Speleological Association of Slovenia
and
Karst Research Institute ZRC SAZU

7th INTERNATIONAL KARSTOLOGICAL SCHOOL

Classical Karst

ROOFLESS CAVES

Andrej Mihevc

Guide-booklet for the excursions
Postojna, June 1999

Organiser:
Karst Research Institute
Centre of Scientific Research of the
Slovene Academy of Sciences and Arts

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PROGRAM OF THE SCHOOL

Sunday, June 27, 1999
Arrival of participants to Postojna, registration and accommodation

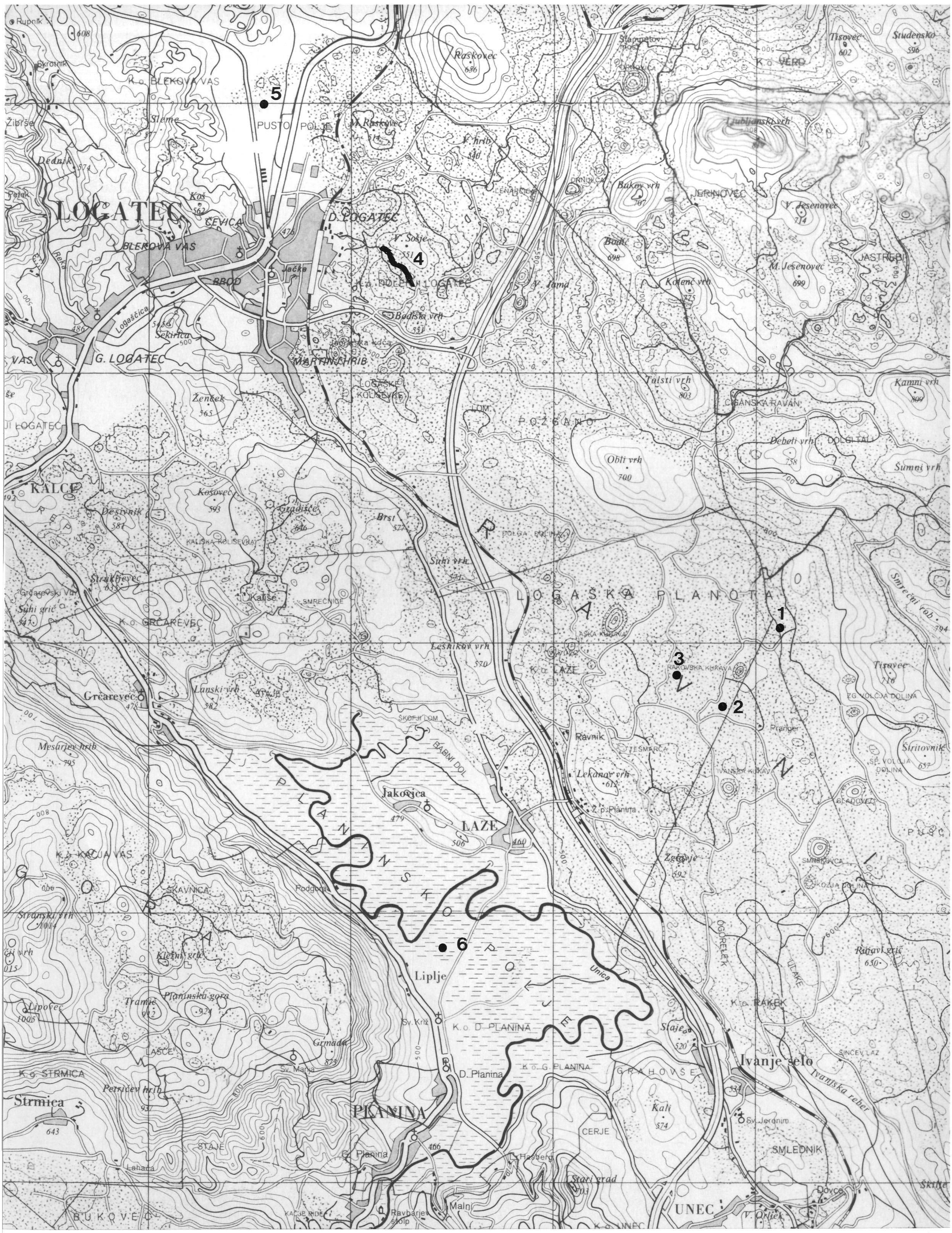
Monday, June 28, 1999
9.00 - 12.00 The opening of the Karstological School and the lectures
12.00 - 13.00 Lunch time
13.00 - 20.00 Field work: Roofless caves of Notranjska region: Bus excursion with short stops and walks on rough karst terrain. No lights or special equipment required, just terrain shoes and an umbrella in case of rain.

Tuesday, June 29, 1999
8.30 - 12.00 Lectures
12.00-13.00 Lunch time
13.00 - 18.30 Field work: Roofless caves of Slavenski ravnik: Bus excursion from Postojna to Slavinje and with about 7 km walk on rough karst terrain between Loza karst levelled surface and blind valley of Rakulšèica stream (about 3 km of unroofed caves). No lights or special equipment required, just terrain shoes and an umbrella in case of rain.

18.30 Invited dinner at restaurant Milena in Hruševje

Wednesday, June 30, 1995
8.30 - 16.00 Whole day excursion: Unroofed caves of Karst. Bus transfer to Matavun, walk trough unroofed cave(s) above Škocjanske jame to Dolnje Le eèe. Stop and lunch at Divaèa.
Bus transfer to Merèe and walk across Taborski hribi hills to levelled karst surface of Lipica ravnik. Visit of different surface - cave interaction features of Besta ovca cave - collapse Perkova peèina, entrance shaft and unroofed cave. Visit of denuded cave at Kanjeduce on Lipica ravnik. There will be about 3 km of walk before lunchtime and about 3 km in the afternoon. No lights or special equipment required, just terrain shoes and an umbrella in case of rain.

17.00 Return to Postojna.



Legend: 1 - 3 unroofed caves at Laški Ravnik, 4. Unroofed caves of Sošje, 5. Logatec polje, 6. Planina Polje.

Monday, June 28, 1999

Unroofed caves of Notranjska

Notranjsko podolje in Logaški Ravnik

Ravnik is a generic name for a karst levelled surface in Slovenian karst areas. One of the largest ravnik is between Begunje on SE and Logatec polje on NE. It is named after Logatec, Logaški ravnik. Parts of it are named after the nearest small villages where the owners of the land are from.

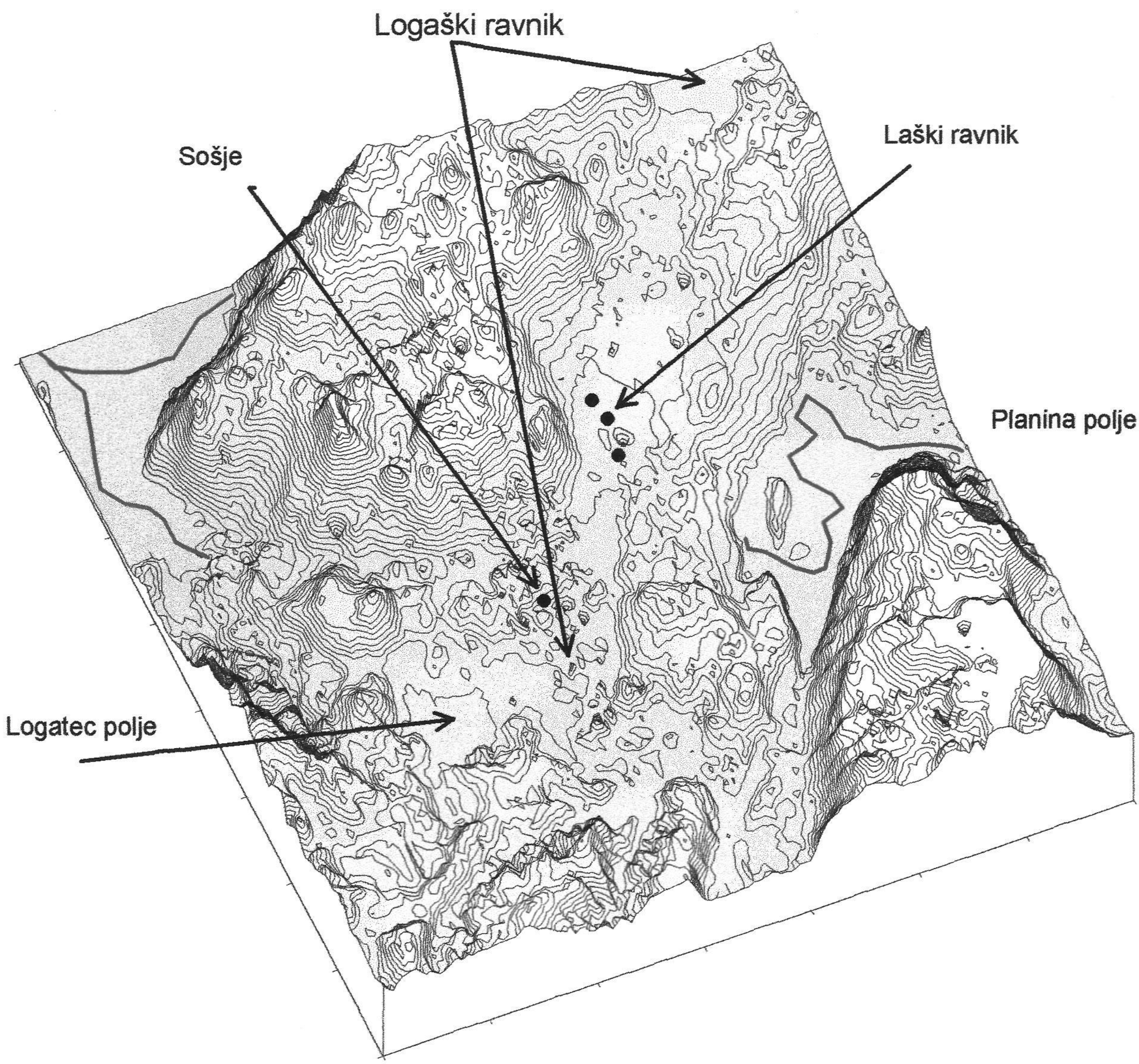


Fig. 2: DEM of Logaški ravnik.

Logaški ravnik is about 20 km long, 1 – 3 km wide surface, formed mostly on Jurassic and Cretaceous limestone and partly dolomites. Surface of the ravnik is on SE in elevation of about 620 m, and about 480 m on it's NW side, where it ends at polje of Logatec in elevation of about 470 m. The surface of the Ravnik is dissected by thousands of dolines and some very large collapse dolines (Šušteršič, 1996, 1994).

W of ravnik, there is the Planinsko polje at elevation of 450 m, and sinking waters from it has to flow under the Logaški ravnik towards the springs of Ljubljanica river at Vrhnika, but there is no known caves to reach that underground channels.

On both sides of ravnik there is a belt of higher karst relief. On W side about 100 m higher ridge separates it from Planina polje. On E there is about 200 m higher plateau. In upper part of ravnik Cerniščica river flows across it in a canyon valley to the Cerknica polje.

On the surface of the ravnik there are different fluvial deposits which probably originate in the catchment area of Cerkniščica. Because of that and its shape ravnik was explained as Pliocene, now dry valley of Cerkniščica river (Melik, 1955).

Unroofed caves in Laški ravnik

Laški ravnik is central part of the Logaški ravnik E of Planina polje. Surface in that part of ravnik is levelled in elevation of about 520 m a.s.l. Dolines are covering practically all the surface of the ravnik. They are small, average doline is about 50 m across and is 5-10 m deep. Among dolines there are some large and deep collapse dolines (Šušteršič, 1973)

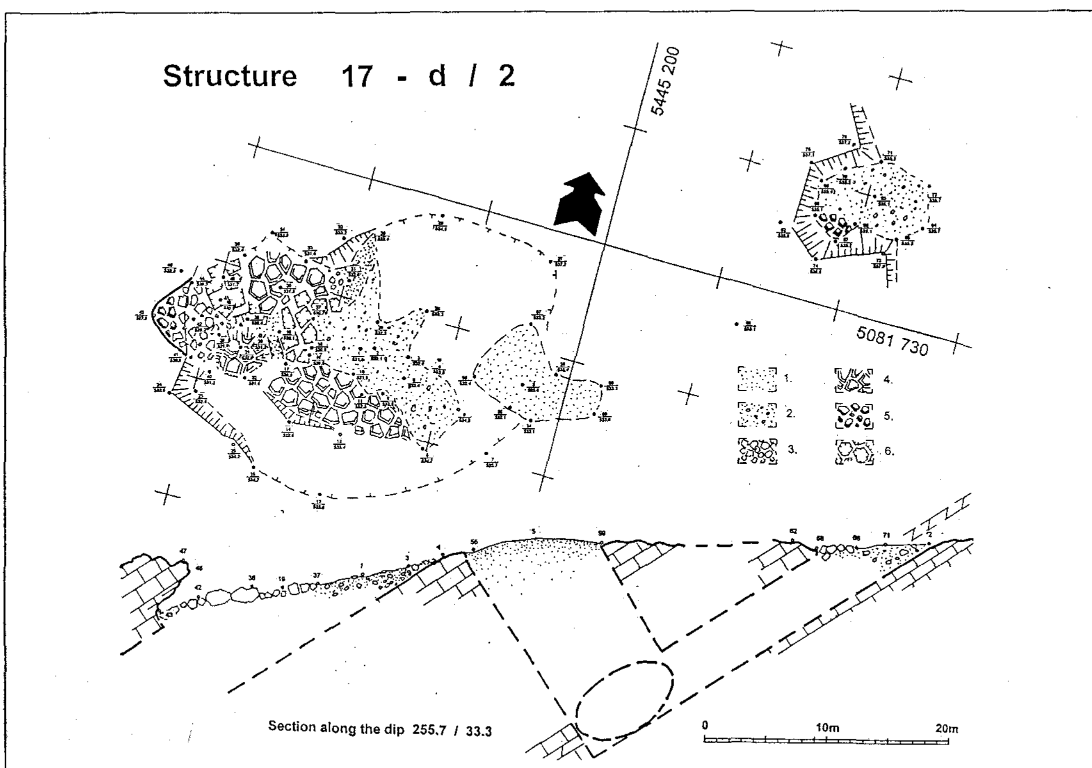


Fig. 3: Structure 17 - d / 2, Ravnik (Šušteršič, 1998).
Legend: 1. Loam (no bauxite pebbles observable at the surface); 2. Loam (bauxite pebbles visible at the surface); 3. Presented collapse material (slabs); 4. Slabs detached from the parent rock but presumed to lie close to their original position; 5. Detached slabs with large gaps between them; 6. Presumably larger blocks, derived by in-situ break-up of the cave ceiling, and supported by the cave fill until it was washed away.

In this area surface several unroofed caves were discovered and analysed. Šušteršič (1998) described the interaction between cave systems and the lowering of the karst surface in that area. He found different relief features formed by surface lowering and cave disintegration and three different types of cave sediments:

1. Fine-grained cave sediments that remain untouched as the cave walls disintegrate. The most widespread fill material is brownish loam with large oolitic bauxite pebbles and coarse clasts of black chert. It lies beneath any other preserved cave sediment, and is referred to as basal fill. If all of the parent rock around a filled cave were disintegrated, the insoluble sediment would remain on the subsequent land surface. Most such concentrations can be related to a nearby outcrop of a denuded cavern.

