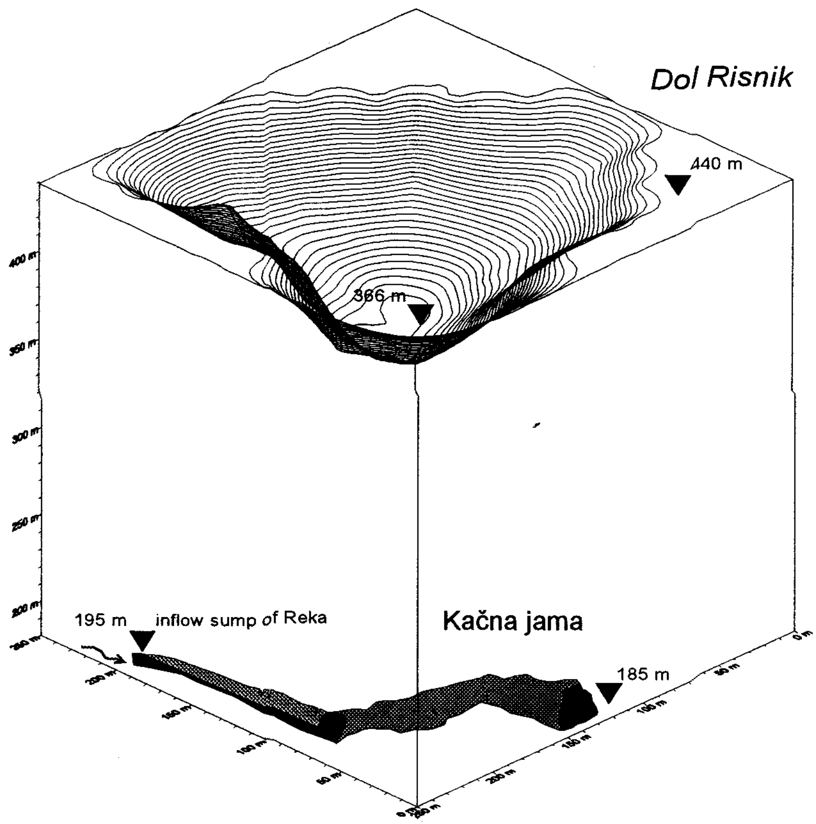
SPELEOLOGICAL ASSOCIATION OF SLOVENIA
and
KARST RESEARCH INSTITUTE ZRC SAZU

8th INTERNATIONAL
KARSTOLOGICAL SCHOOL
CLASSICAL KARST



COLLAPSE DOLINES

GUIDE BOOKLET FOR THE EXCURSIONS
POSTOJNA, JUNE 2000

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

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PROGRAM

Check the timetable!

There are some changes. Due to the large number of announced presentations, the time reserved for the lectures is prolonged. Those of you giving the talks: Be in time.

Monday, June26, 2000

19.00-20.00 Registration

Tuesday, June27, 2000

7.30-8.30 Registration
9.00-10.00 **Opening and lectures**
10.00-10.30 Coffee break
10.30-12.30 **Lectures**
14.00-20.00 Field work: Cerknica-Rakov Škocjan-Planina

Wednesday, June27, 2000

8.00-10.00 Lectures
10.00-10.30 Coffee break
10.30-12.30 **Lectures**
14.00-19.30 Field work: Collapse dolines above Škocjanske jame
19.30- Reception at the Karst Research Institute

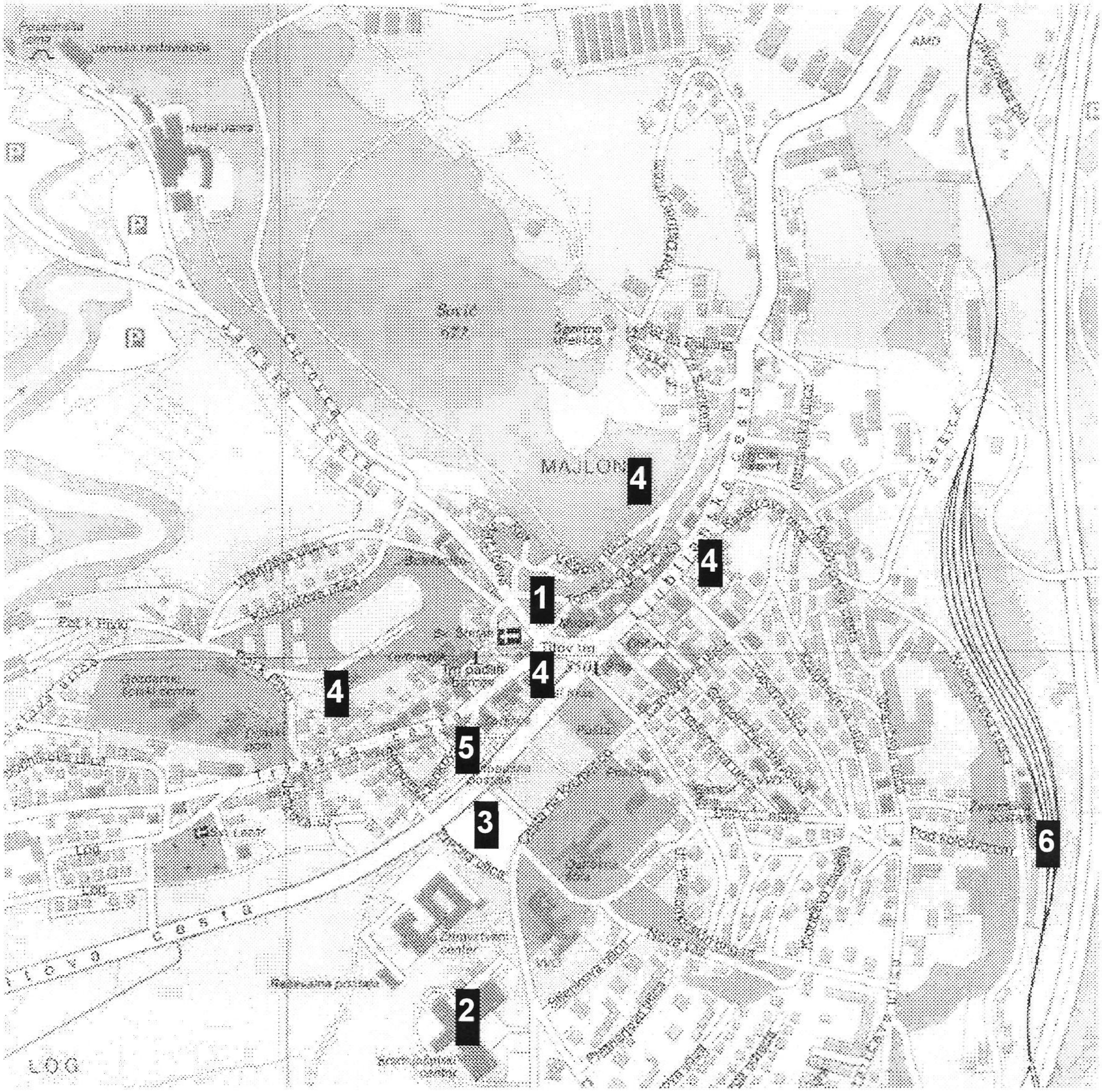
Thursday, June 28, 2000

Whole day excursion: Collapse dolines between Planinsko polje and Ljubljanica springs.

