje ter jame. Izjemnih oblik so tiste, ki so nastale v dnu podolij in ki jih podtalne vode pogosto poplavijo. Imajo povsem svojevrsten, kot vemo tokrat prvič opisani skalni relief. Stare jame, skozi katere so se nekoč pretakali vodni tokovi, pričajo o znižanju gladine podzemeljske vode, ki površje dosega le v najnižjih podoljih ter o verjetnem tektonskem členjenju kraškega površja. Dobršen del jam je zapolnjen z drobnozrnato naplavino in pod njo tudi preoblikovan. Oblikovanje špranjastih jam, ki so večinoma ob navpičnih razpokah, pa bi lahko opredelili kot podtalno. Voda, ki je širila razpoke v špranje jih je sproti zapolnjevala z drobnozrnatimi naplavinami. Skratka, razkrivajo se nam značilnosti plitkega, podzemeljska voda je blizu površja, in z naplavinami pokritega, za Slovenijo svojevrstnega krasa. Te značilnosti bi bilo potrebno kar v največji meri upoštevati pri nadaljnjih poseganjih v kras, saj so nam na prvi pogled skrite, vsakršno poseganje v kras pa nam jih razkrije in mnoge od njih (jame, podtalne škraplje ali kamniti gozdovi) so vredne, da jih zaščitimo in ohranimo.