2. Coarse-grained cave conglomerates are much less common. The conglomerate deposits may lie on or beneath flowstone or are "floating" within the basal fill. This indicates, that this fluvial sediment was deposited and cemented in washed-out old systems in vadose conditions.

3. Flowstone in the denuded caves is younger than the basal fill, but contemporaneous with the conglomerates. Most of flowstone is in the form of wall-flowstone, but true stalagmites appear to be absent. Some flowstone occurs in fractures and other narrow openings, which may be completely filled with flowstone. This flowstone variety has been described as "aureole flowstone".

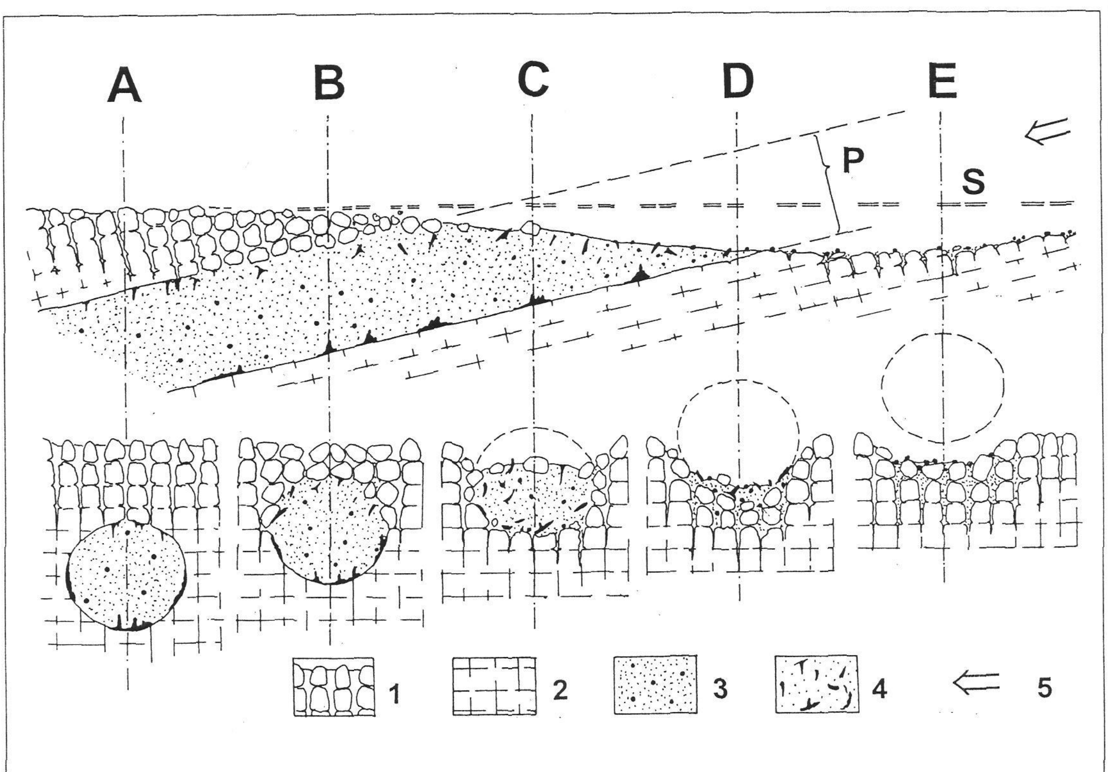


Fig. 4: Stages in the gradual decay of an inclined, sediment filled, phreatic channel (Šušteršič, 1998).

Legend: **A**. The original phreatic channel, not yet reached by the zone of influence of surface weathering.

B. The sediment filled channel is intersected by the surface weathering zone. Breakdown of the channel ceiling takes place and large isolated blocks of the parent rock are supported by the fill.

C. The passage ceiling and the upper parts of its walls are removed as surface downcutting continues. Washing-out of sediment is somewhat faster than the general surface lowering, and a small depression develops on the surface. Large, insoluble clasts gradually concentrate in the floor of the depression.

D. Most of the cave walls have been removed, together with most of the former infill. Fragments of decayed flowstone and insoluble pebbles were preserved along the line of the former cave floor.

E. Both the cave and its parent rock have been totally denuded. A slight secondary depression persists for some time within the new land surface. Insoluble pebbles in its bottom are the only evidence of the former presence of the cave. Remnant concentrations o loamy infill are preserved only locally, within isolated pockets.

P. Contour of denuded cave channel.

S. General level of the undisturbed surface in the neighbourhood.

1.Weatheredparent rock. Note that brown forest soil is not particularly evident between the clients. **2**. Intact parent rock. The joint pattern is conjectural. **3**. Basal fill, comprising loam with bauxite pebbles (marked as rounded black patches). **4**. Flowstone, supported by loam.

Logaško polje

Logaško polje is a border karst polje, developed on the contact of the Cretaceous and Jurassic limestone and older rocks, mostly Permian and carboniferous shales, conglomerates, sandstones and Triassic dolomites. Bottom of the polje is 470 - 480 m a.s.l. Major part of the bottom is built in karstified dolomites covered by younger quaternary deposits.

Logaščica is the only superficial inflow on the karst polje, but in past polje was a confluence of numerous rivers coming from N, W and SE and sinking in the polje. These rivers are now sinking before they reach the polje.

On the polje three different types of fluvial deposits can be recognised. Recent sinking river is transporting dolomite sand and gravel only. From the N in Pleistocene and Holocene the stream was flowing, bringing noncarbonate Permian gravel and sand. Small stream from NW was bringing non carbonate gravel from lower Triassic rocks. Besides this surface sediments we can find in the zone of the polje, specially on it's E edge and in denuded caves two other types of gravels. In one of them are black chert and oolitic bauxite. Similar association of pebbles can be find in the Logaški ravnik SE from polje. It was taught that this gravel was brought by surface river Cerkniščica in Pliocene. Gravel can be find on the surface and in unroofed caves.

The other sediment consists of quartz pebbles and sands. It can be found on few locations in unroofed caves about 50 m or higher above the recent polje level. It originates probably in noncarbonate rocks N of Logatec polje, but exact source of it is not found yet.

Unroofed cave on Sošje E of Logatec polje

On surface E of Logatec polje between hills Malo and Veliko Sošje in elevation between 500 and 525 m about 500 m long and few m wide strip of loam and noncarbonate pebbles can be found. On some places the strip is interrupted. In the sediments there are some sinks and subsidence.

Sediment is represent by yellowish-brown loam with quartz pebbles, largest have to 4 cm in diameter. On same places is seen how the sediment was moved to nearest dolines by solifluction processes.

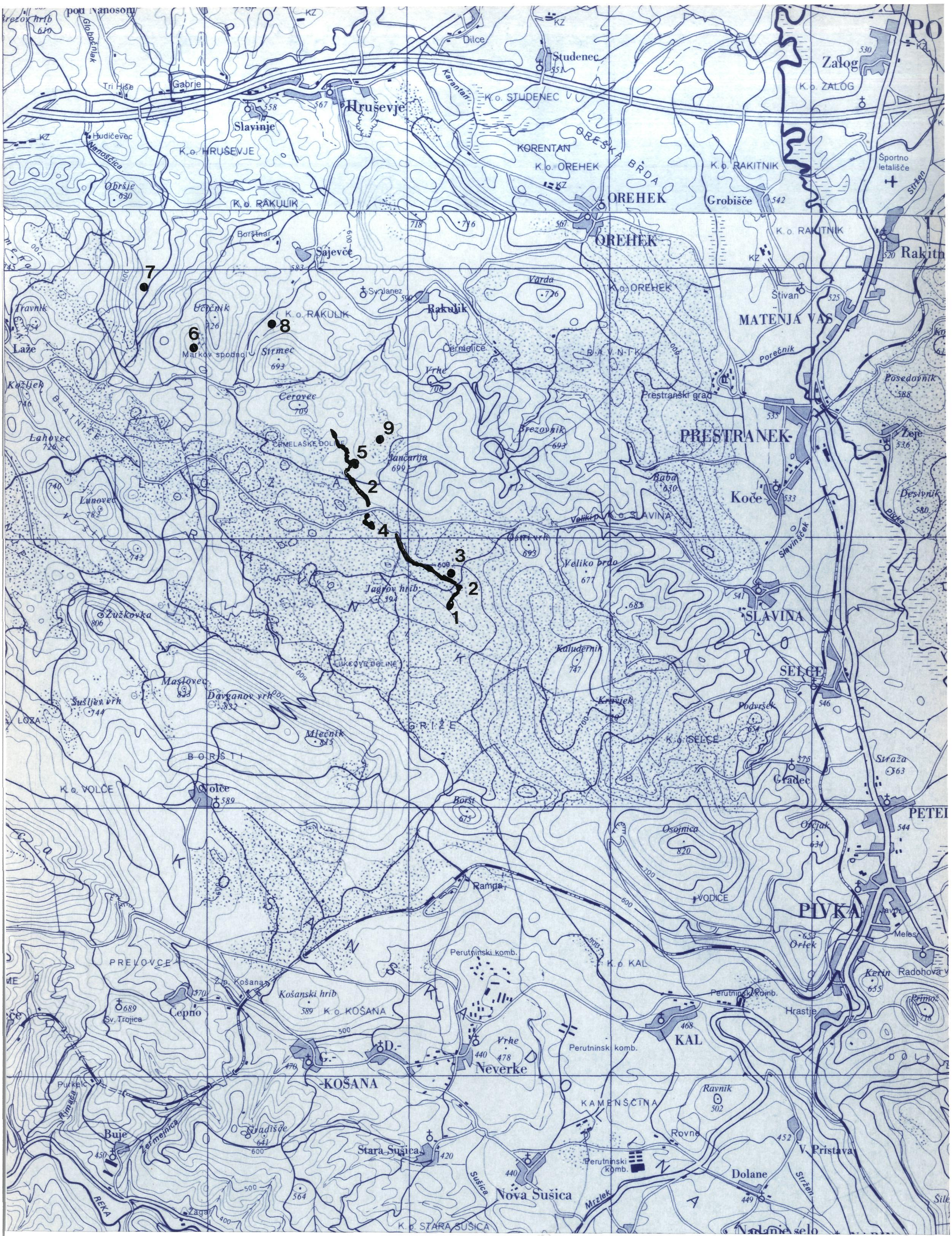
Origin of the pebbles is not clear, but they are probably from the noncarbonate rocks from N of Logaško polje.

Planinsko polje

It presents the most important water confluence in the river basin of Ljubljanica. Dolomite barrier along the Idrija fault zone, which crosses the polje, forces the karst waters to overflow from higher karstified limestone background to the surface and after crossing Planinsko polje toward NE where they can sink at elevation of about 450 m (Gospodarič & Habič, 1976).

The principal Unica swallow-holes are disposed at northern edge, where mostly medium and high waters are sinking. The minimum inflow to the polje amounts to 1,5 m^3/s; mean 24 m^3/s, maximal was estimated to 100-120 m^3/s, the total ponor capacity being about 60 m^3/s. At floods, lasting 1-2 months, the water increases up to 10 m and up to 40 millions of m^3 of water inundate the polje.

The fluvial sediments of the Unica river on the polje are some dolomitic pebbles from the edge of polje, while in the underground there are flood loam only. These sediment differ from the deposits we can find in denuded caves in Logaški ravnik surface.



Legend: 1. Cave Markendelov spodmol, 2. Unroofed cave, 3. Cave Šimčev spodmol, 4. Cave Spodmol ob Selški poti v Lozo, 5. Blind valley Biščevci, 6. Ivačevci blind valley, 7. Blind valley of Rakulščica.

Tuesday, June 29, 1999

Unroofed caves of Slavenski ravnik

Slavenski ravnik

Slavenski Ravnik is called a rather levelled karst surface located between the flysch part of the Pivka basin in the north, Vremščica in the west, Košana valley in the south and karst part of the Pivka basin in the east.

A larger part of this karst levelled surface lies at 550 and 650 m a.s.l. while some peaks at its border are much higher. In the south a series of ridges above the Košana valley reaches the altitude of more than 800 m, in the east and north sides they are about 700 m high. The surface of the peneplain is uneven, dissected by many dolines and larger uvalas. In the northern border three blind valleys developed at the contact with flysch.

There are 80 caves known in Ravnik. The deepest is 79 m deep, the average depth is 20 m. The longest is Vodna jama v Lozi, 75 m deep and 1235 m long cave. Shallow and short caves prevail, there is a lot of remnants of horizontal cave systems having the passages close to the surface.

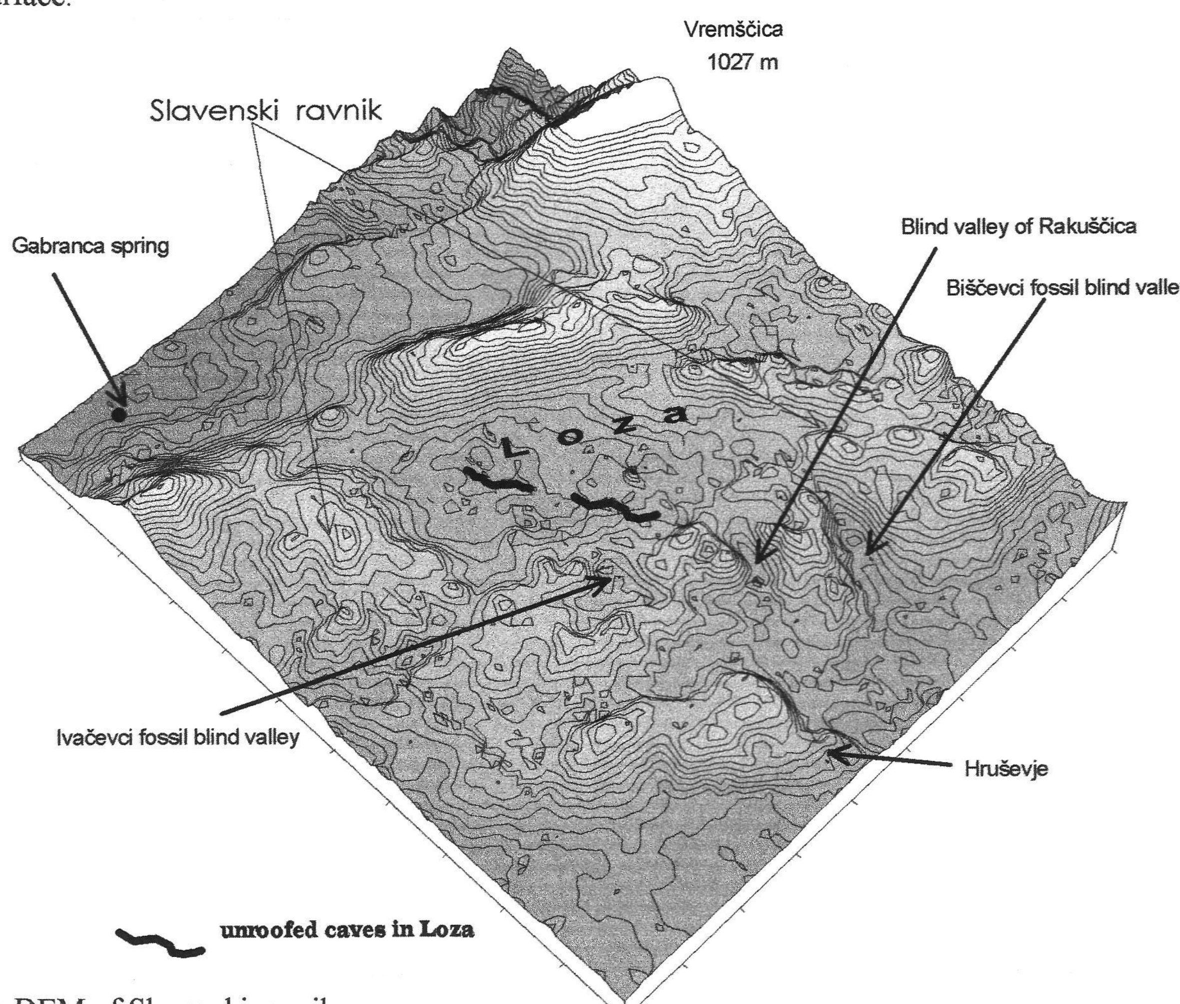


Fig. 6: DEM of Slavenski ravnik.