NOTES AND TIPS FOR THE PARTICIPANTS

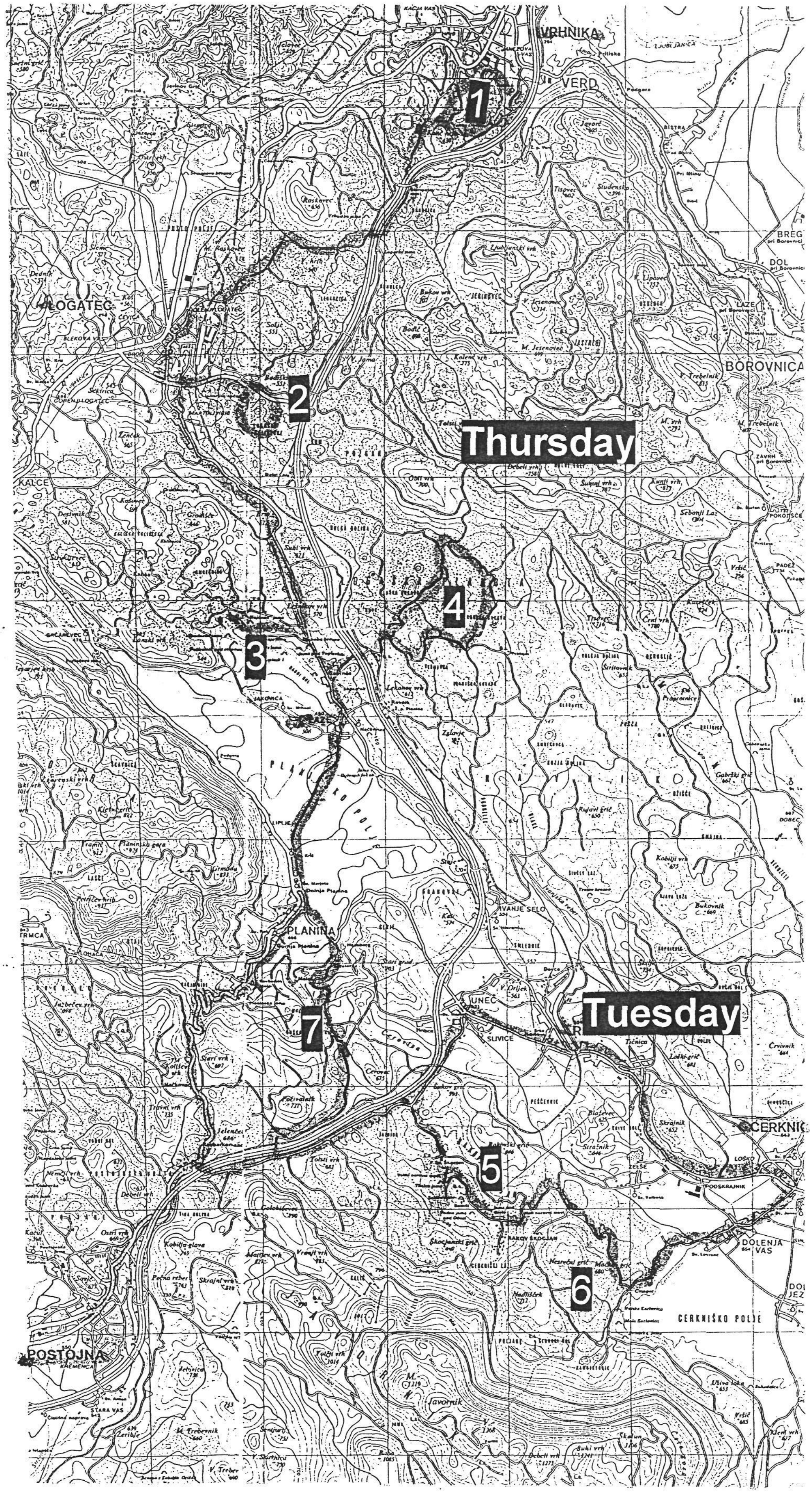
- Since the Institute's hall capacity is too small for the number of participants, the lectures are going to take place in the **Hall of Postojna School Centre** (No.2 in the map).
- Departure for the excursions is going to be from the parking place in front of Business centre Primorka - PTC Primorka. (No.3 in the map).
- Use suitable field shoes and clothes for the field trips.
- Some beverages for the field trips are going to be supplied by the organiser. Still, take some additional with you to avoid dehydration.
- There is a possibility to have an evening slide-show presentations in the Institute's hall. Those of you having something interesting to show, tell this at the registration desk. We will announce this during the lectures.
- **IMPORTANT:** The areas of field trips are populated by the infected ticks. Do not forget to check yourself carefully for the ticks after the excursions.

POSTOJNA WITH SOME PLACES YOU MIGHT NEED



1. Karst Research Institute
2. School centre (LECTURES)
3. Parking place: Departure for field trips
4. Places to eat
5. Bus station
6. Train stations

1.Ljubljanica springs
2.Logaške koliševke
3.Ponor area of Planinsko polje
4.Laški ravnik
5.Rakov Škocjan
6.Šujica
7. Unška koliševka



The plan of the excursions for Tuesday and Thursday 1:100000

AFTERNOON EXCURSION

Cerknica - Rakov Škocjan - Planina
[Tuesday, 27th, June, 2000]

Collapse dolines between Cerkniško polje and Planinsko polje

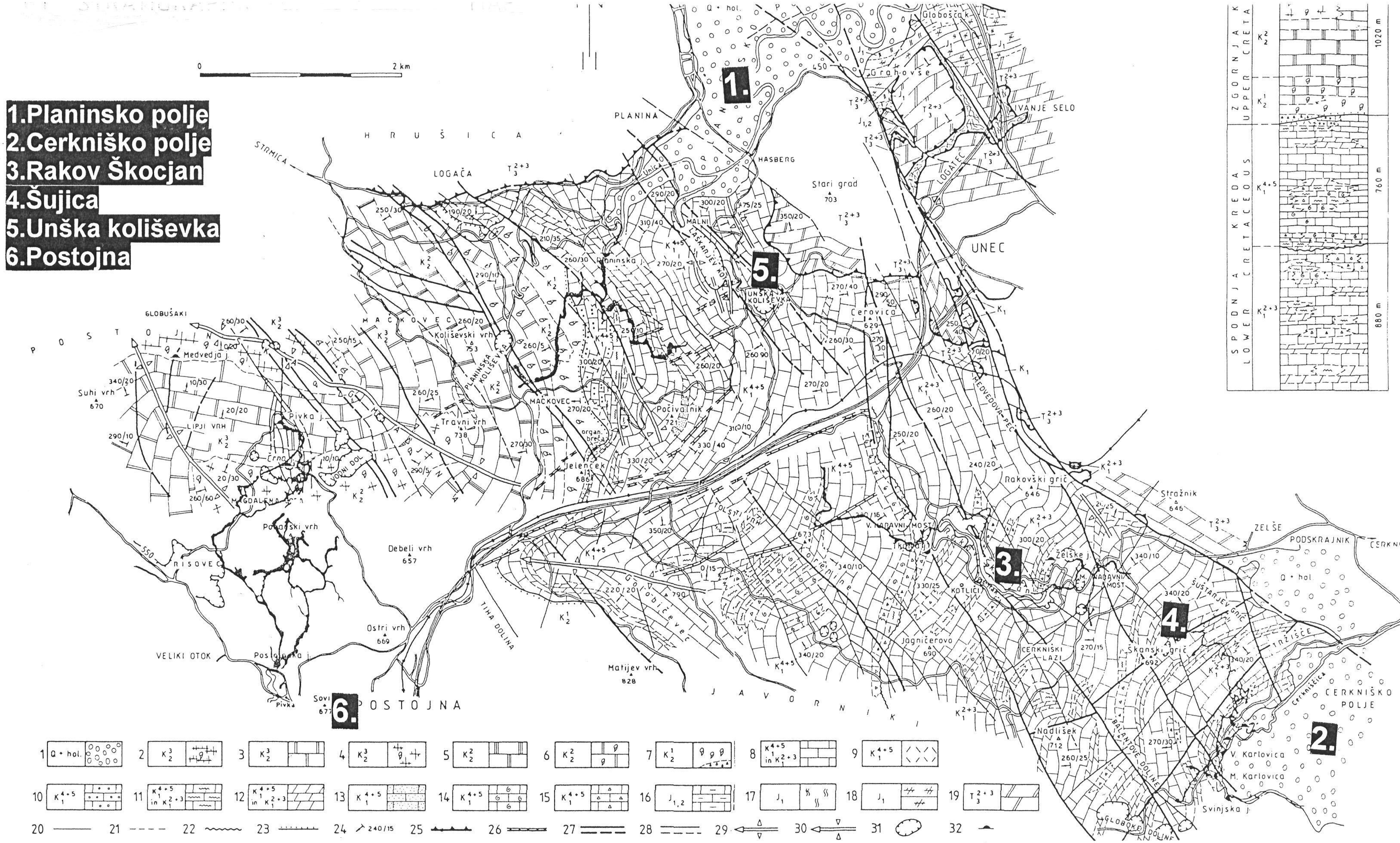
Karst area between Cerkniško and Planinsko polje is one of Slovenian classical karst sites.

Collapse doline **Šujica** is located close to the Cerkniško polje, in the vicinity of Karlovica cave.

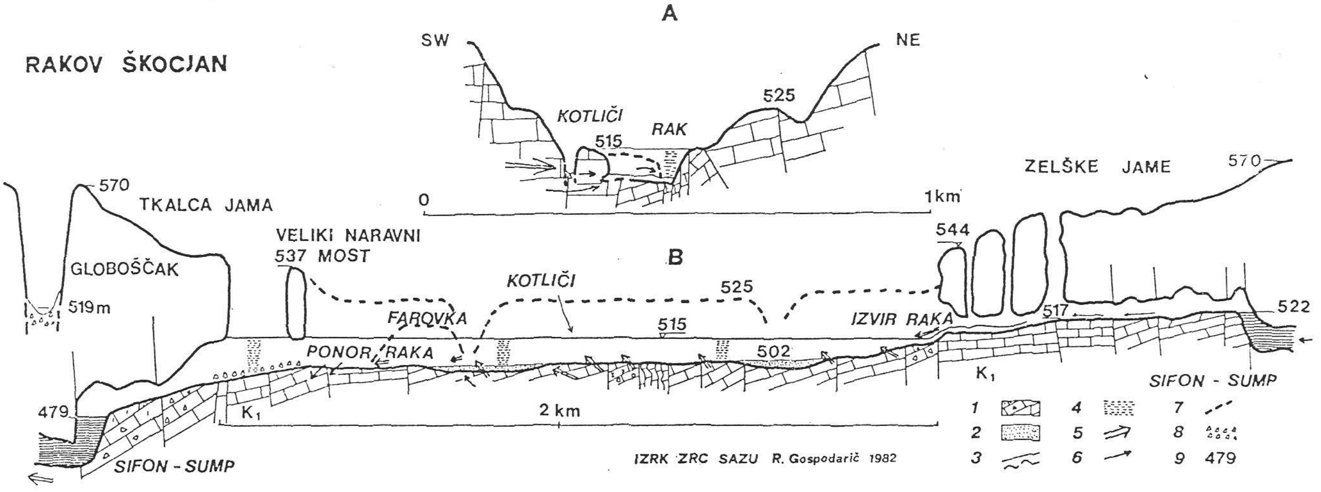
Rakov Škocjan is a karst valley, about 2.5km long and up to 500m wide. It collects the waters from Cerkniško polje and Javorniki. Main stream is a 2km long brook Rak, which springs from Zelške jame and sinks into Tkalca jama. Rak is mainly fed from the waters of ponor caves Velika Karlovica and Mala Karlovica and has additionaly affluents from Javorniki massif along the valley.
Many "collapse" and other karst features can be observed in the valley. Most known are the remnants of the old cave passages and chambers, natural bridges Veliki naravni most (37m high) and Mali naravni most (42m high).

Unška koliševka: 124m deep collapse doline with more than 100m high vertical walls is located close to the border of Planinsko polje. The bottom of doline is 50m higher than the polje level.

Fig.1 Lithological and stratigraphical situation
Fig.2 Longitudinal section of Rakov Škocjan
Fig.3 Unška koliševka, Planinska jama and Planinsko polje 1:5000



1: Stratighraphic-Lithological map of the area between Cerkniško and Planinsko polje



Sl. 2. Rakov Škocjan. A — prečni profil pri izvirih Kotliči, B — shematski vzdolžni profil kotline, 1 — skalno dno, 2 — naplavine, 3 — prelomi in tekstonska cona, 4 — višina poplave 04.01. 1982, 5 — kraški izvir, 6 — smeri vodnih tokov, 7 — terase, 8 — podorne skale, 9 — nadmorske višine

Fig. 2. Rakov Škocjan Depresion. A — cross section at Kotliči springs, B — shematic longitudinal section of the depression, 1 — rocky bottom, 2 — alluvions, 3 — faults and structure zone, 4 — flood height on January 4, 1982, 5 — karst spring, 6 — water flow directions, 7 — terraces, 8 — boulder rocks, 9 — altitudes

Fig.2: longitudinal section of Rakov Škocjan

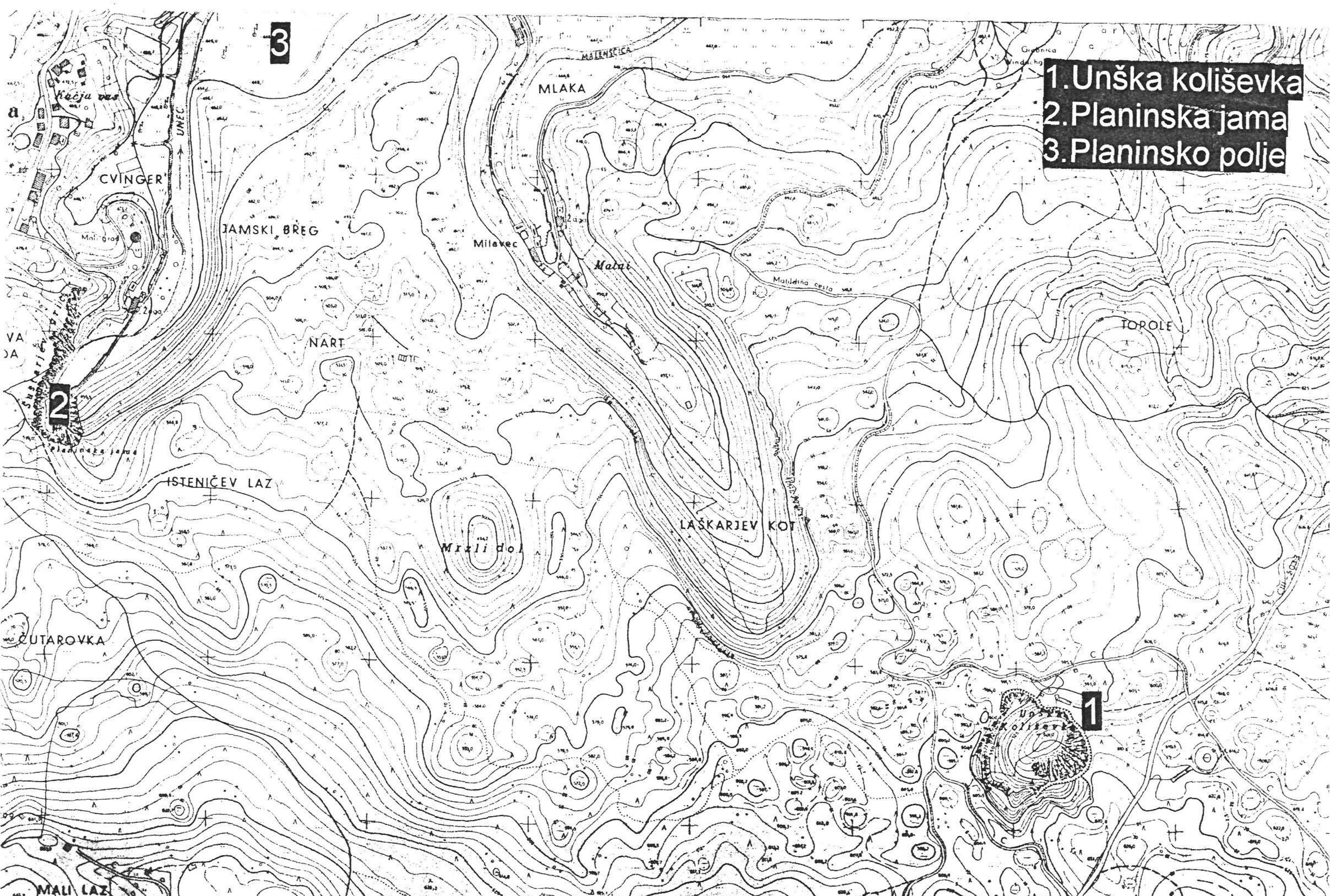


Fig.3: Unška koliševka and Planinska jama

AFTERNOON EXCURSION

Škocjan - Divača
[Wednesday, 28th, June, 2000]

COLLAPSE DOLINES AND THE SURFACE OF THE DIVAČA KARST

Collapse dolines are, by definition, relief forms which occur when ceilings above underground caves collapse. Slovenian expert literature understands collapse dolines as those with exceptional dimensions, and steep or vertical walls. Smaller collapse forms are frequently left aside because of lack of signs of collapse processes.

The relief of Divaški Karst lies 420-450 m above sea level. The relief is levelled with numerous dolines and collapse dolines as the dominant surface relief form.

The largest collapse doline in the area is the Radvanj double collapse doline (volume 9 million m^3). It is followed by the 122 m Sekelak, the volume of which is 8.5 million m^3 and Lisične dale (6.2 million m^3). Then there are: Globočak (4.6 million m^3), Bukovnik (1.5 million m^3), Risnik (1.5 million m^3) and others. As rooms as big are not usual in the Karst, we must assume (Habič, 1963) that collapse dolines this large could develop only with simultaneous rock removal. If this were not the case, the room would fill up with caved-in rock and only collapse dolines much smaller than the primary cave would appear on the surface.

Cave volumes are much smaler. The largest room is Martelova, with a volume of over 21 million m^3 (Mihevc, 1997). The somewhat smaller Müllerjeva and Svetinova rooms have a total volume of 873,000 m^3. Other rooms in Škocjanske or Kačna caves are much smaller, with volumes up to a few 10,000 m^3.

We compared the area of dolines, collapse dolines and smooth Karst relief in an area covering 31 km^2. In this way we identified speleological elements in the present relief. We calculated the volumes of the 15 deepest collapse dolines and compared them to the volumes of dolines. The volume of an ordinary doline, 10 m deep with a diameter of around 40 m, would be 5,000-7,000 m^3. We marked 761 dolines in the selected area and 15 collapse dolines. The line between dolines and collapse dolines was drawn artificially at a depth of 30 m.. Higher densities, up to 240 dolines per km^2 and an average of 25 dolines per km^2, occur on cretaceous limestone.

The total area covered by dolines and collapse dolines represents 11% of the total area: 761 dolines make up 7% and 15 collapse doline make up 4% of the area. Most of the surface (88%) are levelled and smooth. The ratio between the volumes of depression forms presents a different picture. The total volume of the selected 15 collapse caves is 38,000,000 m^3, while the total volume of dolines is 6-10 million m^3.

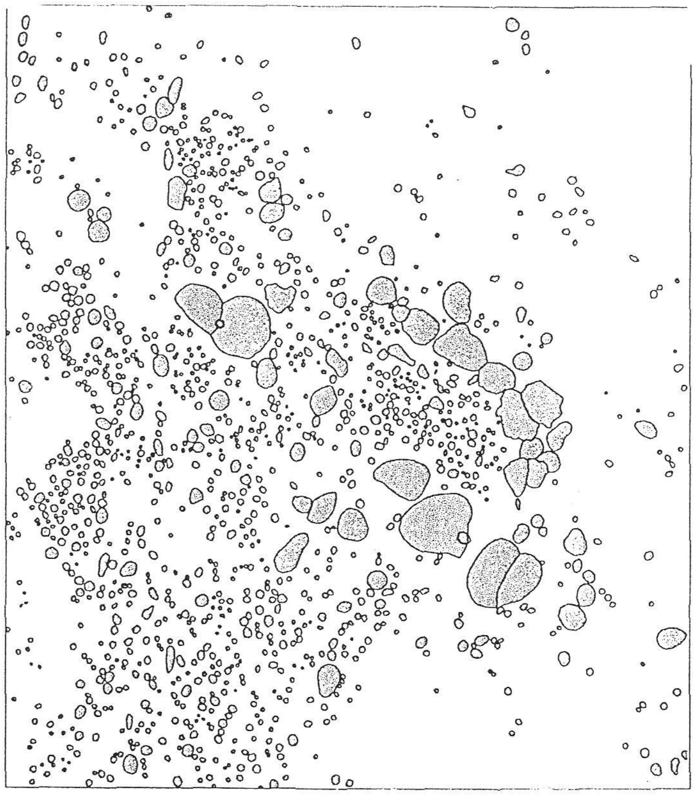


Fig. 1: Dolines of the Divača karst area.