There are no superficial flows on Ravnik. At its border many streams sink flowing from the Pivka basin flysch (Mihevc, 1990). Water tracing tests showed that waters coming from north and sinking at the Ravnik border at low water level flow underground towards the

Timavo springs. At high water level they rise from the Gabranca shaft in the Košana valley about 3 km to the south of Ravnik; at high waters many m^3/s flow out the shaft, while at low water level the shaft is accessible to 196 m deep (218 m a.s.l.); this is the highest oscillation of the karst water level in Slovenia.

In Ravnik the underground water flow may be reached only in Markov spodmol swallow-hole, where the outflow siphon lies 550 m a.s.l. and in Vodna jama v Lozi in the middle of Slavenski ravnik. In this cave the underground river flows about 50 m below the surface at 490 m a.s.l.

Denuded caves

In Loza, the central part of Slavenski Ravnik there are many denuded caves; their study has just started. For the time being we located many such objects and sampled sediments in them. This excursion will visit two roofless caves which probably belonged to the same cave system. They are separated by 500 m of surface where the features cannot be traced for sure.

The north-eastern section of the roofless cave can be traced at the surface for about 800 m from the cave-shelters Markendelov spodmol to Šimčev spodmol. This roofless cave which is morphologically well-defined was explained by Hribar, Habe and Savnik (1955) as a dry sinking riverbed leading to swallow-holes, Šimčev or Markendelov spodmol.

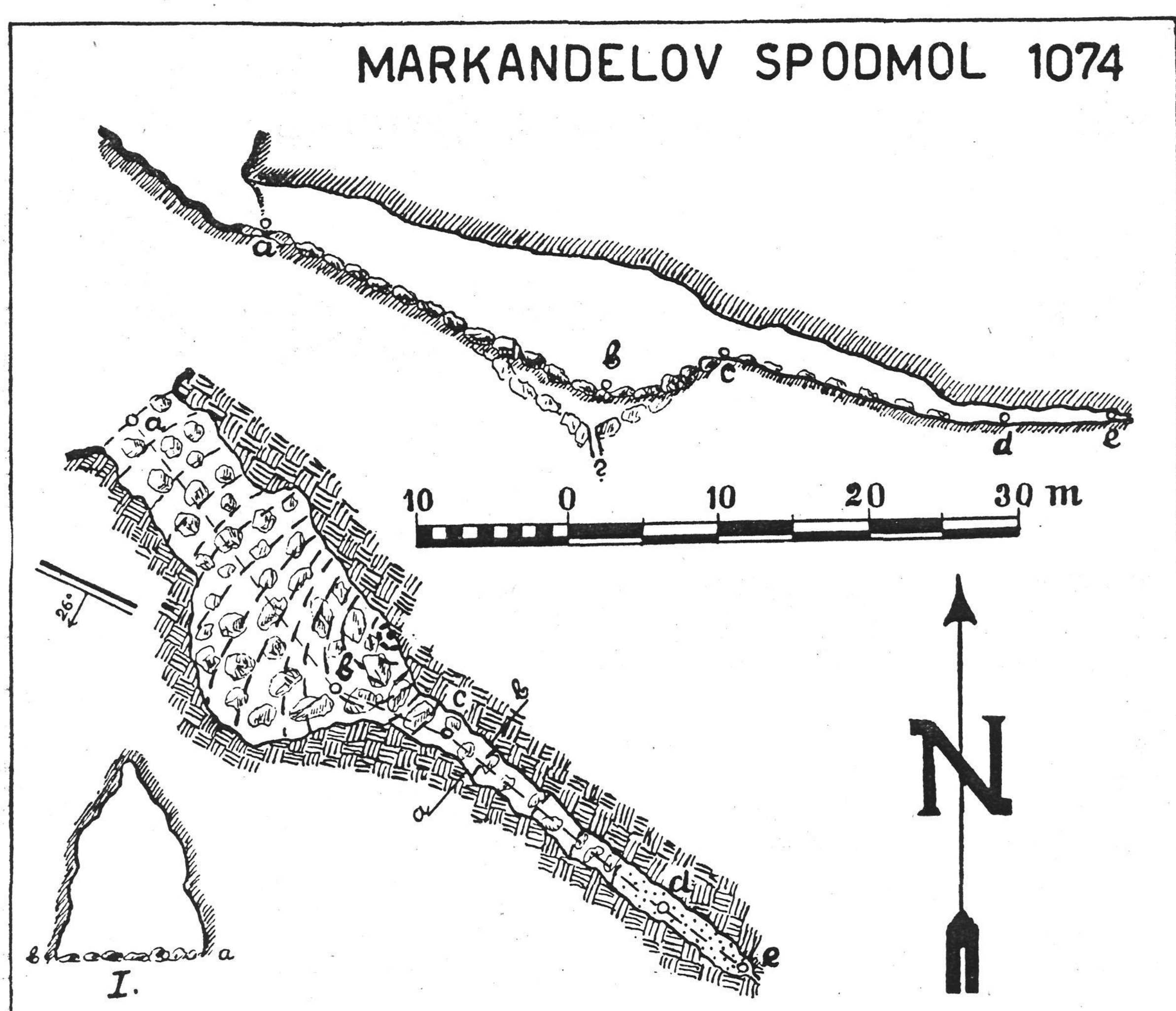
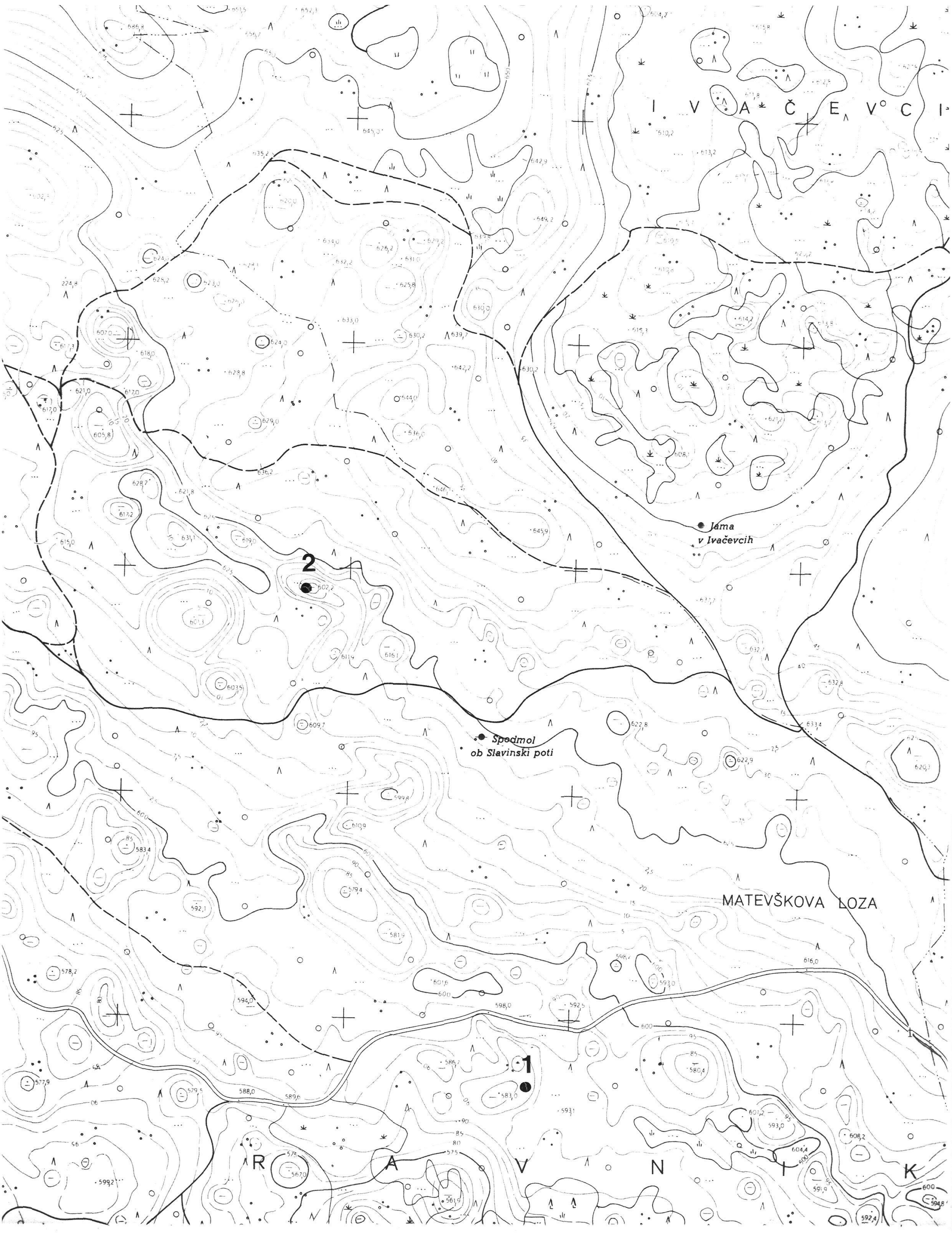


Fig. 7: Cave Markendelov spodmol.

Fig. 9: Segment of topographic map 1:5000. The unroofed cave is expressed by contour lines between point 1 (cave Spodmol ob Selški poti v Lozo) and 2 (subsidence with flowstone) and large doline on NW side of map.



In this part the roofless cave resembles an oblong series of dolines, having their bottom at about 570 m a.s.l. Later it may be traced north-westwards at the altitude of about 580 m as a ditch, 4 m deep and about 15 m long. The bottom of the ditch is covered by a layer of loamy sediment, in its extreme northern part there are also remnants of stalactites and massive flowstone as well as non-carbonate pebbles deriving probably from basal conglomerates of the Eocene flysch. Similar pebbles may be found in the Postojnska jama cave system and at many places in the Pivka basin.

At the right, north-eastern flank of the denuded cave lies the entrance into Šimčev spodmol. This cave-shelter reaches the opening into a shaft after 35 m of horizontal passage at the height of the denuded cave. The shaft is 32 m deep and it opens also to the surface. Probably the cave-shelter developed at the same time as the denuded cave, it is its segment respectively, while shaft is the remnant of the passage developed in phreatic circumstances.

In the ground plan above the horizontal part of the cave a small doline, about 3 m deep, is located between the entrance into the cave-shelter and the shaft; the cave does not exert any visible impact on its development.

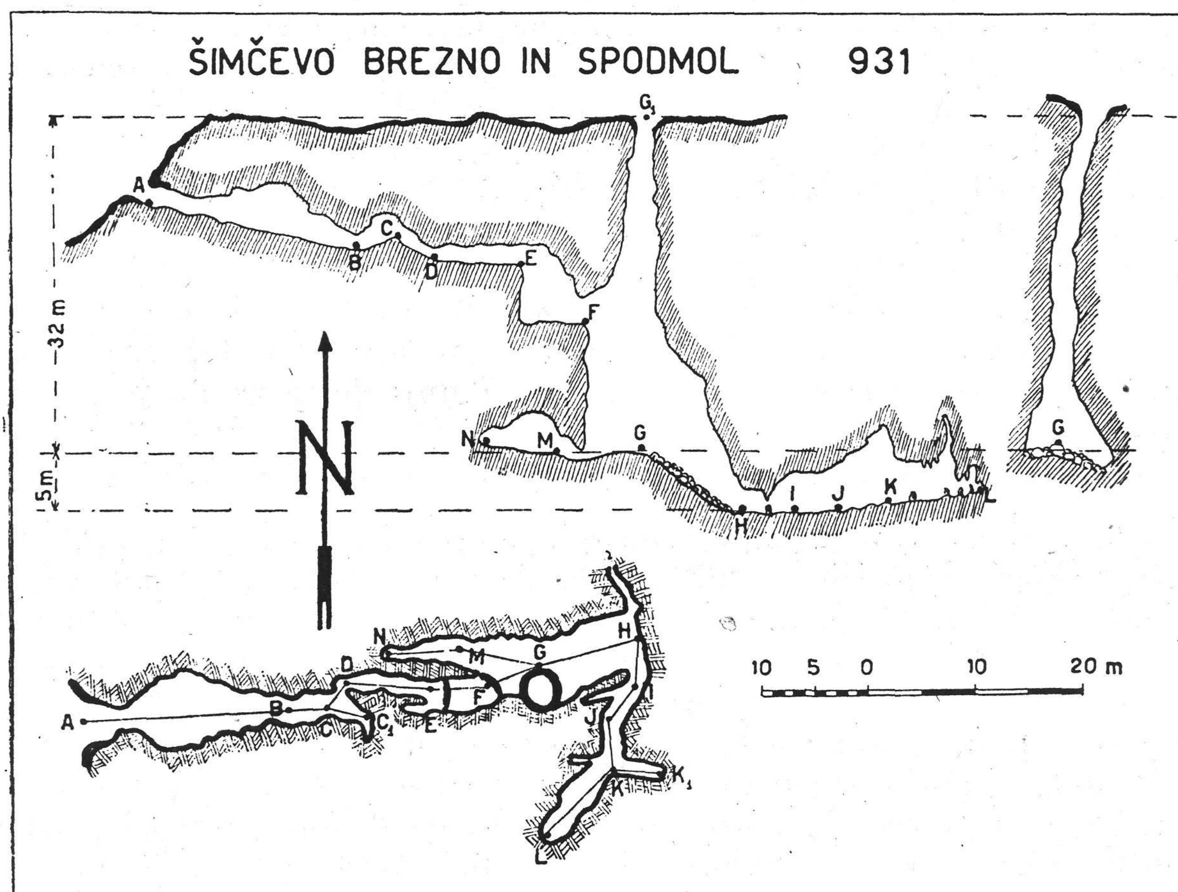


Fig. 8: Cave Šimčev spodmol in brezno.

The main part of the roofless cave in Loza is about 2200 m long; it may be traced as morphologically well-defined ditch with thick layers of loam at the bottom and remnants of cave breakdown and massive flowstone in one place. The bottom of the ditch is 10 m wide and from 3 to 7 m below the nearby rocky surface dissected by dolines. In the south-east the roofless cave rises from 583 m to 615 m a.s.l. In its southern part the entrance opens into Spodmol ob Selški poti v Lozo, 14 m long and 5 m deep. The sediment at the bottom in the central part of the roofless cave was washed into lower karst cavities, and a suffosion depression developed where breakdown rocks, flowstone and columns remained. The breakdown had been cemented with flowstone, showing its origin in the cave environment.

Both segments of the cave cannot be testified by flowstone and other cave sediments in their total length. Nevertheless it seems that these are parts of the same cave system which had drained the waters from 600 m at the NW and 550 m at SE towards south-east. It is difficult to assess the thickness of the roof that was removed yet it was at least 10 m thick. The recent active flows transporting gravel are now about 50 m lower.