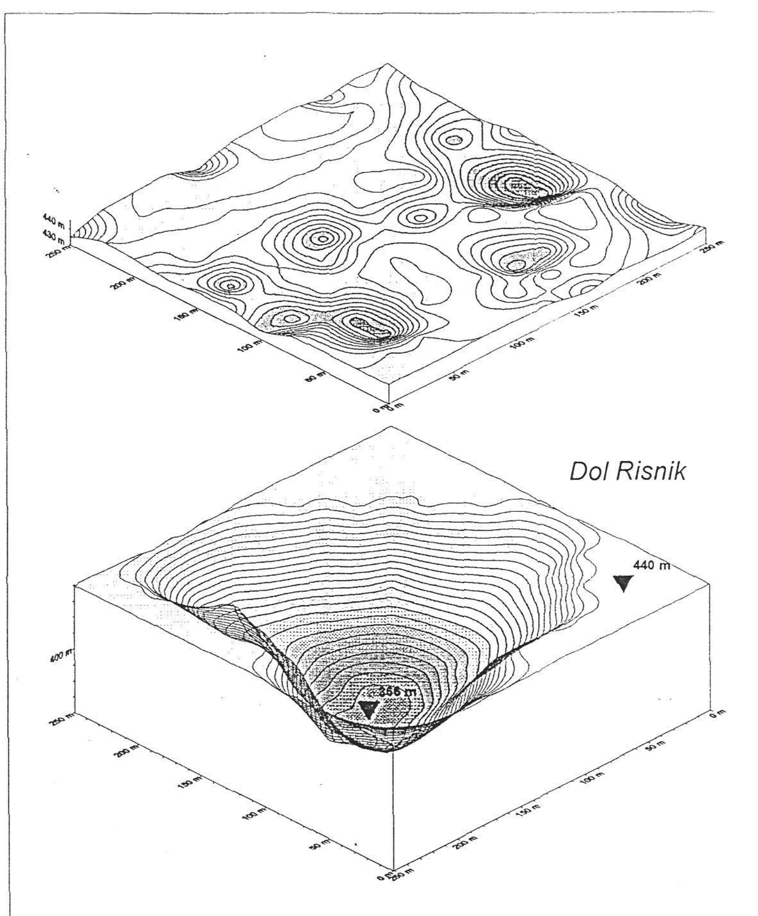


Fig. 2: Comparison of two areas of equal surface (250 X 250 m). Collapse dolina is Risnik.

Velika in Mala dolina in Škocjanske jame

There are 7 large collapse dolines in the Škocjanske caves area, and in the cave itself there are large chambers in the cave, where we can see the recent processes and structures important for the collapse development. These can be applied to the collapse dolines of the Škocjan too.

Velika and Mala dolina (Big and Small dolina) is double collapse dolina with river Reka flowing trough them and divided by thin ridge in trough which Reka formed short cave.

Velika dolina has edge in elevations between 446 m and 363 m on the lowest side. Bottom of dolina – level of the river and lake is in elevation of 269 m – 271m a.s.l. High waters in dolina can reach the level 346 m a.s.l There is solid rock forming the bottom of dolina, scree and boulders are scarce and the slope scree is only on S side of dolina. In vertical walls several entrances to Škocjanske jame are widely open.

The bottom of Mala dolina is 306 m a.s.l. Most of the sides of dolina are vertical walls, scree slopes are only on S side of dolina.

Origin of both dolines is probably similar to those of the large chambers of Škocjanske jame: by collapsing the walls between the parallel shafts formed in a zone of phreatic jump between tectonised bedding planes which are in the cave itself up to 175 m apart.

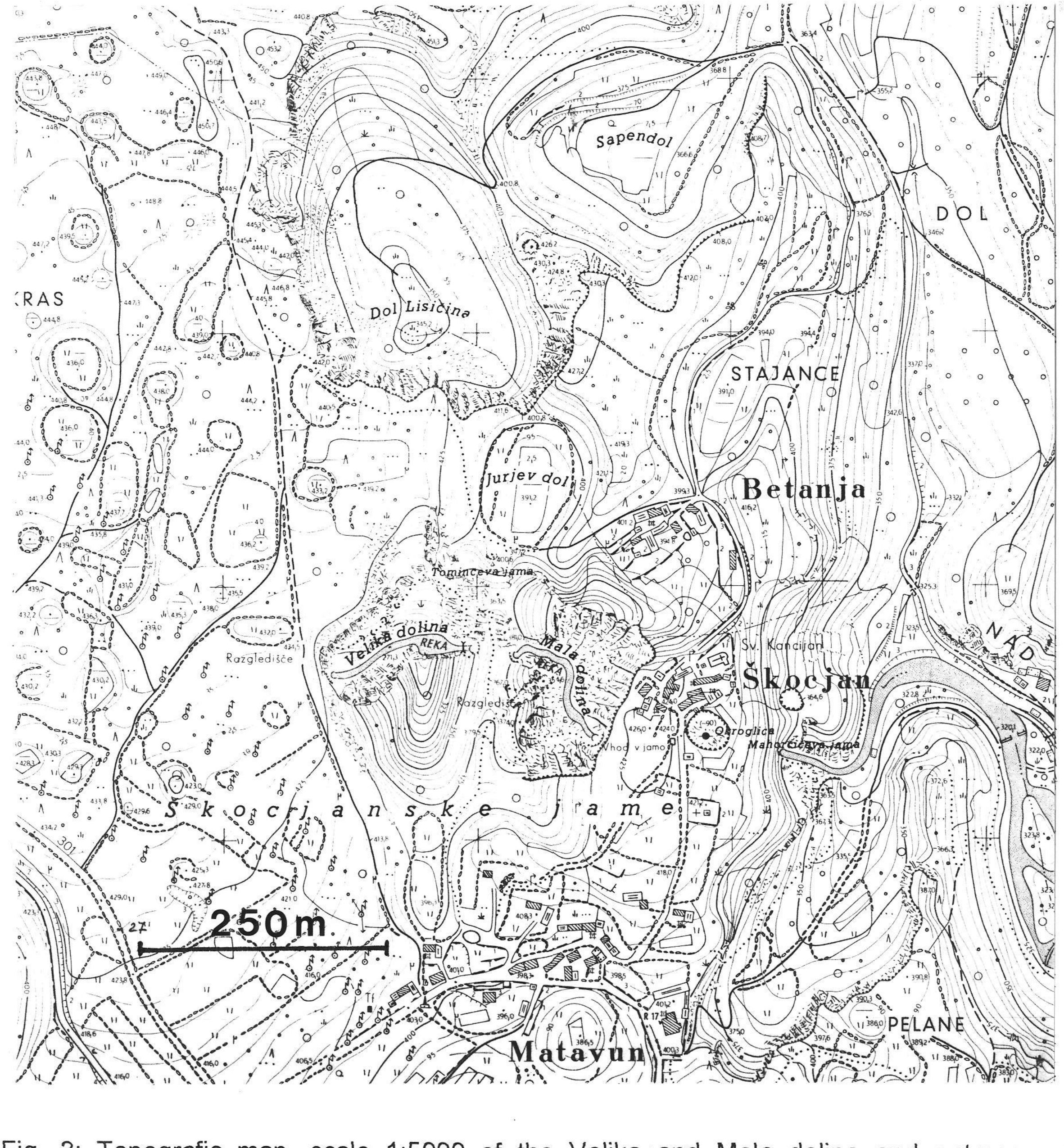


Fig. 3: Topografic map, scale 1:5000 of the Velika and Mala dolina and entrances to Škocjanske jame caves.

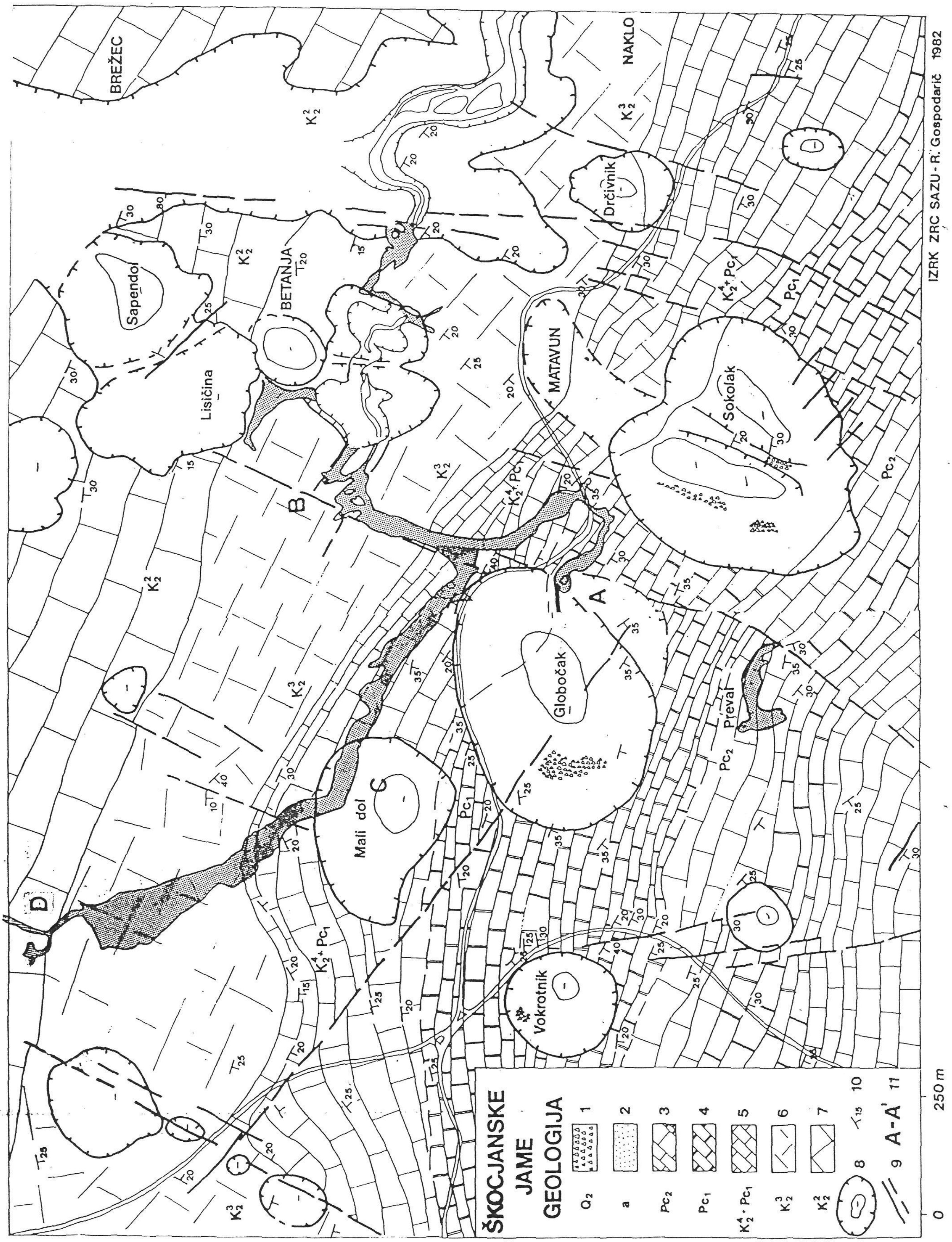


Fig. 4: Geology of Škocjanske jame. Geology og the surface, Škocjanske jame and outlines of collapse dolines are marked. Gospodarič, R., 1983: O geologiji in speleogenezi Škocjanskih jam. Geološki zbornik, 4, 163-172. Ljubljana.

Risnik in Divaški in Gorenjski Radvanj

Risnik is about 80 m deep collapse doline situated south of Divača village on levelled karst surface. Its edges are on elevation about 440 m, and bottom at 366 m a.s.l. Most of the doline has vertical walls in upper parts and boulders and scree in lover part of doline.

About 50 m N an E of the doline there are galleries of Kačna jama where Reka flows at 190 m a.s.l. There is no signs of connection between the doline and the gallery, so we have to suppose, that the Risnik was formed above unknown passages of Kačna jama.

Only 50 m W of Risnik is dolina much larger, 800 long and 450 m wide double dolina Radvánj. According to owner – villages the E dolina is named Divaški Radvanj and W dolina Gorenjski Radvanj.

Surface above dolina is in elevation between 460m on S side and 435 m on its N side. Deeper E dolina has bottom in elevation of 363 m, W dolina at 381 m a.s.l. Volume of both depressions is about 9.000.000 m³. The slopes of Radvanj are no steeper than 30° and there is no scree material on them. The bottom of dolina is covered with thick colluvial soils.

On the W slope of Radvanj there is in elevation of about 400 m about 20 m wide belt of alochtonous fluvial cave deposits an flowstones, probably continuation of Divaška jama cave. Therefore we can connect the origin of Radvanj to the very old caves in elevation of about 400 m.

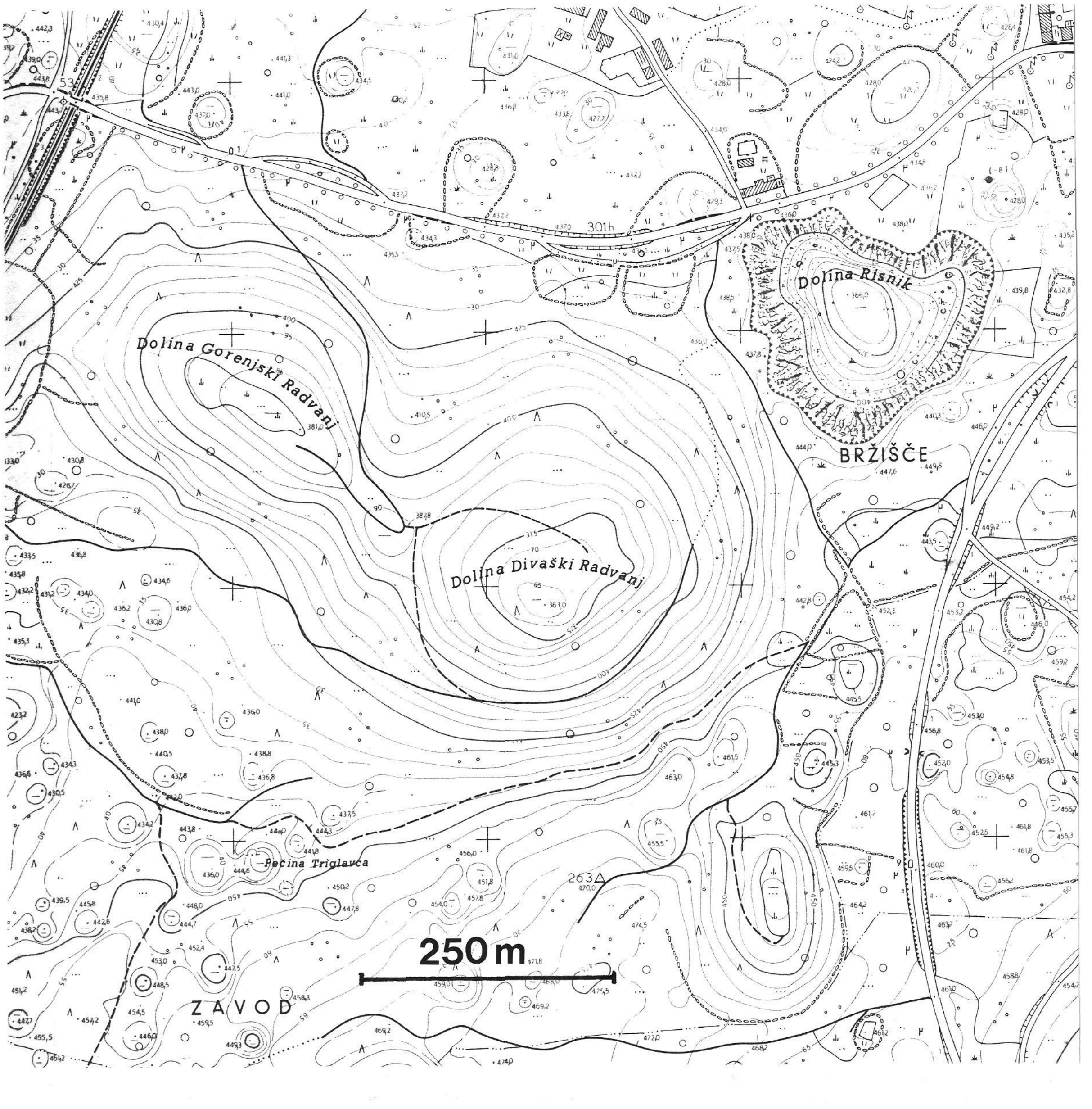


Fig. 5: Topografic map, scale 1:5000 of the Risnik and Radvanj collapse dolines.