Biščevci

The western part of the Pivka basin consists of flysch rocks; the flysch surface covers about 80 km^2. On this surface about 17 sinking streams flow and sink separately. Various relief features developed along them typical of contact karst.

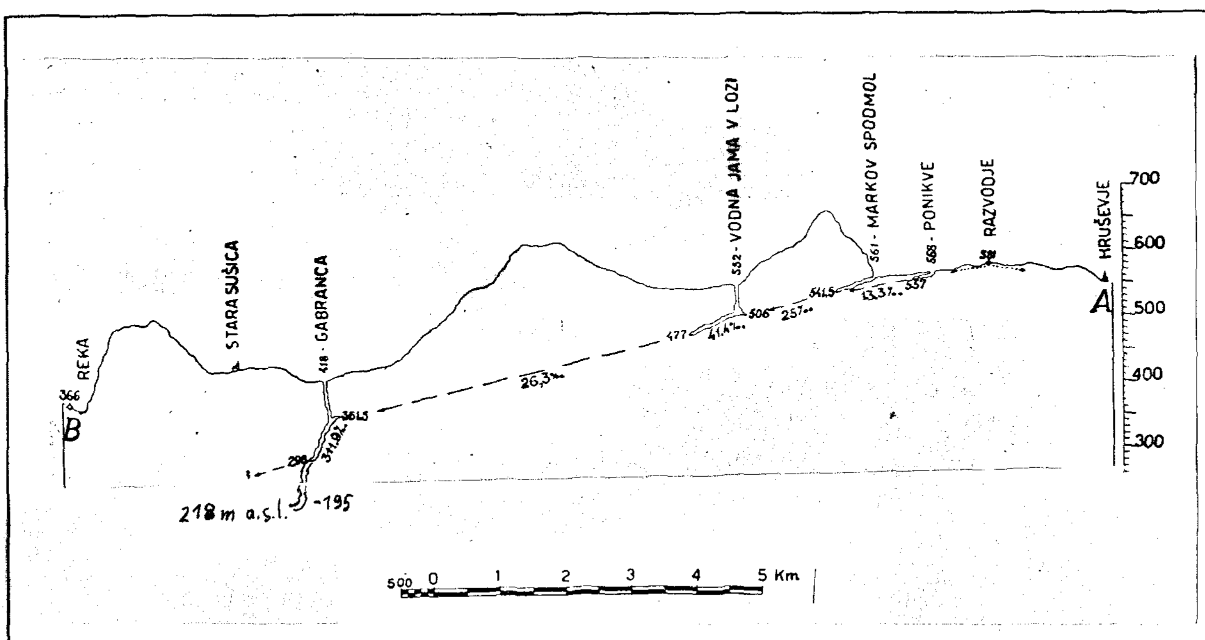
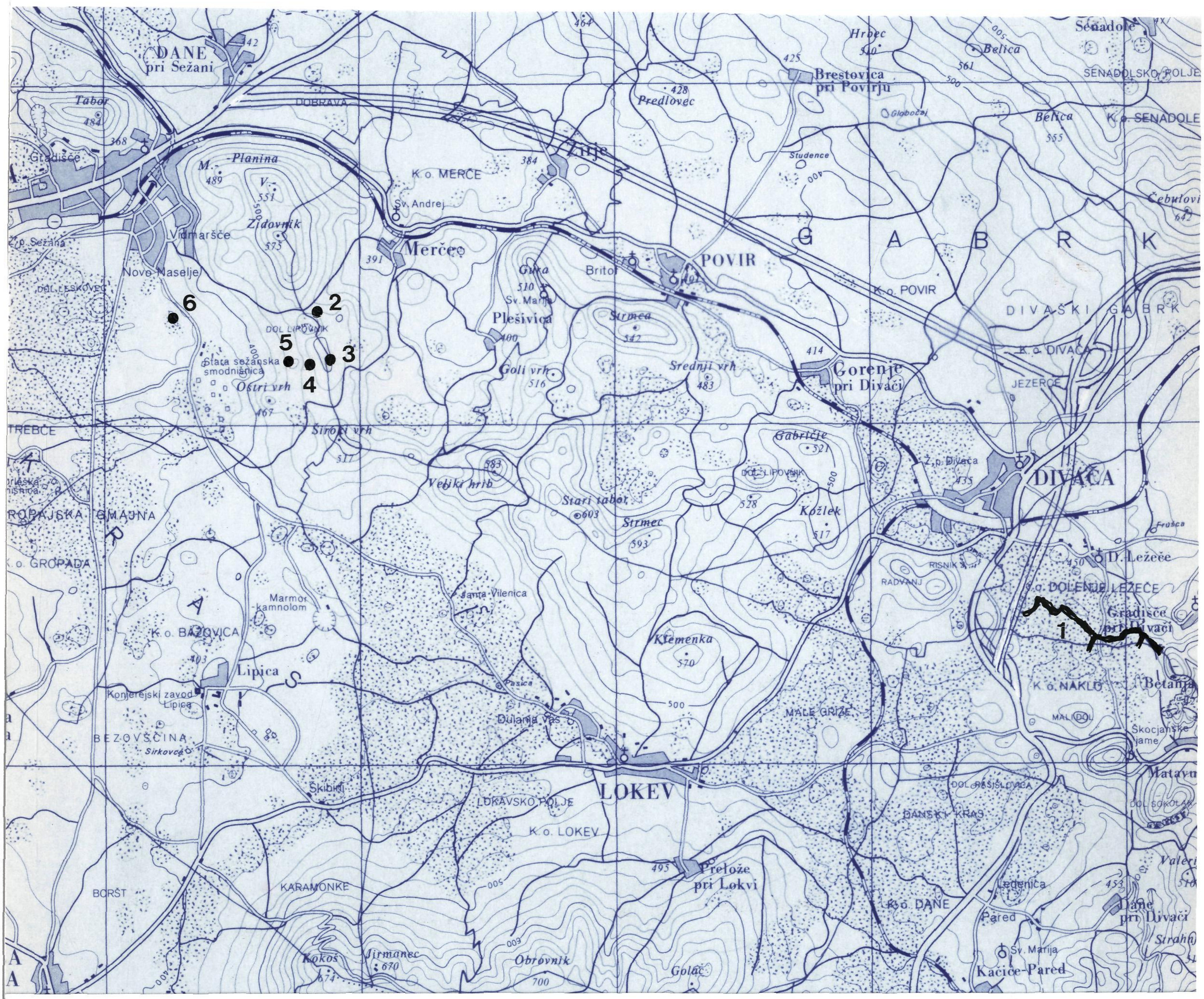


Fig. 10: Cross section of the Slavenski ravnik from Pivka basin on north (A) towards south (B). The main unroofed caves are in the surface where the entrance to Vodna jama v Lozi is located (Hribar et. al.1955).

At the southern border of the flysch basin three blind valleys had developed in the N edge of Slavenski ravnik. Only the Rakulščica blind valley is active now with the bottom at about 560 m (Habe & Hribar, 1965). Water tracing test showed that high waters from here flow into Gabranca, while low waters into the Timavo springs at the coast of the Trieste Bay (Habič, 1989).

The other two blind valleys are fossil. The Biščevci valley lies to the west of Rakulščica blind valley, the bottom being at about 550 m. The valley is 1,5 km long, narrowing southwards. The blind valley was probably formed by the upper flow of the Nanoščica which later drained towards the Pivka. Besides typical shape of blind valley there are also pebbles as an evidence of the former flow, probably originating from basal conglomerates of the Eocene flysch while pebbles of flysch sandstone weathered into quartz sand. During the rain a small stream takes its source there flowing by shallow winding riverbed, cut into limestone northwards out of the valley into the Nanoščica at 539 m a.s.l.

The second fossil valley related to size is Ivačevci blind valley which is no more reached by the waters from flysch as they sink immediately after reaching limestone. Its bottom is dissected into uneven doline-dotted surface at 630 m a.s.l. Flysch sediments are preserved in the dolines where sinkholes occur.



Legend: 1. Unroofed cave at Lipove doline, 2. Dol Lipovnik, 3. Perkova pečina cave, 4. Bestažovca cave, 5. Dol Bestažovca, 6. Kanjeduce.

Wednesday, June 30, 1995

Unroofed caves of Karst.

Divaški kras

Karst surface above Škocjanske jame Divaški Kras or sometimes named after the largest cave, Škocjanski kras, is a part of the Kras plateau between the sinks of Reka river and the village of Divača. It is built mostly by Cretaceous and Paleogene limestones. The surface is levelled in elevations between 420 and 450 m a.s.l, inclined slightly towards NW. The karst features of these part of the karst that occupies 32 km^2 are exceptional, there are sinks of Reka river and two smaller brooks, 15 large collapse dolines and hundreds of dolines.

The largest caves of the area are Škocjanske jame and Kačna jama. Škocjanske jame, 5800 m long and 250 m deep cave was formed by the Reka sinking river (8.9 m^3 mean discharge) sinking in elevation 317 m a.s.l. flowing trough passages to siphon at elevation of 214 m. In front of siphon lies the chamber Martelova dvorana with volume of 2,1 million m^3. Kačna jama is the longest cave system of Reka river in the continuation of Škocjanske Jame. The entrance lies west from Divača 435 m a.s.l. The total length amounts to 12500 m. The upper level of the cave is dry, periodically reached by Reka flood waters as it increases up to 90 m. In the lower level the actual underground flow of Reka is met at 185 m respectively.

Dolines, (if bigger they are called dol) are most common relief features, bigger ones are of the collapse origin. The largest collapse doline is Sekelak. It is 122 m deep and has volume of 8,5 mil. m^3. Globočak is smaller, it is 90 m deep and has a volume 4,8 mil. m^3.

If we compare the surface of karst features, we can see, that the levelled surface which occupies about 88% of the area prevails. This points out the prevailing surface levelling process in the present conditions. About 7% of the surface is covered by dolines, and 4% by collapse dolines. But if we compare their volumes, the ratio between dolines and collapse dolines is different, as even 5 times more rock was removed in the collapse dolines by collapse as a speleologic process.

In the Škocjan karst there are known 64 caves with the total passages length of 18,500 m. On the surface there are several unroofed caves, measuring together 2.900 m. These caves were formed deep under the surface, and then the surface approached to these caves owing to denudation. By the arch thinning over such a cave, there naturally occurred a collapse in the final phase, but we have to distinguish it from the collapse process when a cavity is opened to the surface and forming collapse dolines with large volumes.

Unroofed caves in the Divaški kras

On several places allogenic sediments, quartz sands and pebbles can be found on the karst surface. Their appearance was usually explained as remains fluvial deposits of surface rivers. These was the basis for the presumption of prekarstification period and several karst forms were described as a remains from that period (Radinja, 1969).

Geomorphologic mapping and attending ground works during the highway have shown that the cave elements are an important part of the surface morphology (Knez & Šebela, 1994; Mihevc, 1996; 1996; Slabe, 1996; Mihevc & Slabe & Šebela, 1998). Unroofed caves were recognised by the relief as oblong trenches or low oblong closed depressions – dolines. But more reliable morphogenetic indication were characteristic cave sediments, mainly massive flowstone, autochthonous gravel, collapsed blocks, and allochthonous fluvial sediments which were deposited in the cave by the underground rivers. By their help we could reliably ascertain that a certain relief form is in fact a unroofed cave.

By first such described cave, 230 m long Brezstropa jama at Povir we have called them "brezstropa jama" or roofless cave. Its "gallery" was 6 m wide and over 5 m high. Volume of the gallery was about 6900 m^3, and it was filled with allochtonous fluvial deposits, yellowish-brown loam, quartz sand and gravel. Therein characteristic cave forms on walls were identified, from scallops we could determine the flow direction and velocity. We observed the cave walls and the surface, and on this basis we defined the ratio between the plane lowering and collapse processes. We analysed sediments from it and dated the flowstone (Mihevc& Zupan 1996). On the studied surface we found several similar caves. In one of them we determined by the paleomagnetic investigation the minimum sediment age to 1.67- 1.87 Ma (Bosak P. & al. 1998).

Some roofless caves in the area were completely filled up with sediments. On the surface they were expressed only as areas where the surface was less stony. Owing to the thick soil on the cave sediments we noticed them on aerial photographs in the infrared technique.

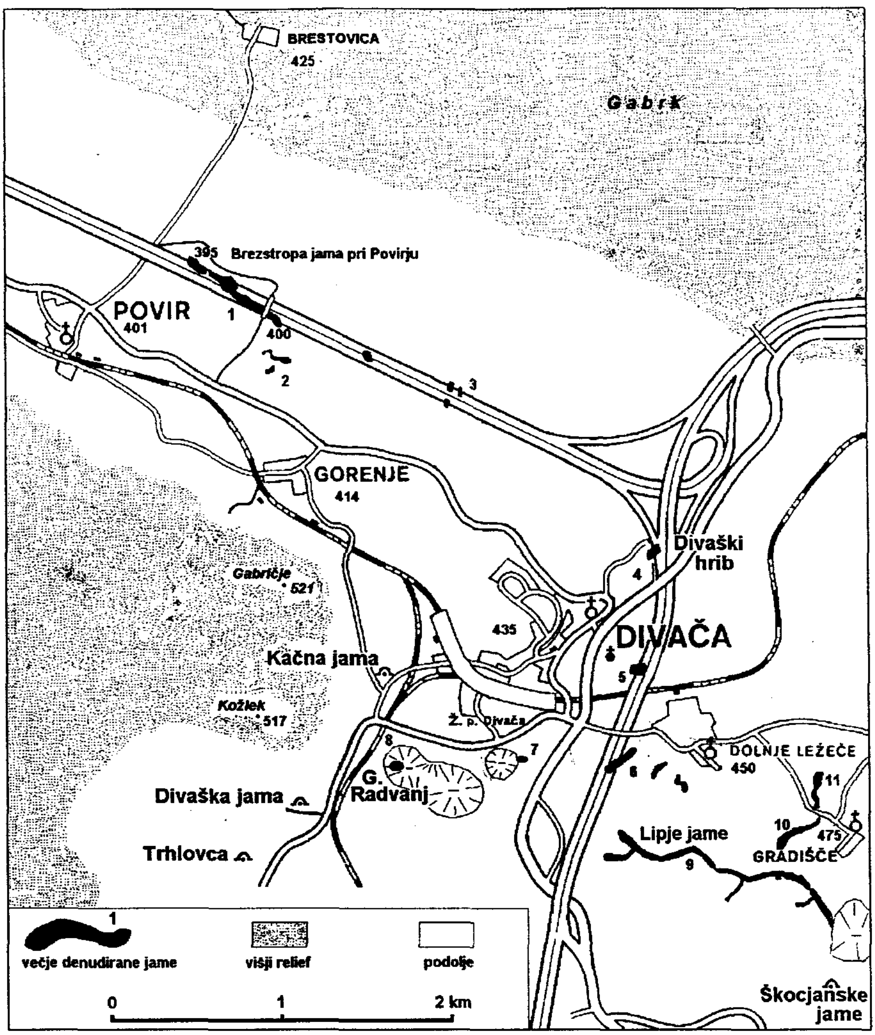


Fig. 12: Unroofed caves of Divača kras.
Legend: 1. larger denuded caves, 2. higher relief, 3. levelled surface.