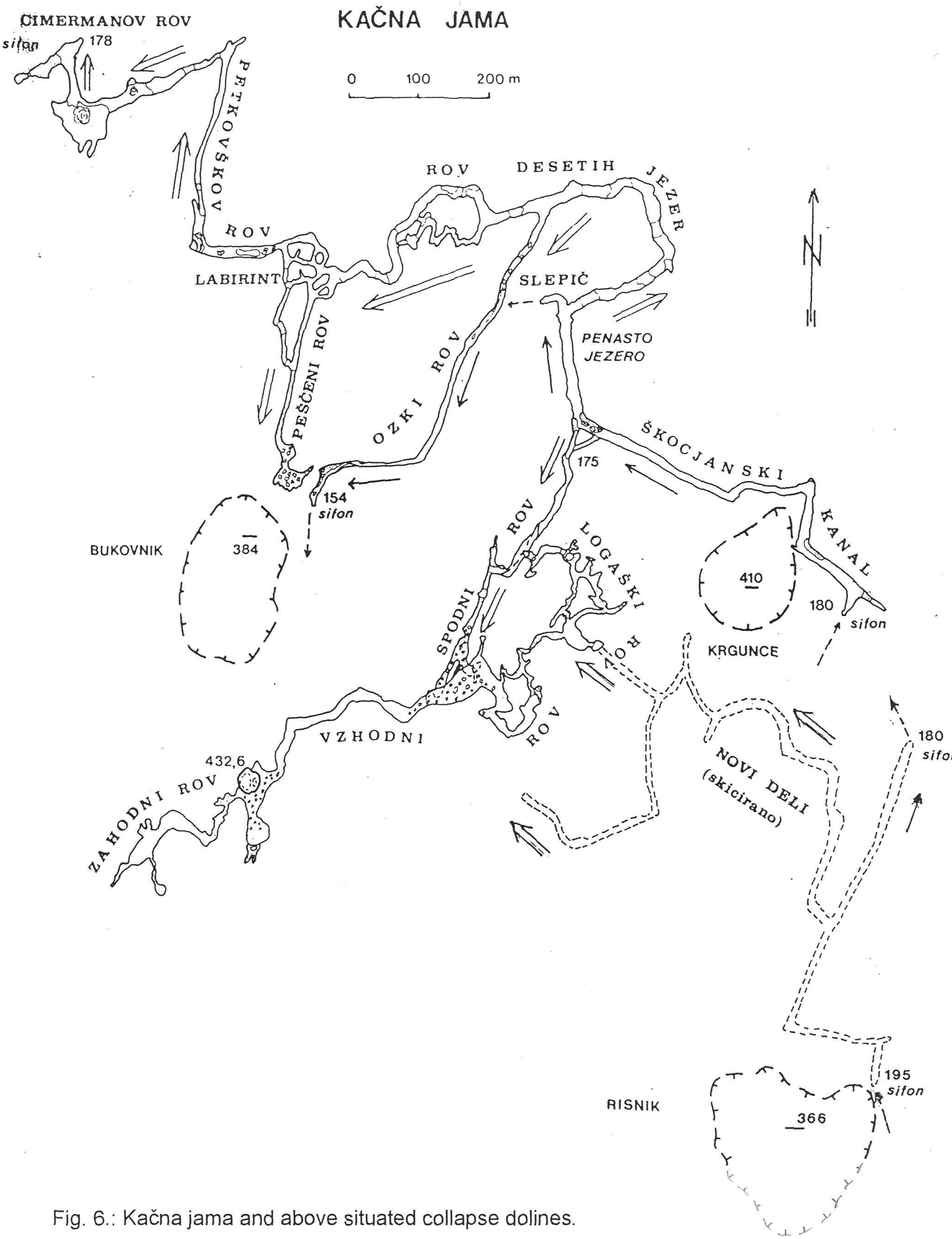


Fig. 6.: Kačna jama and above situated collapse dolines.

Dolina Šator

Is one of the largest collapse dolines. It is in the surface of about 345 m a.s.l. and it is about 500 m wide. The flat bottom of doline is 281 m a.s.l. Slopes of the doline are steep only on the E side and there is no vertical parts or scree. Bottom of the dolina is about 20 m wide and is covered with thick colluvial soils and sediments. There is no remains or evidence of collapse processes forming these dolina or large known caves in near vicinity so we name it collapse dolina only because of its dimensions.

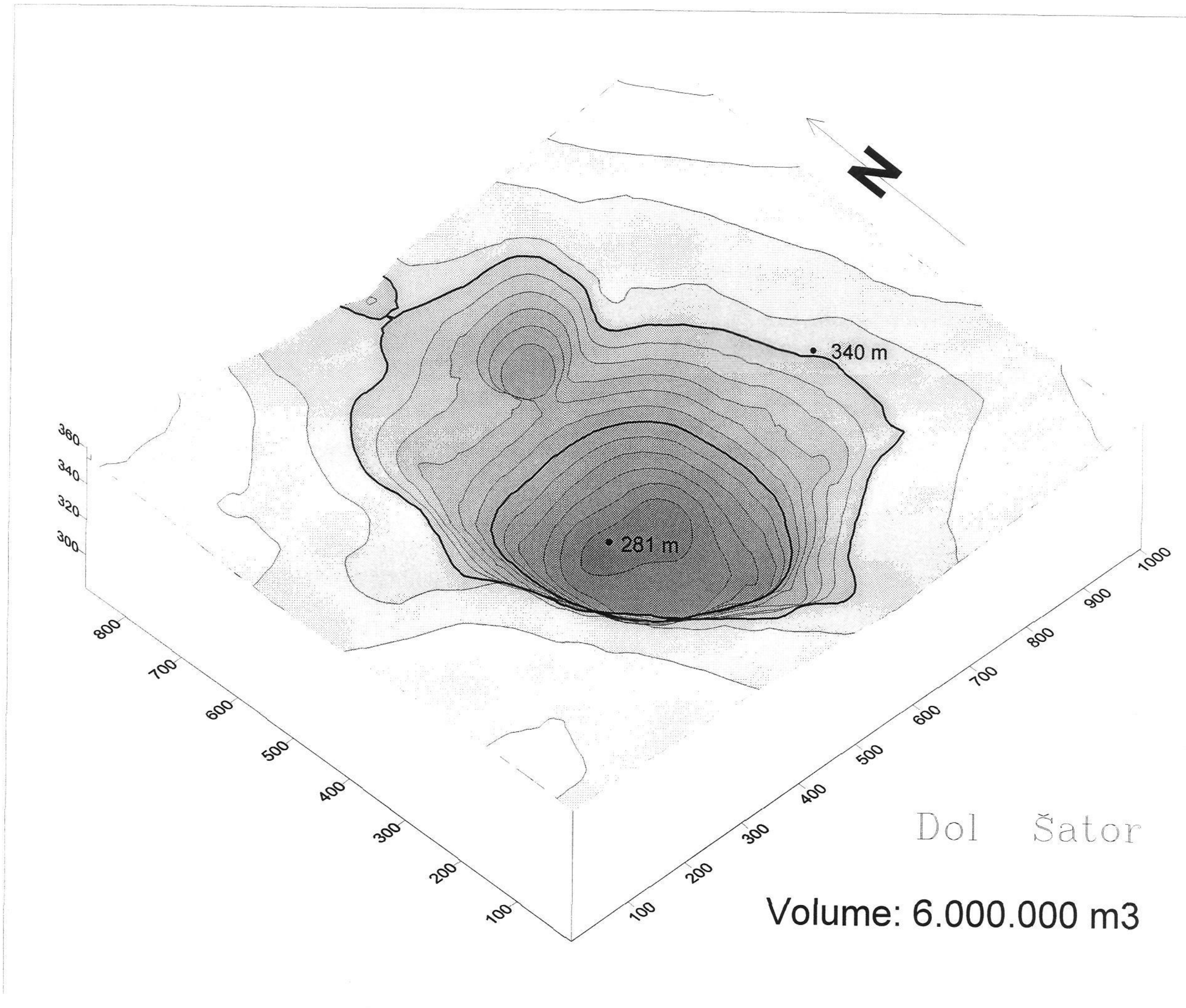


Fig. 7: DEM of Dolina Šator

THE WHOLE DAY EXCURSION

Laze – Logatec - Vrhnika
[Thursday, 29th, June, 2000]

COLLAPSE DOLINES BETWEEN PLANINSKO POLJE AND LJUBLJANICA SPRINGS

OVERWIEV

The catchment area of Ljubljanica river is one of the big Classical karst region. Beside other karst features there are more than 150 large colapse dolines. These are most frequent just behind the ponor areas at the rims of karst poljes and on the low plateau directly above the springs of Ljubljanica river. They are numerous also inbetween. Part of these area is shown on the DEM on fig.1. Main towns and some sites where our excursion will stop are shown. See also the map on the previous page. Note the plain areas which represent the Planinsko polje, Logaško polje Cerkniško polje and Ljubljana moor. Numbers represent some sites of our first (Tuesday) and last (Thursday) excursions.