Denuded cave at Lipove doline

During the surface quarrying of quartz sand for casting in Lipove doline a massive flowstone deposited over the sand and also flysch pebbles were unearthed, giving an evidence that the sediments were deposited in a denuded cave (Pleničar, 1954), but no special attention was devoted to it. Not until morphological mapping of surface was taken it was proved that

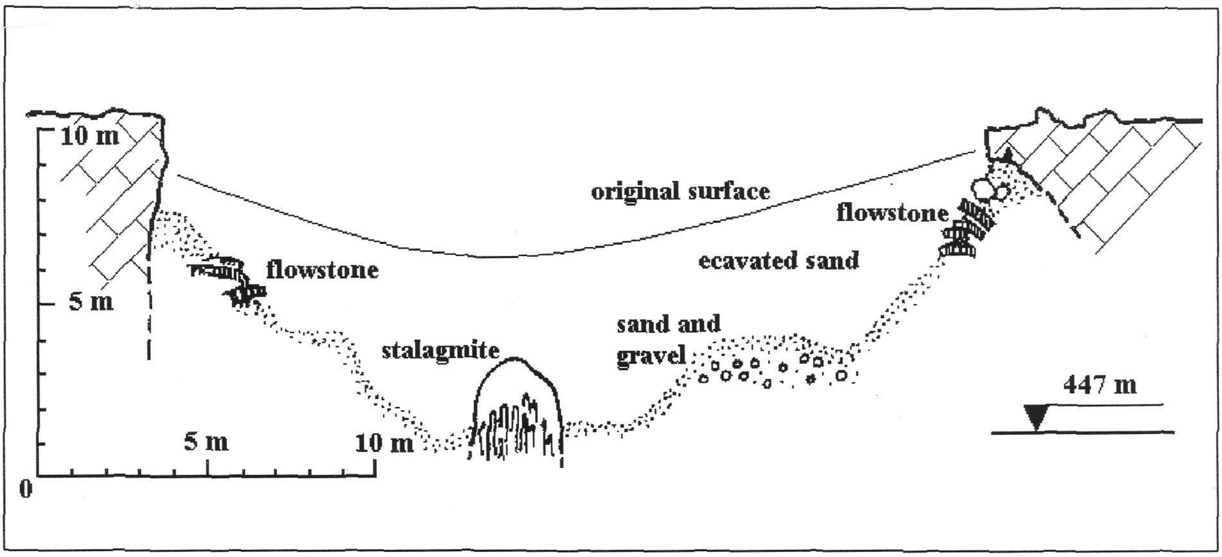


Fig. 13: Cross section over the unroofed cave at Lipove doline.

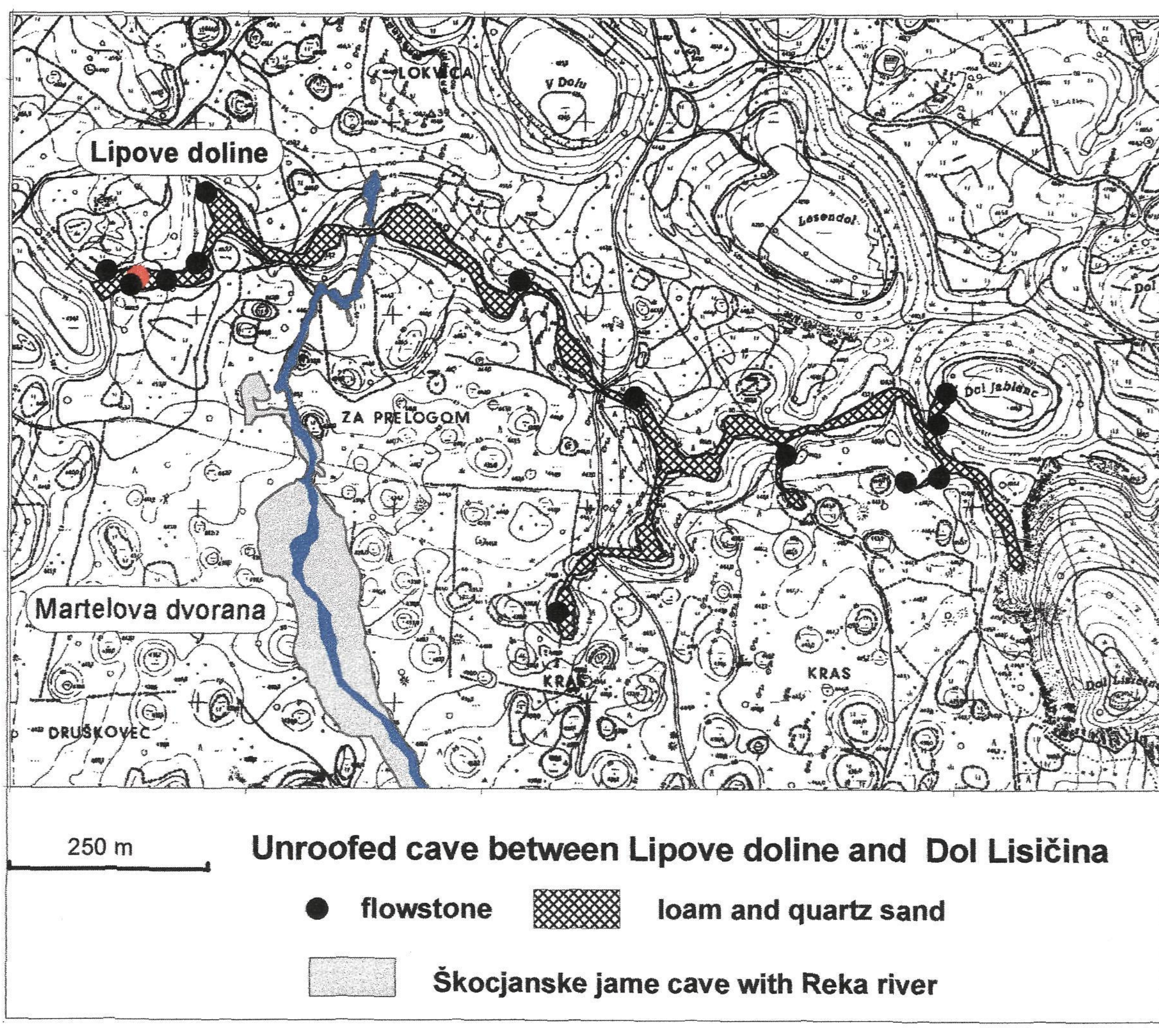


Fig. 14: Topographic map with positions of unroofed cave at Lipove doline and škocjanske jame. Legend: 1. flowstone, 2. cave fluvial sediments.

was a part of big denuded cave, which was on the surface expressed as 1800 m long series of elongated dolines in which we can find quartz sand and flowstone (Mihevc 1998). The surface of the unroofed cave is about 50.000 m^2 of the surface, that is important for the soil development and land use too.

Gallery of the cave was up to 20 m wide and more than 10 m high in elevation of about 430-440 m a.s.l., and is above the recent active channels of Reka river in Škocjanske jame, which are at 214 m a.s.l. respectively.

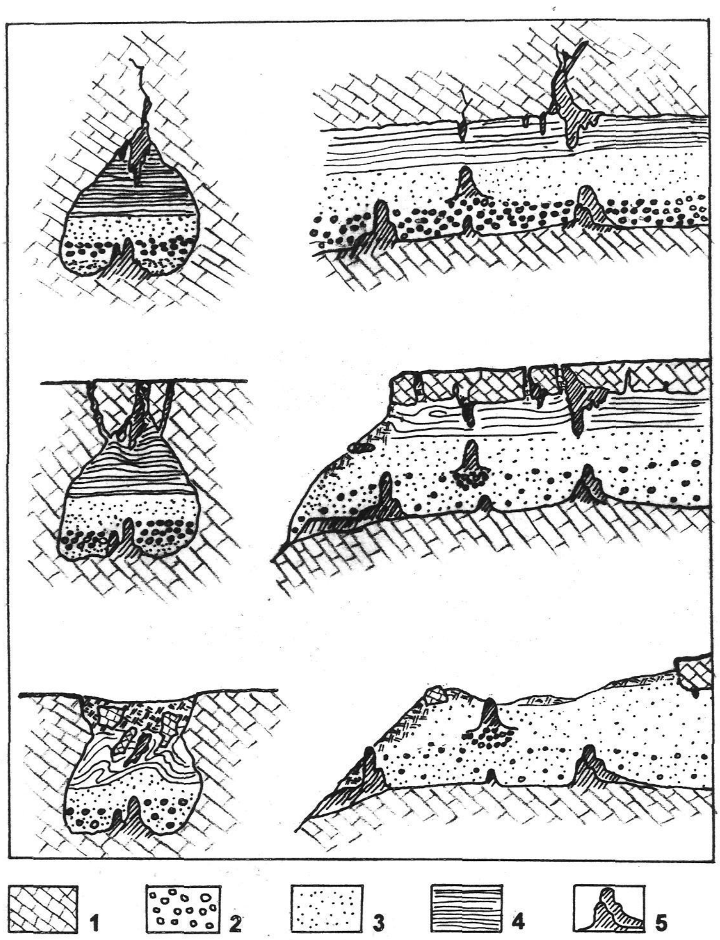


Fig. 15: Transformation of the cave, that was filled with sediments, into unroofed cave by the surface lowering (model is basing on the field observations from Divača karst).
Legend: 1. Parent rock, 2. Gravel, 3. Sand, 4. Laminated loam, 5. Flowstone.

The cave is developed NE from today's passages of Škocjanske jame. It was formed by sinking river probably the forerunner of present Reka. The age of the cave is not known yet.

The age of denuded cave can be determined just indirectly with the rate of lowering of the surface. According to Gams (1962) karst denudation on Divaški kras is about 60 m/Ma. If the thickness of the rock above the cave was 50-100 m, it could be corroded in 1-2 Ma. In such time period the level of underground rivers lowered from 450 m to 317-214 m, to the levell of actual Reka in Škocjanske jame under denuded cave.

Despite old and thick vadose zone where vertical percolation is most prevalent as also washing of sediments and soil down to the cave, a lot of old sediments is still preserved in the cave. In such sediments we can't notice suffosion features.

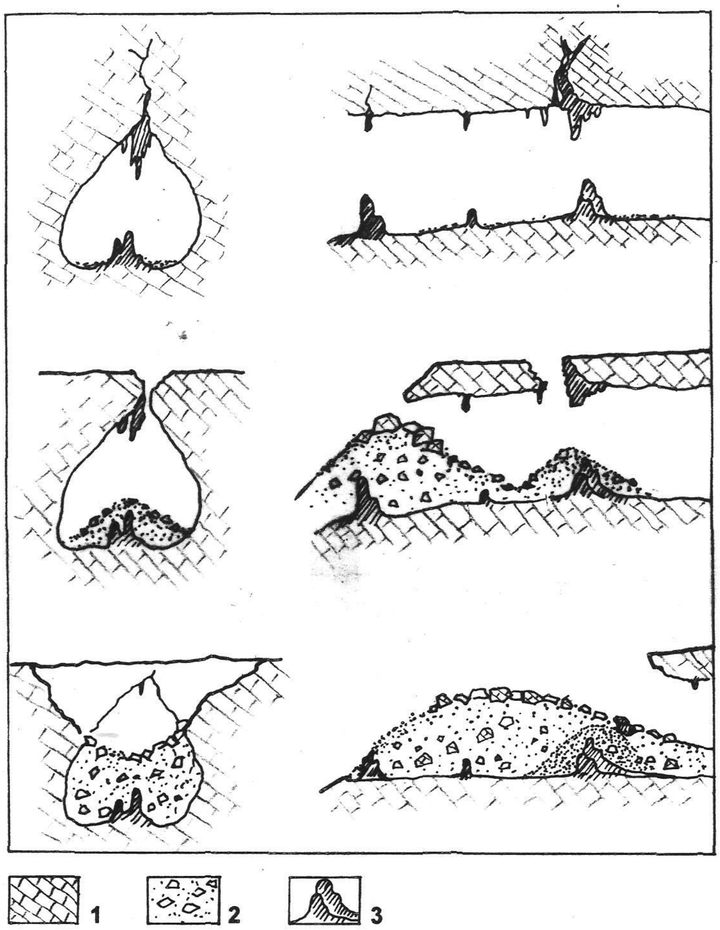


Fig. 16: Transformation of an "empty" cave into unroofed cave (model is basing on the field observations). Legend: 1. Parent rock, 2. Collapse rubble, 3.Flowstone.

Taborski Griči hills

Between Lipiški ravnik karst levelled surface at elevation 400 m and depression which is spreading from Divača (435 m) towards NW the higher relief of Taborski Griči hills occur. Between high conical peaks of V. Zidovnik (575 m), Stari tabor (603 m), Strmca (593 m) and Gabričje (521 m) there are more lower isolated hills with more shallow depressions between them in altitudes of 400-450 m. SW edge of hills is lowering from the elevation of 500 m to Lipiški ravnik levelled surface. The surface is covered with dolines which are less common on dolomite and steeper slopes.

North slopes of Taborski griči are built of Cretaceous dolomites, central, the highest and south part is built of Cretaceous bedded and massive rudistic limestone which dips towards SW. The same beds built also Lipiški ravnik in the south.

In Taborski griči there are many known caves, mostly shafts, but also old collapse dolines, horizontal caves and remains of caves opened to the surface by denudation.

Jama Bestažovca:

The cave is 280 m long and 43 m deep. It was formed at the highest level of Taborski griči hills at the Hrbec ridge near 200-300 m wide Lipovnik doline. The entrance to the cave is situated on gentle slope at the elevation of 483 m. 50 m W from the cave entrance there is the edge of big doline Dol Bestažovca and E, above the cave the collapse doline with Perkova pečina is developed.

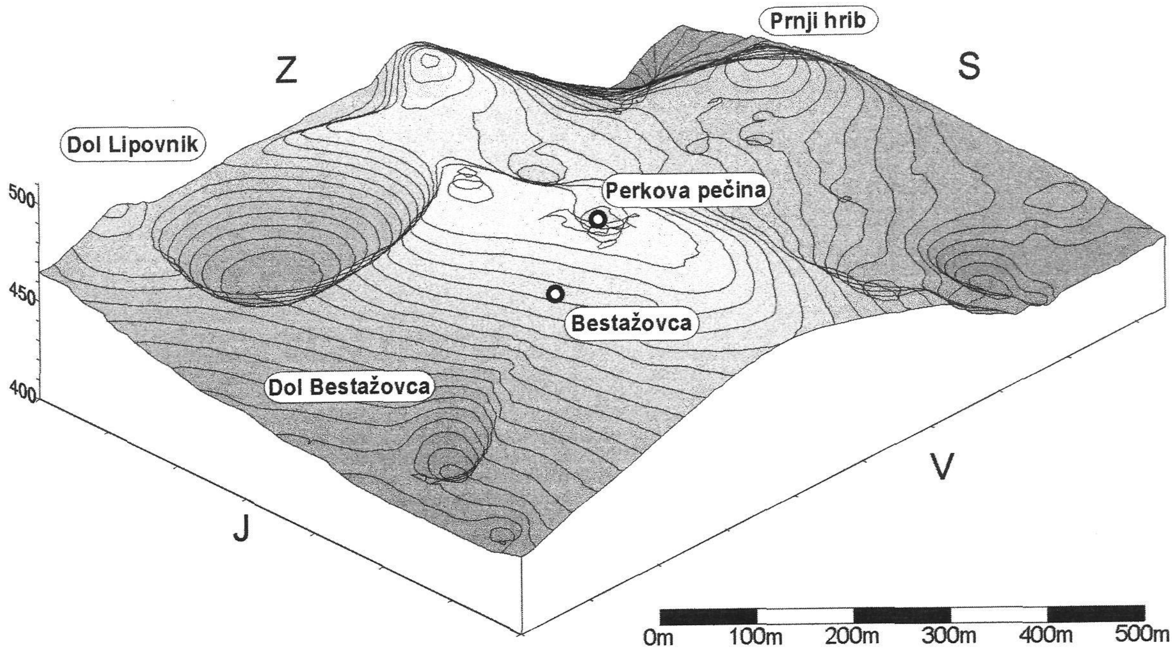


Fig. 17: Digital relief model of the surface in the surroundings of Bestažovca cave.

Dol Lipovnik

Big doline, Dol Lipovnik, is situated 200 m north from the entrance of Bestažovca cave on the top of the ridge. The upper edge of Dol Lipovnik is on altitudes of 465-500 m, bottom is at 443 m and the diameter of doline is 220-300 m. The bottom contains thick layer of soil what was the reason to be levelled and used as small field. Because of the dimensions of Dol Lipovnik we suppose that it was formed by collapse.

Bestažovca

The cave is made of two well expressed morphological units which are entrance chamber and inner principal passage. The cave is 280 m long and 43 m deep.

The entrance to the cave is developed in the crest of 20 m high chamber. It was formed along the fault inside which several meters thick flowstone was deposited. The principal part of the cave is more than 150 m long gallery. It runs from E to W as about 5-10 m high phreatic passage at the elevation of 445-460 m. The passage dips towards W where it ends filled with different sediments, flowstone, rubble and loam.

Towards the E the passage runs under the of Perkova pečina. Regarding the ground-plan that part of the cave ends 5 m southern and 9 m under it. Both caves were connected in the past and only lately the passage was filled with rocks mixed with loam, soil and neolithic ceramic, which slide from the shelter of Perkova pečina.

Perkova pečina

Perkova pečina is situated on southern part of the doline which is 70 m wide and about 25 m deep. The doline lies on the top of the ridge and 120 m east from the entrance to Bestažovca cave. Northern slope of the doline is low angle, southern slope has vertical walls under which there's 30 m long cave is was formed. The bottom of the cave is covered by rubble. The lowest point of the it is at the elevation of 476 m, that's just 9 m above the eastern edge of Bestažovca.

Dol Bestažovca

Dol Bestažovca has oval shape with longer axis 150 m and shorter axis 110 m. The upper edge of the doline is at the elevation of 470 m, the lower edge is in 439 m a.s.l. Lipiški ravnik levelled surface starts 300 m W from Dol Bestažovca at the elevation of about 370 m.

The bottom of the big doline is at 426 m a.s.l. Slopes are steep and rocky just E part of the slope is covered by yellowish-brown loam. In the W part of the doline blocks of massive crystalline or bedded flowstone appear on the surface.

According to zone of sediment and flowstone we assume that the sediment was filling bigger about 10 m wide cave, which was at the elevation of 430-450 m with general direction E-W. It's obvious that unroofed cave is the continuation of principal passage of Bestažovca cave.

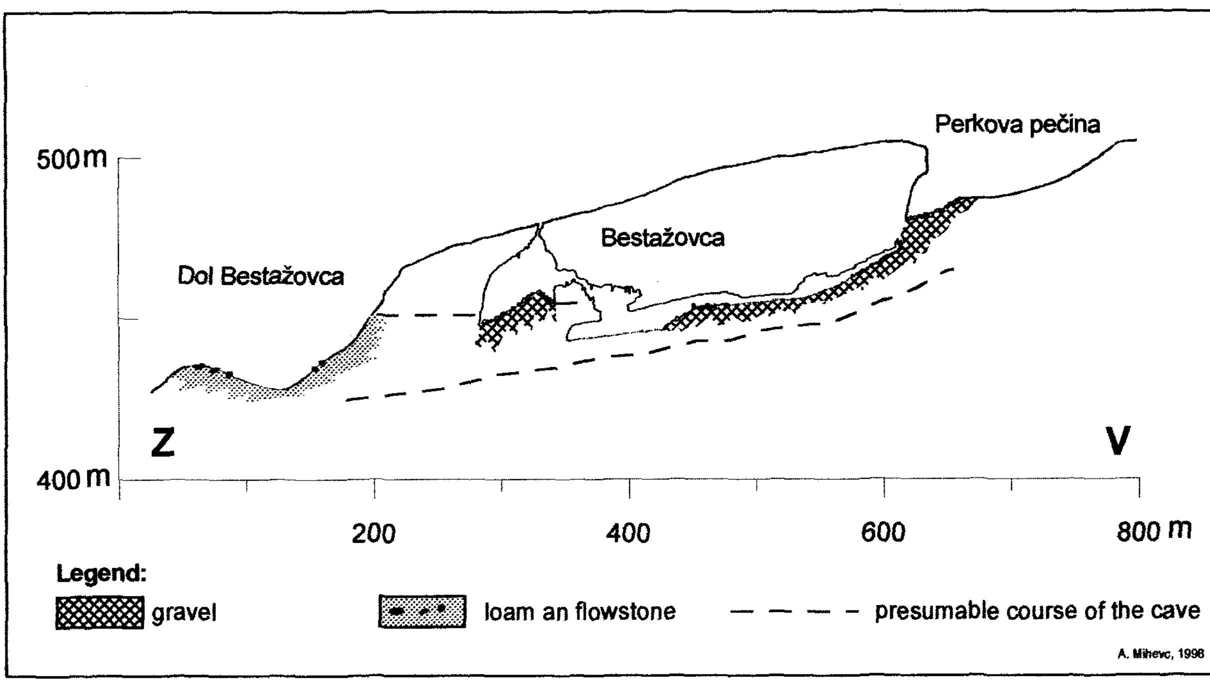


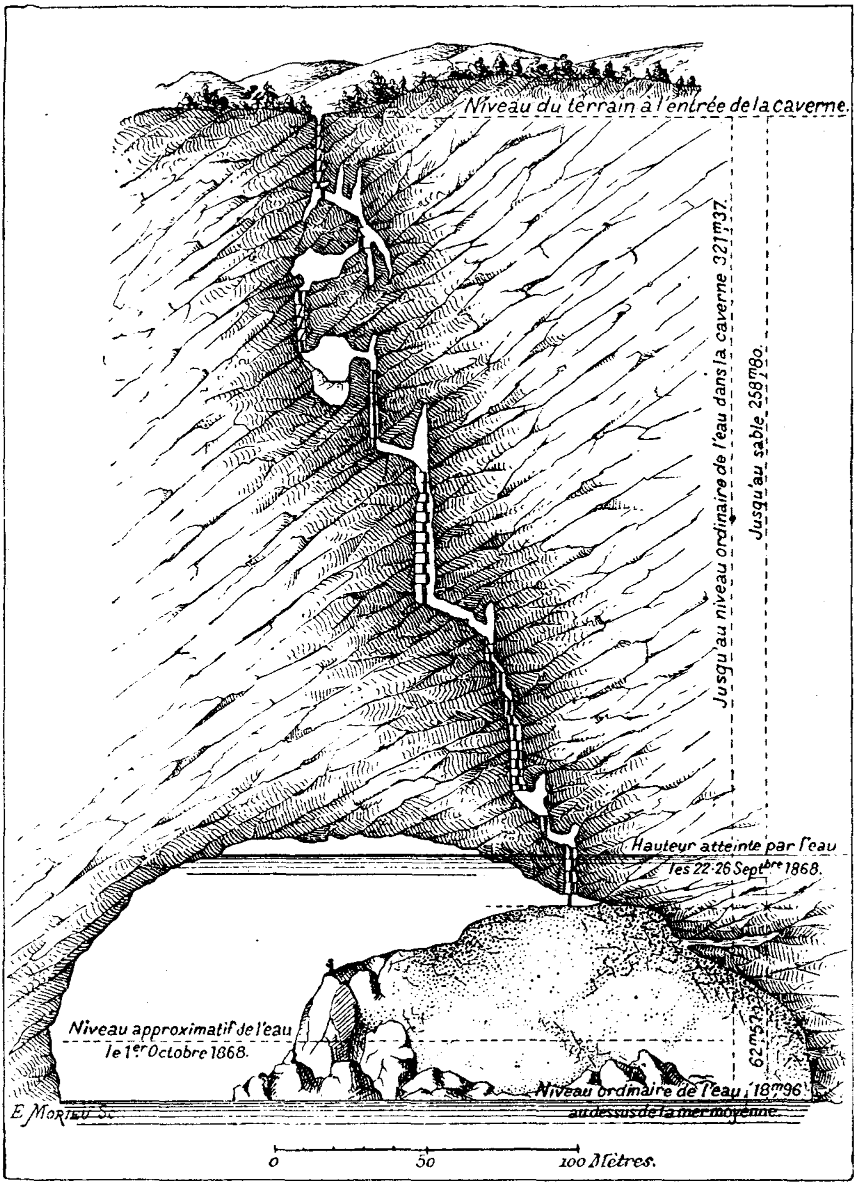
Fig. 18: The position of Dol and cave Bestažovca and Perkova pečina. The cross section is in E-W direction.

Lipiški ravnik

Lipica ravnik or Lipica karst levelled surface is in elevation of about 400 m. Levelled surface is dissected by hundreds of dolines, 65 per a km² in average, larger collapsed dolines and entrances to caves. Most of the known caves are shallow shafts, but there are also some larger caves. There are two deep caves, where we can reach the recent underground water, 346 m deep Grotta Claudio Skilan is cave and Labodnica or Abisso di Trebiciano cave. The latest is situated about 4 km NW from Lipica. Cave consists of a series of parallel shafts which hit a large room formed by the underground Timavo river.

Entrance to the cave is in altitude of 341 m a.s.l, bottom at 12 m only. Cave was explored in 1841 to the depth of 329 m and was for a long time the deepest cave of the world.

Main morphotypes of the cave are vertical shafts and a large room, the Lindner Cavern, very extensive, at the bottom of which the Reka river flows. The genesis of the Lindner Cavern may be attributed to the action of the Reka river, while other parts were probably formed by percolating water.



COUPE VERTICALE DU GOUFFRE DE TREBIČ.

Fig. 19: The plan of Labodnica or Grotta di Trebiciano cave (Les Abimes, E. A. Martel, 1894).

Cave was discovered by the strong air currents coming from fissures after heavy rains, when Reka was flooding their galleries. The same evidence of flooding we can observe in Lipica ravnik on several other places, the most known are the "breathing holes" of Kanjeduce.

"Breathing" caves at Kanjeduce

Kanjeduce are about 4 km away from Labodnica cave. Here are 3 bigger blowing holes from which the blowing starts just some hours after the water raises in Škocjanske jame. The air flow through them lasts several hours until Reka is flooding. After that there's a silent interval, then holes start to suck the air.

At high waters in October 1997, when the Reka in Martel's chamber of Škocjanske jame rose for less than 18 m and in Labodnica more than 30 m, blowing holes in Kanjeduce were

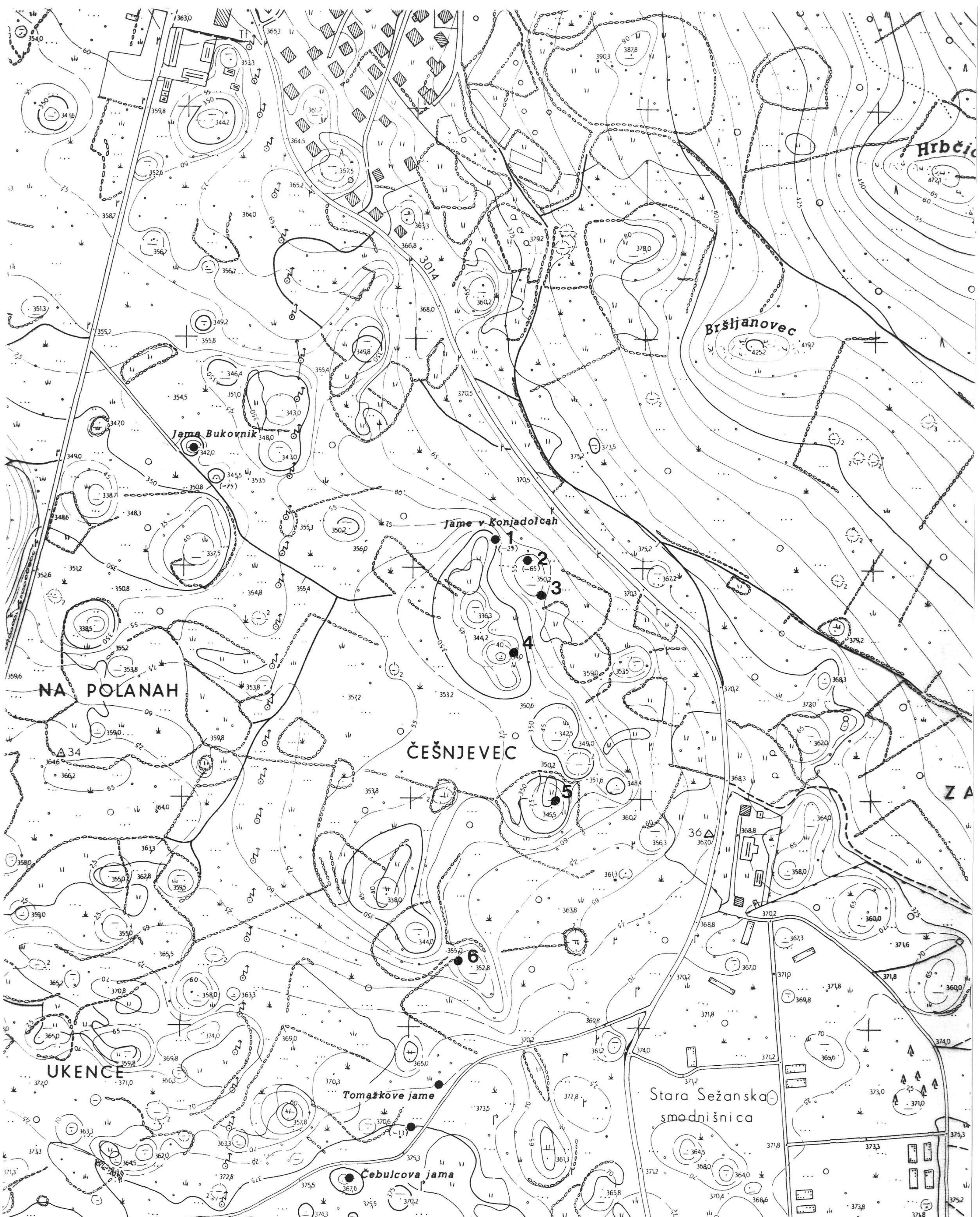


Fig.20: A segment of a topographic map in scale 1:5000 with cave entrances (1- Jama II v Kanjeducah, 2- Jama I v Kanjeducah, 3- Brezno v Kanjeducah, 4 -Razpoka v Kanjeducah, 5- Pečina v Kanjeducah, 6- Opatova pečina). Lover relief, possibly formed by denudation of caverns can be seen.

working for about 10 hours, from the cave Jama 1 v Kanjeducah it was blowing with the velocity of 2 m/s. The flood pressed out from the underground about 200.000 m^3 of the air.

In the cave Jama 1 v Kanjeducah, following the strong draught and hoping to reach the underground river, cavers started to dig in the cave before the 1st World War. The work is still going on, now they are already 60 m deep. The cave consits of short shafts, narrows and smaller chambers and runs mostly vertically down. It is simirar to the upper parts of the Grotta di Trebiciano cave.

Unroofed cave(s) in Kanjeduce

The Kanjeduce is a toponim for a group of dolines near the route Sežana-Lipica. The dolines are in 2 principal lines in NW-SE directions, parallel with the transition of the slope of Taborski hribi into Lipiški ravnik.