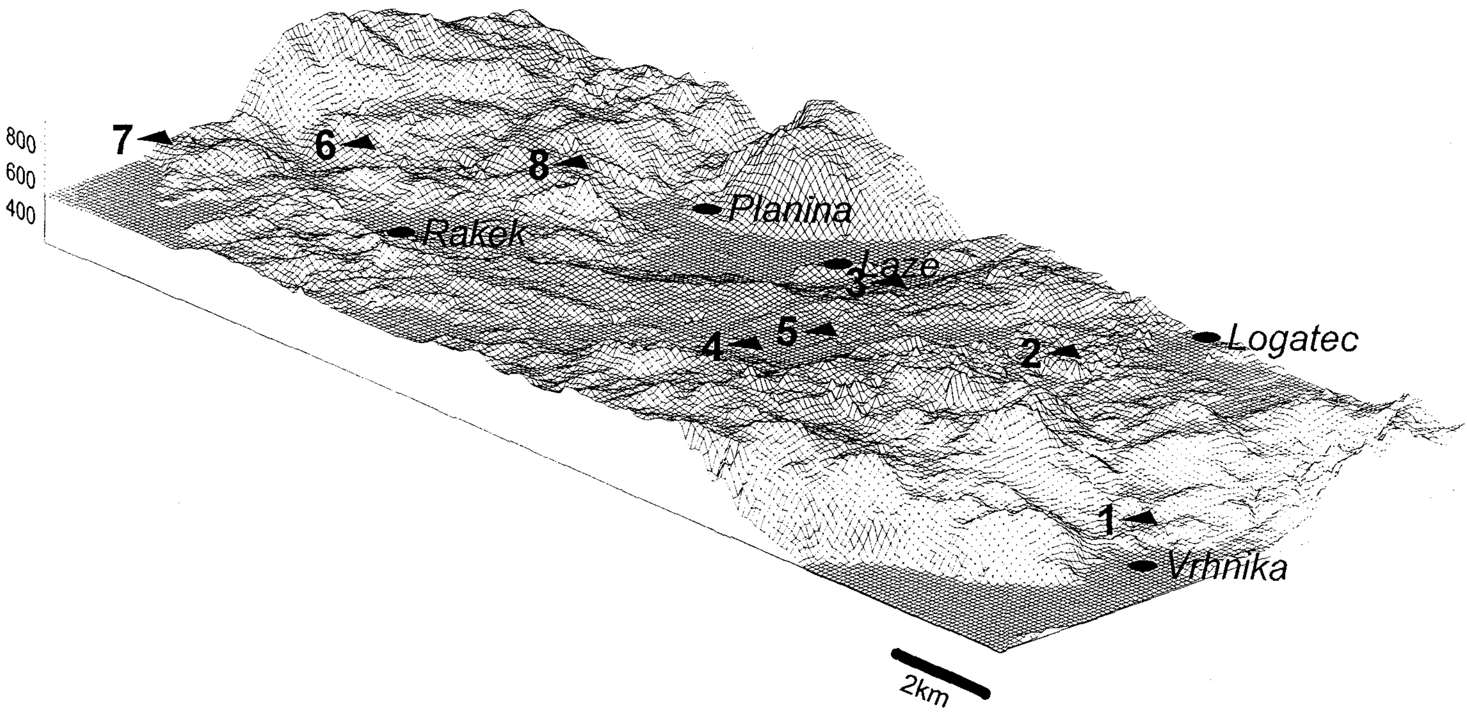


FIG.1 : Main part of the Ljubljanica river basin (DEM)

1. Colapse doline in the background of Ljubljanica springs
2. Logaške koleševke
3. Collapse dolines behind the ponor area of Planinsko polje
4–5. Rakovška kukava and Laška kukava in Laški ravnik
6. Rakov škocjan (Thuesday)
7. Šujica at the rim of Cerkniško polje (Tuesday)
8. Unška koliševka (Tuesday)

Another interesting view on the area is shown on Fig.2., which shows the cross-section between Ljubljana moor and Cerkniško polje and Pivka valley. Dolines close to Ljubljanica springs and those at the poljes rims are subjected to the water table fluctuations. Beside these, only the bottom of Laška kukava (not on the profile, No. 5 in Fig.1) reaches close to the water table.

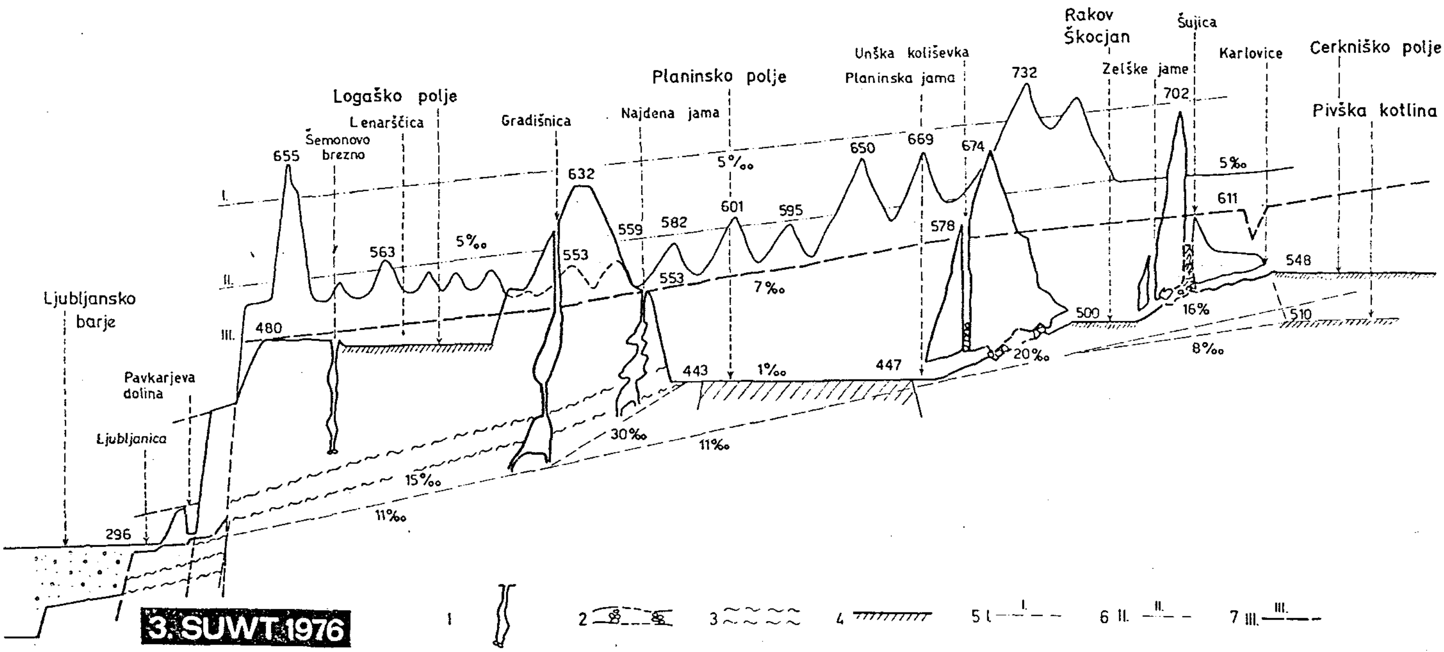


Fig. 2. *Longitudinal cross section of central part of Ljubljanica karst river basin.* 1 — active cave or pothole, 2 — unknown parts within known active caves, 3 — the supposed zone of former active caves between Planinsko polje and Ljubljansko barje (Ljubljana Moor), 4 — karst polje's bottom, 5 — Gradišče relief level, 6 — Bodiški vrh relief level, 7 — Dolina relief level.

FIG.2: Cross-section of the central part of Ljubljanica river basin (Habič,1976)

A SHORT DESCRIPTION OF THE SITES

1. Area of Lanski vrh

Lanski vrh area, bordering to the NE part of Planinsko polje is one of speleologically most explored area in Slovenia. Most common rock of the area is thick-bedded limestone ($K_{1,2}$). With more than 200 caves are registered there, the area has one of the highest numbers of cave entrances per square kilometre in the country.

The longest cave in the area Najdena jama (fig.3,4) is now more than 5km with newly discovered parts still being explored. The collapse in »Konglomeratna dvorana« of Najdena jama connects the cave to the nearby Vranja jama (fig.3), which opens to the surface as big collapse doline with vertical walls. An easy passable Skednena jama (fig.4) is situated between two collapse dolines. The opening in the thin roof leads to a 40m high chamber of Jama na meji (fig.4) which is the one with the closest relation to the term »collapse«. The filled passage in the cave is now being dig and explorers expect new parts of the cave in the near future.