The bottoms of dolines are in elevations of 330-340 m, surrounding surface is at about 360 m. Transitions between dolines are rocky and some meters lower than surrounding surface. In dry wall and on slopes, and especially near shafts there's a lot of flowstone. Some flowstones are still in primary position. Some dolines are shallow and have been levelled and transformed into small fields at the bottom, other dolines are very steep, deep and rocky.

In the row of dolines on the length of 700 m there are 6 caves. 3 of them are breathing holes, which show the connection with underground river Reka channels, which are here probably at the elevation of 20 m a.s.l.

Flowstone on the surface, several caves, some of them can be 300 m deep and deep rocky dolines are showing the possibility that Kanjeduce dolines were formed with denudation of strongly karstified zone. During that process horizontal parts of caves were changed into long, shallow depressions, while shafts were transformed to deeper and rocky dolines.

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ABSTRACTS OF THE PAPERS

THE FORMATION OF DOLINES AND POLJES IN THE TAURUS MOUNTAINS

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The limestones of Mesozoic and Tertiary are very rich in terms of the karstic forms such as doline, poljes, lapies, ground river valley, caves and travertine deposits in the western part of Taurus Mountains in Turkey. The formation of poljes and dolines show different situations. Dolines which are very spread in the Taurus mountains occur on the both horizontal limestone strata of Tertiary and Mesozoic comprehensive limestones. But the shapes of the dolines are determined by the inclination of the layer and purity of the limestones. For example the dolines which have been formed on the horizontal strata are fring-pan shape. But dolines occurring on the comprehensive Mesozoic limestones are in "V" shapes. These dolines have formed as the result of dissolution processes.

As to poljes, most of the poljes are widespread along the tectonic-karstic zones of the Taurus mountains. In other words, vertical faulting movements and karstification have introduced the formation of the poljes. The formation of the poljes have begun to develop towards the end of Mesozoic. Some of them were occupied by Neogene lakes in which lime and clayey materials were accumulated. For this reason some of which contain lignite deposits. The fresh water lakes such as Lake Beyşehir and Eğirdir are found in the tectonic-karstic depressions in the western parts of the Taurus Mountains.

Generally speaking, dolines mostly appear on the pre-Neogene and Neogene horizontal and slightly inclined terrains. Extensive occupying areas is the Taşeli (Rocky region) middle part of the Taurus mountains which is composed of Tertiary clayey and sandy limestones. The shape of the dolines are determined by the inclination of the layers. Mesozoic and Palaeozoic crystallised limestones have produced deep and sinkholes due to karstification has taken place long time. While vertical tectonic activity had contributed an important role in the formation of big poljes so that they extend along the tectonic-fractured zones in the Taurus mountains. The karstification processes is longer than that of the dolines formation. Poljes are also main agricultural lands of the karstic terrains and contain sink holes. When sink holes are obstructed the poljes sometimes are occupied by lakes.

KARST VALLEY OF BREAKOUT OF THE IRKUT RIVER

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The study of karst at active tectonic stresses with large amplitudes of displacement is a complicated task. Karst processes in these conditions often manifest themselves in a many-storeyed way and cause sinkholes and bifurcation of stream channels.

The investigated karst valley of breakout of the Irkut river is located in the south-western part of the Baikal rift zone within an intermountain link between the Khoitogolsky and Mondinsky basins. It is related to the Tunka regional fault zone, which separates the Tunka Alps from the Khamar-Daban mountain system. The fault is traced along the marbles of the Irkut suite of Proterozoic. This zone is characterized by intensive fracturing, a specific feature of which is a complex kinematics combining extension and compression of single, rather small blocks. All these factors predetermined specific features of karst process and emergence of the breakout valley.

Morphologically the Irkut river valley looks like a small, 50-70 m deep gorge. On the right side it joins a terrace-like scarp in the form of a concave relict of an ancient valley, which is separated from the recent gorge by a hill composed of crystalline limestones. Well-rounded cobbles and pebbles are found in the relict valley.

The morphology and type of sediments in the relict valley of the Irkut river produce the following idea of mechanism of formation of the breakout valley. At the end of the last glaciation, the Irkut river valley might have primarily been traced along the above-mentioned relict. Nevertheless, an intensively fractured fault zone, extending from the Khoitogolsky basin, was opened by the river within the Khamar-Daban intermountain link. It may have resulted in bifurcation of the Irkut river channel. An underground flow along a through karst cave, spatially related to zone of the most intensive crushing, originated at the same time with the surface channel. It is evidenced by a number of factors. First, the recent valley of the Irkut river does not have any morphological relationship with that ancient on the surface and is laid in its left board to the slope upwards. Second, this valley is undeniably related to roof collapse, as on its left board there are some relicts of a karst cave. A hypsometric position of an underground flow has once become lower than that of the flow in paleochannel.

The collapse of the roof of the cave and formation of the karst valley of breakout were quick and rather recent. It is indicated by short, suspended streams, turning from the paleochannel to the present-day channel of the Irkut river. It should be noted that these flows are very fresh, as they are hardly effected by denudation, and are ended by washout basins, which testifies to a high rate of water thrown off the paleochannel.

Thus, in terms of geology, the formation of breakout valley and some reconstruction of the Irkut river valley occurred at that part rather quickly. The latest investigations of this territory show that an underground stream of Irkut is still captured along the fault trace.

KARST AND CAVES IN SALT DIAPIRS, SE ZAGROS MTS., IRAN

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About 200 salt diapirs (plugs) have been known in the region of the Persian Gulf. They penetrate through up to 12 km thick pile of Phanerozoic sediments of the Folded Belt of the Zagros Mts. Numerous salt diapirs are still active, forming morphologically dominant peaks. The annual uplift of plugs was estimated to 1-200 mm, from which about 110-170 mm can be dissolved by rainfall (about 280 mm per year). Most of plugs are located on faults or plunges of folds. Plugs are composed of evaporites, carbonate rocks, siliciclastics and volcanic rocks of the Hormoz Complex (Upper Proterozoic to Middle Cambrian). Buyoant activity of salt transports large blocks of „exotic" non-evaporitic rocks.

Salt plugs can be divided to small (up to 6 km in diameter) and large (max. 17 km in diameter). According to shape they are circular, linear (veins) and combined. According to activity, plugs are active, passive and ruined.

Karst rocks are represented by a rock salt of the Hormoz Complex, less frequently by gypsum and anhydrite of the Hormoz Complex, by cap rock and by brownish gypcrete. Brownish gypcrete represents a product of salt dissolution, it is more or less indurated and reaches up to 10 m in the thickness.

Karst forms are developed especially in passive salt plus in which activity ceased some time ago. In active plugs, karst forms are small and scattered and certain forms of karst are missing. Karst forms in ruins of salt plugs are mostly missing, as salt and other evaporites were already dissolved.

Karst forms are completely comparable with karsts in classical carbonate rocks. A wide variety of forms can be distinguished: karren, cylindrical solution pipes, solution dolines, solution-collapse dolines (sometimes with water at the bottom), uvala-like to polje-like depressions, blind valleys and canyon-like erosion forms, ponors and karst springs and caves.

Long caves are developed especially in a form of ideal watertable caves, sometimes in 2-3 levels. They are connected with plugs near the sea coast, where the groundwater table can be formed. They often connect closed depressions (polje-like) within the plug with outlets at plug margins at and/or near the coast-line. Other caves at bottoms of collapse-solution dolines or swallow holes are subvertical or inclined and their exploration is difficult.

The *Tøí naháèù Cave* (with total surveyed length of 3 160 m the 3rd World longest cave in salt) is opened in the SE margin of the Namakdan salt plug (Qeshm Island) by entrance 8 by 3 m partly flooded by a lake. It is composed of tunnel-shaped passages with large halls, some collapses and lakes. I one place the cave is branching into two corridors, i.e. with an active stream and to a large passage with halls. The largest hall is 35 by 20 by 10 m (Hangar). The end of huge passage named the Namakdan Highway was not completely explored. In the caves, there exist several deep shafts (40 m) connecting the cave with the surface. The *Namaktunel Cave* (about 400 m long) is opened by a huge entrance (about 15 by 15 m) in the S slope of the Namakdan plug (Qeshm Island). The entrance leads to huge meandering tunnel with abundant collapses. After several hundreds of metres, the tunnel terminates by very narrow passages. The cave is also nicely decorated by abundant curved stalactites.

The *Ghár-e Daneshyu Cave* (total surveyed length of 1 909 m, the 4th World longest cave in salt) is situated in the NW part of the Hormoz Island. The entrance is opened in small canyon. It is formed by broad but not high passage, irregularly meandering. In one place, there is a fossil cave level at +6 m. The cave is richly decorated by salt speleothems (curved and branching stalactites, more than 2 m long, cubic salt crystals, ...).

Karst processes are caused dominantly by dissolution of salt, less frequently of gypsum. The major role plays the process of subrosion of halite under gypcretes. Deep circulation of meteoric waters were proved in some plugs, often supporting deep porous collectors in surrounding non-evaporitic Phanerozoic rocks.

MORPHOLOGY AND GENESIS OF SOME SPELEOLOGICAL FEATURES OF CRES ISLAND (CROATIA)

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Cres island is located in Kvarner bay (northern Adriatic). Together with nearby Krk island it is the largest Adriatic island. Due to the favourable conditions it is rich in most of the karst forms. Among them until 1999. there were 42 speleological features registered.

Analysis of data from earlier and recent explorations showed that pits are the most common forms. Except the deepest one (Banićeva pećina, -101 m) they are mostly up to 50 m deep. Small caves (up to 50 m long) also predominate. Among them man can find different morphological, hydrological and genetic types.

Two investigated caves are partially submerged by sea, so abrasion participates in its forming too.

INFLUENCE OF TECTONIC FORCES ON DOLINE DEVELOPMENT; VELEBIT MOUNTAIN RANGE, CROATIA

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The influence of tectonic forces on karstic relief development has been studied using dolines as the geomorphological markers which represent a sensitive indicator of tectonic activity. Stress has been invoked in the explanation of a number of minor forms, developed mainly in granite (e. g. Jennings and Twidale, 1971) but also in other lithological settings. Therefore, to test the relation between the tectonic forces and the doline development in the quantitative manner, the strain and stress directions, as well as the deformation rate, has been calculated from the spatial distribution of dolines. The centre to centre method (Ramsay, 1967; Fry, 1979) has been used to obtain the local results. To pass from the local to the regional scale the projection method (Panozzo, 1984) has been used. Both of those methods were adapted to the new surface conditions. The results allow the interpretation of recent local and regional deformations of the Velebit mountain range. They also confirm the strong relationship between tectonics and the spatial distribution of dolines.

GEOECOLOGICAL STUDIES ON THE KARSTIC TERRITORIES OF THE PLANNED PROTECTED AREA IN WESTERN MECSEK, SOUTH HUNGARY

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Earlier studies on the karst in Western Mecsek have already shown this area is worth being protected due to its nearly conserved natural state. In consequence, declaring protected area the karstic territory with its wider environment is being considered in the Danube-Drava Natural Park.

In order to prove the almost untouched natural state of an area good starting point is to examine its soil and flora.

Soil studies focus on determining the pH, souring the tendency of a shift towards lower pH values and on examining the calcium content. In the future measurements to check the heavy metal content that are especially suitable for showing the levels of antropogenic contamination will be added to the above mentioned studies.

Investigations on the flora based on the examination of water balance, soil reaction and determination of the rank according to the categories of nature conservation value offer a support to the claim of being protected.

The results show, that indirect antropogenic effects can be detected by the pH shift towards lower values, but the same tendency of turning into sour is less characteristic in dolines which are the most sensitive points of karstic fields. However, the relatively high calcium content favors the resistance against lowering pH values.

Examining the vegetation, and paying special attention to the ranking into nature conservation categories a significantly high ratio of association forming and accompanying species and the presence of protected species in relatively high numbers can be seen that proves the nature conserving feature of the territory.

On the basis of the investigations carried out the maintenance of the present state of the territory can be a desirable objective and in order to realize it the protection of the area is absolutely justified.

UNROOFED CAVES MET DURING THE MOTORWAY CONSTRUCTION NEAR KOZINA AND THEIR RECOGNITION ON KARST SURFACE

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Unroofed caves are old caves exposed due to lowering ofthe karst surface, yet they are preserved by means ofmostly fine-grained sediment infills. Flowstone and rocky rim are frequently preserved also.

A special attention was given to this important superficial karst feature due to earth-works during the motorway construction when several types ofroofless caves on the karst surface were revealed.

During the motorway construction the entrances to old caves and shafts open. Old caves are either void or filled with sediments. They originate as a part of cave systems below the underground water level. Later the aquifer was relatively uplifted by tectonics and the level of surrounding impermeable rocks lowered. The water level in

the aquifer lowered also, being now more than 200 m below the surface, as well as the karst surface. The transformation ofthe aquifer cavernosity followed.
Unroofed caves represent a very special superficial karst feature, partly transformed by superficial processes making an important part of epikarst. Typical shapes of unroofed caves were met during the motorway construction near Kozina also. Single passages and larger cave systems ressembling dolines, series of dolines or rift valleys on horizontal or inclined karst surface were discovered.

EVIDENCE OF LATE QUATERNARY KARST DENUDATION RATES

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Two unroofed caves were surveyed on Zion Hill, about 3 km north of Katherine, NT Australia. One of the caves contain proliferent speleothem deposits as well as a lithified bone breccia displaying pleistocene animals (bats and snakes). Other, truncated cave entrances also display speleothem deposits.

Uranium- series dating (by alpha particle spectrometry) reveals that almost all speleothem deposits are of finite ages (i.e. < 350 ka), which in turn imply that these caves were unroofed some time during that time.

Based on modern analogues in the area, a roof thickness of 5 m or so is required to produce speleothems of the same size as those exposed in the unroofed caves. This in turn imply that 5-7 m of limestone has been removed from Zion Hill during the last 240 ka, i.e. an average denudation rate of 0.02 - 0.03 mm/ka.

This result violate the hypothesis posed by Twidale (1984) that the Tindal karst plain, of which Zion Hill is a part, is indeed an exhumed, sub-Cretaceous karst plain. It it rather suggested that the present Tindall plain is a result of Pleistocene fluviokarstic floodplain processes and subaerial denudation. The process is exemplified with the recent (1998) flood in the Katherine Gorge which inundated the Tindall Plain. These types of flood has a recurrence interval of some hundered years.

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WHY AND HOW ARE CAVES "ORGANIZED": DOES THE PAST OFFER A KEY TO THE PRESENT?

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Many caves within carbonate (and perhaps other) rock sequences display marked spatial organization, particularly a tendency to group within vertical clusters. Most past explanations of clustering involve "recent" effects and interactions. New ideas, based on study of "denuded" or "roofless" caves, acknowledge but re-interpret features and relationships that were observed long ago and commonly dismissed as "atypical", "irrelevant" or "impossible". Traditional explanations of vertical clustering must now be re-assessed.

Assumptions that any stratigraphical (bedding plane) or joint/fault fissure in carbonate rock provides (or provided) a de facto route for fluid transfer, and hence a focus for void development, are not confirmed by observation. Primitive pre-cave, but potentially cavernous, carbonate masses are not inevitably active hydrologically; nor are they geologically homogeneous. New evidence, and re-evaluation of earlier observations, implies that dissolutional void "inception" is related to a minor subset of all stratigraphical partings, which dominate initially, imprinting incipient guidance for later cave development. Recognition of this fundamental role provides a possible key to understanding the organization of cave systems and necessitates acceptance of an expansion of speleogenetic timescales back to the time of diagenesis.

ROOFLESS CAVES, A POLYGENETIC STATUS OF CAVE DEVELOPMENT WITH REFERENCES TO CAVEREGIONS IN THE EASTERN LIMESTONE ALPS OF SALZBURG, AUSTRIA

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The phenomenon of roofless caves was reported early by DAWKINS as the brakedown of cave passages up to valleys in Devonic formations of England. Also Franz KRAUS found by fieldwork, that brakedowns and roof collapses are the first steps from a normal subterrainian cave to a doline-line with cave remnants and consequently to a gorge or valley with steep walls, later on to a valley with flater slopes. KRAUS demonstrated Rakov Škocjan with his different valley parts, natural bridges as an example for old cave systems on their limits. He also pointed out, that surface and subsurface features make caves roofless. Special surface denudation thinner the roofs and than roofs collapses, like in "Lončarevec Cave" nearby Great Otok in the Postojna region. The roof of this cave became thin, down to 40-50 cm, than roof windows opens (KRAUS 1894: 73-75, 114). Consequently he wrote, that cave fillings on karstic surface, furrows and valleys are remnants of caves in regions with a high denudation rate during the time (1894: 203). He showed some examples from Postojna region.

Karst in alpine regions is often dominated by glacier erosion. The force of lateral and ground erosion of main or local ice streams formed the typical valley morphology. Sometimes a lot of caves in steep slopes became open. In plateau regions with gently inclined slopes caves became sometimes roofless by erosion on the bottom. Some examples can be shown from east alpine limestone massifs in Salzburg, special from the massifs of Steinernes Meer and Tennengebirge.

The ice flow carved the plateau surfaces. So cave systems became open in inclined slopes like dots. On plane surfaces the caves roof become shaved down. In some lokal areas we can find nowadays a lot of mostly small caves, as cuted parts of former cave system. This characterises more or less a "niveau", wich was called "Cave-Ruin-Niveau" (Höhlenruinen-Niveau). The name is not really correct, because in higher parts of the plateau - in not denudated montains are long caves developed and not ruins. Only on surface it looks like ruins. Nevertheless karst massifs with a plateau character (special Steinernes Meer, Hagengebirge, Tennengebirge) shows in an altitude of 2000-2200 m a lot of cave remnants. Some of them are connected by roofless wall parts, sometimes with cave wall morphology, cave sediments and speleothems. In other cases cave wall morphology is absent. Typical surface forms with different kinds of karren are present, even in sinter layers.

Special references are given to the Hennekopf and Rotwandl region in the massif of Steinernes Meer and the region of Sandkar in Tennengebirge.

UNROOFED CAVES AS GEOMORPHOLOGIC AND SPELEOLOGIC FEATURES

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After the definition the caves are features of karst geomorphology that are formed under the surface. Trough time different geomorphologic and speleologic processes, like denudational lowering of surface or cave collapse, can bring them to the surface, and they became in integral part of the karst surface morphology.

Detailed geomorphologic studies on the several karst areas in W Slovenia have shown that on the present surface there is a lot of different cave elements. Those are unroofed caves, cave entrances and collapse dolines. Together with them become exposed to the surface cave sediments.

There are morphologically important unroofed caves, trench like surface relief forms which are remains of horizontal cave passages. Largest of them known is over 2 km long. In such features flowstone, allochtonous sediments and by morphology are testifying their cave origin.

They developed due to the surface denudation lowering which re-formed caves into the surface relief forms. More irregular, smaller and vertical cave features are also transformed into surface features, but it is difficult to be certain about theirs origin. They may be an important element for the doline formation.

Likewise the majority of cave entrances originated due to the surface denudation lowering, and its approaching to the caves. In the cave entrances new, surface influenced processes can start. Some of them, freezing for instance can accelerate the cave transformation, but some of them, like flowstone deposition can protect the cave walls.

On the other side there are speleogenetic processes which can expose caves to the surface. Most common are the collapses and collapse dolines. We can distinguish two types of collapse dolines. Smaller collapse dolines originated by simple collapsing, but as a rule the volume of collapse features is smaller than the cavities they arose from.

Morphologically most expressive are great collapse dolines, with volumes several millions m^3 . Their volumes frequently exceeds for an order of magnitude the volume of the largest known chambers, showing that the collapsing is a special speleogenetic process. They occur in special structural, hydrogeologic and speleogenetic conditions only.

Flowstone and allochtonous fluvial sediments originating from unroofed cave are important as a source for the soil formation and for the explanation of past hydrological conditions on karst.

Geomorphologic observations of karst in Slovenia have shown, that there are many different cave elements that were exposed to the surface. Such elements, unroofed caves, cave entrances, cave collapses and cave sediments found on the surface are important element and can give us an important information of the karst development.

THE RECONSTRUCTION OF THE DEVELOPMENT HISTORY OF KARSTIC WATER NETWORK ON THE SOUTHERN PART OF THE GÖMÖR-TORNA KARST ON THE BASES OF RUINED CAVES AND SURFACE FORMS

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In my lecture I demonstrate the surface development of the Gömör-Torna karst situated on the Hungarian-Slovakian border from the Tertiaty until the present day.

I follow the process of transition from the covered karst conditions to the open karst on the karst plateau, and its effect upon the surface forms and the karstic water network. During my research I studied the evolution of surface and sub surface water network, the regularity of the movements of underground rivers based on water indicating experiments. I reconstructed the ancient surface outflow directions of the covered karst from the scarce remains of the epigenetic valleys inherited from cover deposits unto the limestone surface, from ruined swallow hole lines in valleys, as well as from perishing water conducting tubes generating from earlier phases (caves).

RELICT KARST FEATURES IN APUSENI MOUNTAINS (ROMANIA)

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The paper presents some relict karst features (natural bridges, arches, inactive cave segments, paleokarst, pillars) from three different units of Apuseni Mountains (Metaliferi, Padurea Craiului and Gilau-Muntele Mare Mts.). As the karst landscape in the three units developed on different petrographic support (limestone of age between Lower Palaeozoic up to Upper Cretaceous) the paper also deal with the presentation of causes that led to the formation of these karst relicts.

PALAEOMAGNETIC STUDIES IN THE ČERNOTIČI QUARRY (ČRNI KAL, SLOVENIA)

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Unique profile of laminated speleothems was studied in the western wall of the Černotiči Quarry (Crni Kal, Karst Edge, SW Slovenia) in the rest of a palaeocave

destructed by the blasting. The profile was situated only several metres below present leveled surface of limestone plateau. The profile consisted of about 1.6 metres thick sequence of reddish brown, light brown, brownish light gray and ochreous, laminated to banded speleothems. The sequence was deposited over highly corroded surface of massive grayish white coarsely recrystallised speleothems (preserved thickness highly over 2 m), filling probably side notch. The laminated sequence consisted of several layers separated by about 11 thin layers of red clay (most probably redeposited terra rossa soil) with variable thicknesses from thin film up to 10 centimetres and by some corrosional surfaces without clay. In some clay layers, there existed fine rounded clasts of a little bit consolidated red clay. Speleothems consisted of an alternation of massive laminae to bands with detailed internal lamination, in places, and more porous, rather ochreous laminae to bands. This feature indicates the alternation of different conditions of speleothem growth, i.e. more rapid (porous) and slow (massive laminae), proving changing climatic conditions during the carbonate precipitation.

Palaeomagnetic sampling was carried out in laminated speleothem sequence (23 samples). The sampling of white coarsely recrystallised speleothems below laminated sequence was not carried out owing to expected low remanent magnetization preserved, which is a typical feature of such type of rocks.

Palaeomagnetic research detected normal polarised magnetozone in lower 1.2 m of speleothems and one reverse polarity magnetozone containing not completely proved narrow normal polarity magnetozone in the upper 0.4 m of profile. Thus, the profile begun in normal polarity magnetozone and finished in reverse polarity magnetozone. The calibration to commonly applied charts of geomagnetic polarity is highly problematic. The situation is complicated, more, by numerous breaks in speleothem deposition represented by clay interlayers and corrosional surfaces. High thicknesses of speleothems deposited within normal polarity and reverse polarity magnetozones indicate that the deposition took place within a long time-periods. From the duration of individual Neogene/Quaternary magnetozones therefore results that the *youngest possible age* of the boundary of normal/reverse polarity within our profile has to be correlated with Matuyma/Gauss boundary, i.e. 2.47/2.60 Ma.

Data obtained indicate very ancient age of the karstification (which corresponds with the position just below recent surface) and relatively stable character of conditions for the carbonate precipitation in a palaeocave environment. The cave itself must be much more older as speleothems studied overlain deeply corroded/eroded and highly recrystallised older speleothems of large thickness.

THE "UNROOFED CAVE" NEAR THE BUNKER (LAŠKI RAVNIK)

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Situated in the Laški Ravnik, about 4 km east of Planinsko polje (Slovenia), this unroofed cave is the longest of many found in the area. More than 200 m of denuded passage has been traced at the surface. The cave's general trend is north-south, and it continues southwards to an overhang, which appears to be the termination of a collapsed cave channel. Three main "passages" making up the unroofed cave have been recognised, and each has been transformed in its own way. Disintegration of parts of the former cave roof is apparent, forming "false solution dolines", between which the ceiling is partly preserved, either in-situ or as isolated blocks lying on cave sediment. In the down-dip direction, passage sides have disintegrated almost completely, and detached blocks have slid down into washed-out portions of the former cave passages. All three passages developed along bedding planes, but in different directions, such that two of them now "emerge" above the surface whereas the third plunges down and is completely choked by loam. The unroofed cave passes southwards into a "normal" underground route, where a barely accessible, very low and wide passage is accompanied by two "vertical" shafts, which are presumed to be former phreatic jumps. This part of the system is not considered in this paper.

MORPHOLOGICAL AND GEOLOGICAL CHARACTERISTICS OF TWO DENUDED CAVES IN SW SLOVENIA

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During beginning of constructions of highways across Kras in Slovenia in 1994 the first so-called denuded (or roofless) cave was discovered near Povir on highway Divača-Dane. Because of the highway construction detailed topographic maps in 1:1.000 were done. Altitudes on such map are determined on 1 m and sometimes also on 0,5 m. On the map the obvious morphological depression is shown which runs from altitudes of 395,3-401m. General direction of the denuded cave is NW-SE. It runs between cross section 701-681 on the highway. The cave is 320 m long and up to 10 m wide.

The cave is developed in Liburnian formation (K-Pc) which is bedded and contains platy limestone, marly limestone and limestone breccia (Jurkovšek et al., 1996). In NW part of the cave limestone dips towards S for 20^0, in central and SE part limestone dips towards SW for $20\text{-}30^0$. The thickness of the limestone beds is 0,2-0,4 m. According to geological map of Jurkovšek et al. (1996) between denuded cave and Divača fault a syncline is situated in general direction NW-SE. It dies out just in that area between the cave and Divača fault. According to geological measurements in the cave we can confirm that idea.

The denuded cave near Povir is situated about 100 m north from Divača fault (NW-SE direction). In the cave the fault $50/70\text{-}90^0$ is well expressed from central to E part of the cave. We can also follow the fractured zones 70/80, 150 and 140^0. In the western doline we have fractured zones 70/30, 70, 60 and 340/80. The cave passage is mostly developed according to direction of bedding planes.

With preliminary investigations before highway construction Divača-Kozina 4 denuded caves were determined (Šebela, 1996), with highway construction 2 more denuded caves were found. The cave between cross section 139 and 149 on the highway was very good morphologically expressed even before highway construction. All together about 80 m of the cave was determined. General direction of the cave is E-W. In the W part roofless cave was morphologically deepened for 0,5-1 m. After about 30 m cave passage was lost in the doline (bottom of the doline 497,2 m) which was probably former cave chamber. The continuation of the cave towards E is not well determined. We think that the cave has still the roof in that part. The roofless cave was possible to follow about 20 m E from the old road Divača-Kozina what is also well seen from the morphology on the topographic map (1:1.000). The cave is situated between 505-497,2 m a.s.l. It's filled with cave sediments. Between 80 m long cave about 20 m still has the roof.

The cave is developed in Eocene limestone in SW part of the syncline which runs in Dinaric direction (NW-SE) between Dane pri Divači and Kačiče-Pared. Alveolinid-numulitid limestone dips towards NE for 10-30^0. It's bedded alveolinid and numulitid limestone; locally limestone with chert and limestone with lithothamnians, corals and hydrozoans (Jurkovšek et al., 1996). The direction of the principal fissured to broken zones is 290/70 or 110^0. The fissures in the direction 40^0 and 190/80^0 are present.

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VERTICAL ZONATION OF SPELEOGENETIC SPACE

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Recognition of "unroofed caves" has revealed not only the existence of a spatial domain where underground karst phenomena are being systematically transformed, but also that application of this knowledge allows the role of caves within geospeleological space/time to be described more consistently. Speleogenetic space is defined as those parts of the Earth's crust within which karst caverns may be formed. Accordingly, a karstified rock mass is defined as activated speleogenetic space. Due to the effects of denudation and water table lowering, a specific cave will appear to move upwards through speleogenetic space as time passes, until it reaches the surface. Because the denudational logic of the karst surface is vertical, the rock mass suffers disintegration through the full thickness of its outermost layers, and the same argument applies to in-rock features. Consequently, the concept of the speleothanatic zone is introduced. Within this zone the whole of the rock mass is attacked, on any possible surface, and the ultimate result is its complete annihilation. It may be deduced that all structures, of whatever origin, that expose rock surfaces to the effects of aggressive water will evolve via some form of speleothanatic progression, and three vertical zones of specific formative/de-formative processes can be demonstrated to exist within speleogenetic space.

RESEARCH OF THE SOILS ON KARST AREAS IN HUNGARY (BUKK MOUNTAIN)

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In my essay I studied the characteristic of the economy of the soil's nutrients on the karst areas. I examined an 8 km^2 part of the Bukk plateau (Bukk National Park, Hungary). From every km^2 we collected 2 soil samples (from different depths). These came from different ecological conditions: beech forests, pine forests, beech with pine forest, woodland nursery and open field.

In the last ten years the investigation of the soil that occur on the karst came into limelight. The soil has an important role in the ecological system because it can buffer the harmful environmental effects that take affect quickly.

Of the nutrients of the soil I measured the quantity of total soil-nitrogen plus the quantity of plant available phosphorus, potassium, calcium, magnesium. Although it isn't actually a type of nutrient I also measured the collective quantity of exchangeable and solution natrium. This enabled me to calculate the S-value (exchangeable basis) of the soils.

The *investigation of the soil can not do without the knowledge of pH and the* carbonate content of soil. Therefore during the investigation I determined the pH (H_2O) and pH (KCL) plus the carbonate content of soils. The soil moistness - which is important because of the plants to take of nutrients - was also part of investigation.

The determination of pH and carbonate content of soils isn't important only because of the nutrients. In the case of karst areas it is important to know these connections because the characteristic of the bedrock point towards the fact that the soil has high carbonate content and according to this has neutral pH. After the measurement I made I found that the soils of Bukk plateau has a low carbonate content which has a big influence of the presents of the nutrients. In connection with this the pH of the soils is also lower than expected.

In the case of ΔpH ($=pH(H_2O)-pH(KCL)$) the often high (around 1) values show that in these soils the acidification is important.

The knowledge of the pH plus the N, P, K, Ca, Mg content of the soils can be influental towards the protection of the environment, the upkeeping of the forestry and management of the meadows.