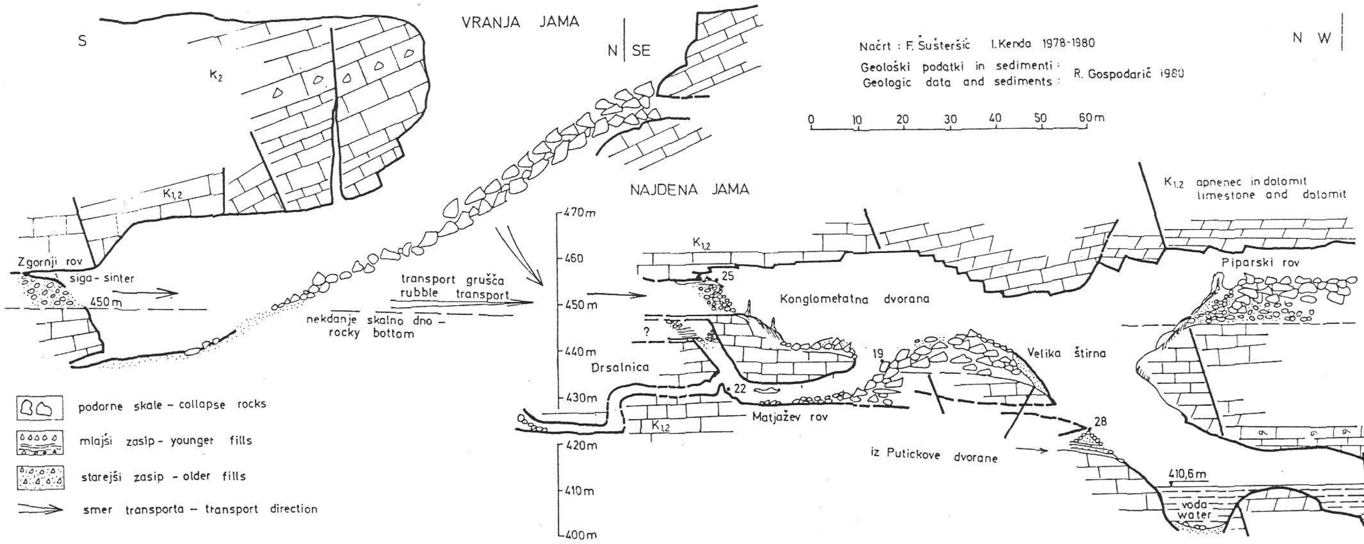


FIG.3: Vranja jama and a part of Najdena jama

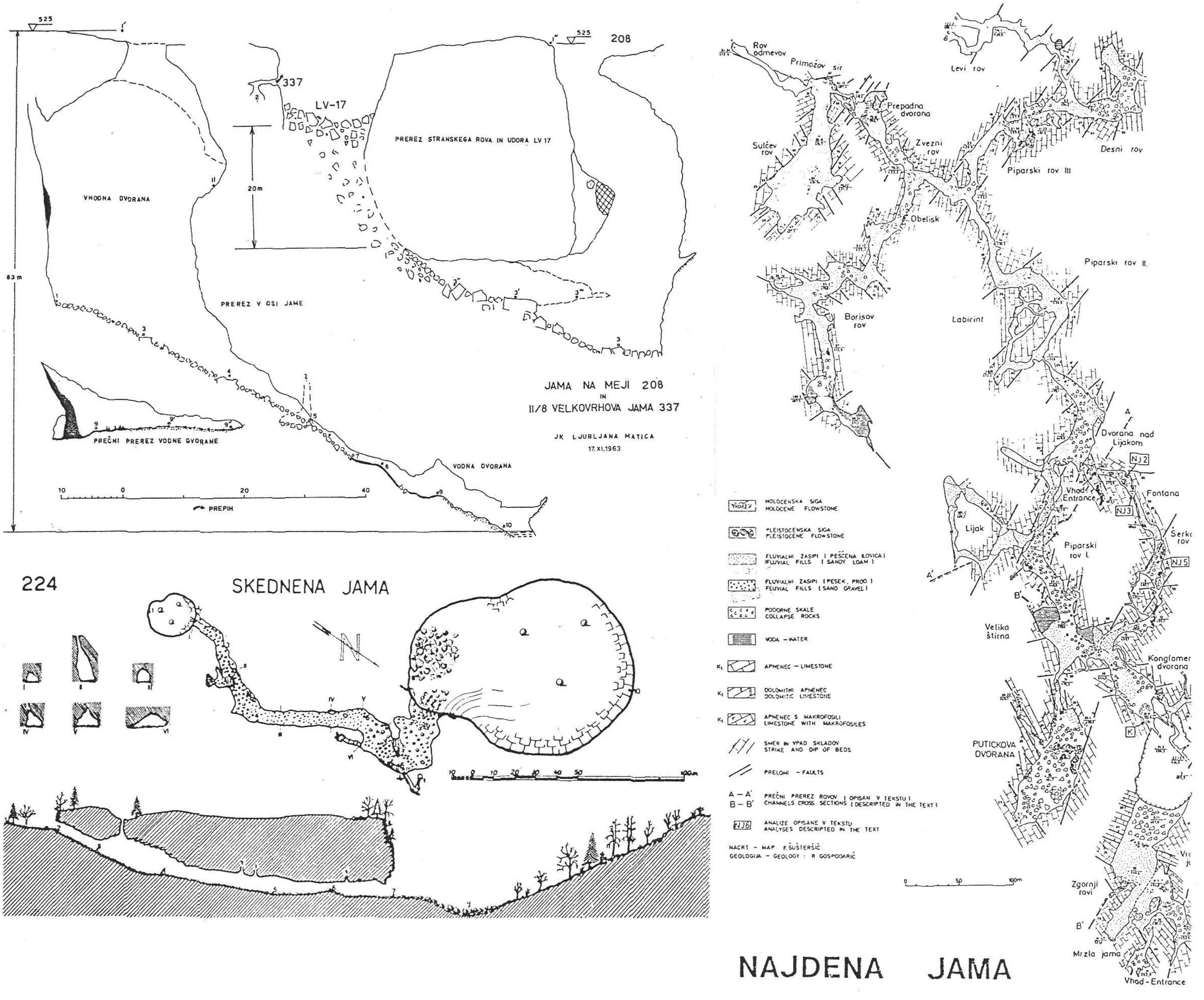


FIG.4: Skednena jama , Jama na meji, Najdena jama

2. Laški ravnik

Laški ravnik is central part of Logaški ravnik area E of Planinsko polje and NW of Cerkniško polje. All the surface of ravnik os covered by dolines. Beside many small dolines there are some large and deep collapse dolines We are going to see two of those: Rakovška kukava and Laška kukava. Fig. 5 presents the view on Rakovška kukava and its cross-section as marked on the projection.

The excursion will take us to the the bottom of Laška kukava is below the level of Planinsko polje. Relatively fresh depressions at the bottom show the recent deepening of the doline.

Rakovška kukava*

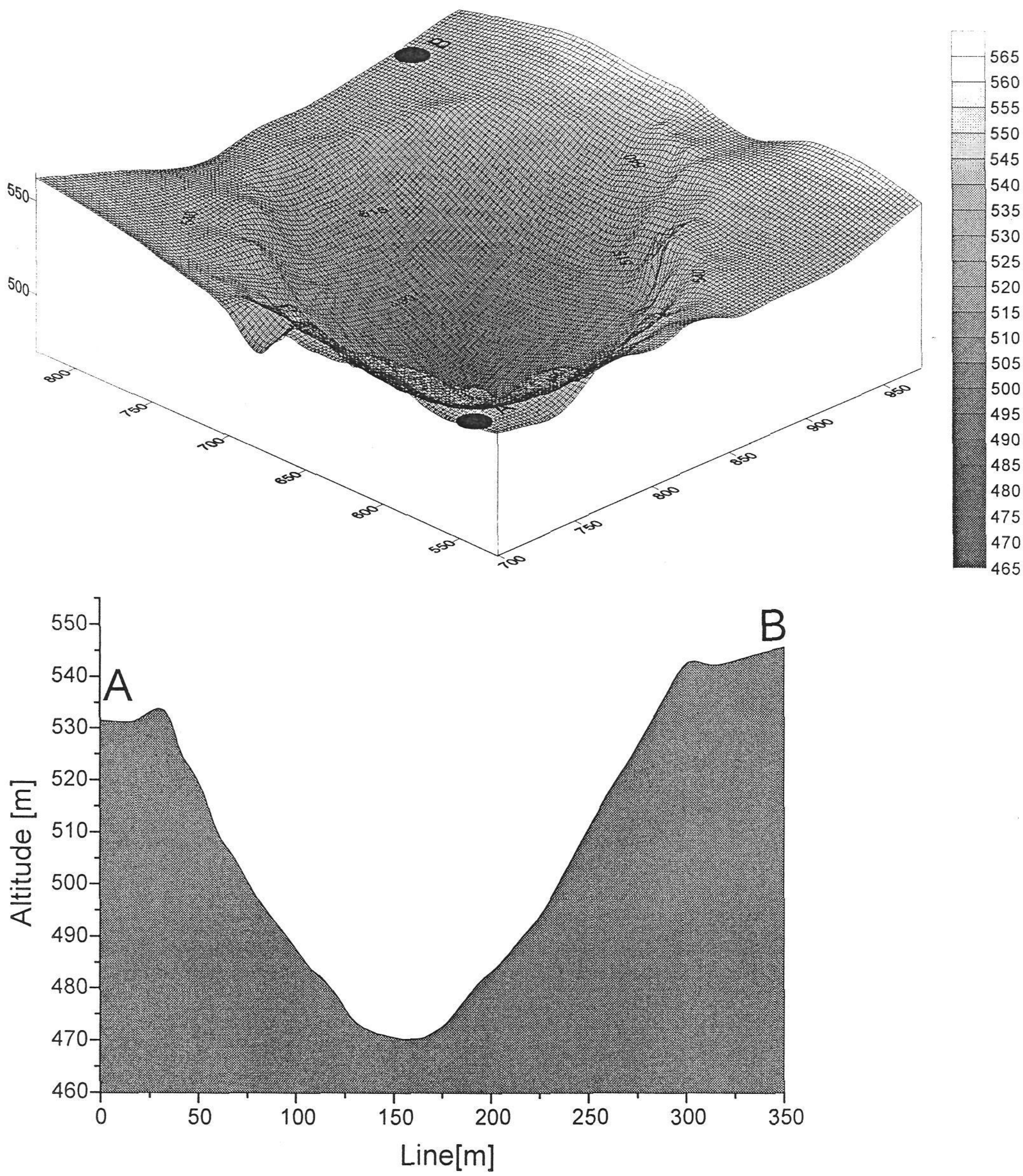


FIG.5: Rakovška kukava: prerspective view and the cross-section

Data Šušteršič (see also Šušteršič, 1997)

3.Logaške koleševke

At the SE part of Logaško polje an interesting set of collapse dolines called »Logaške koleševke« is located (fig.6 and 7).

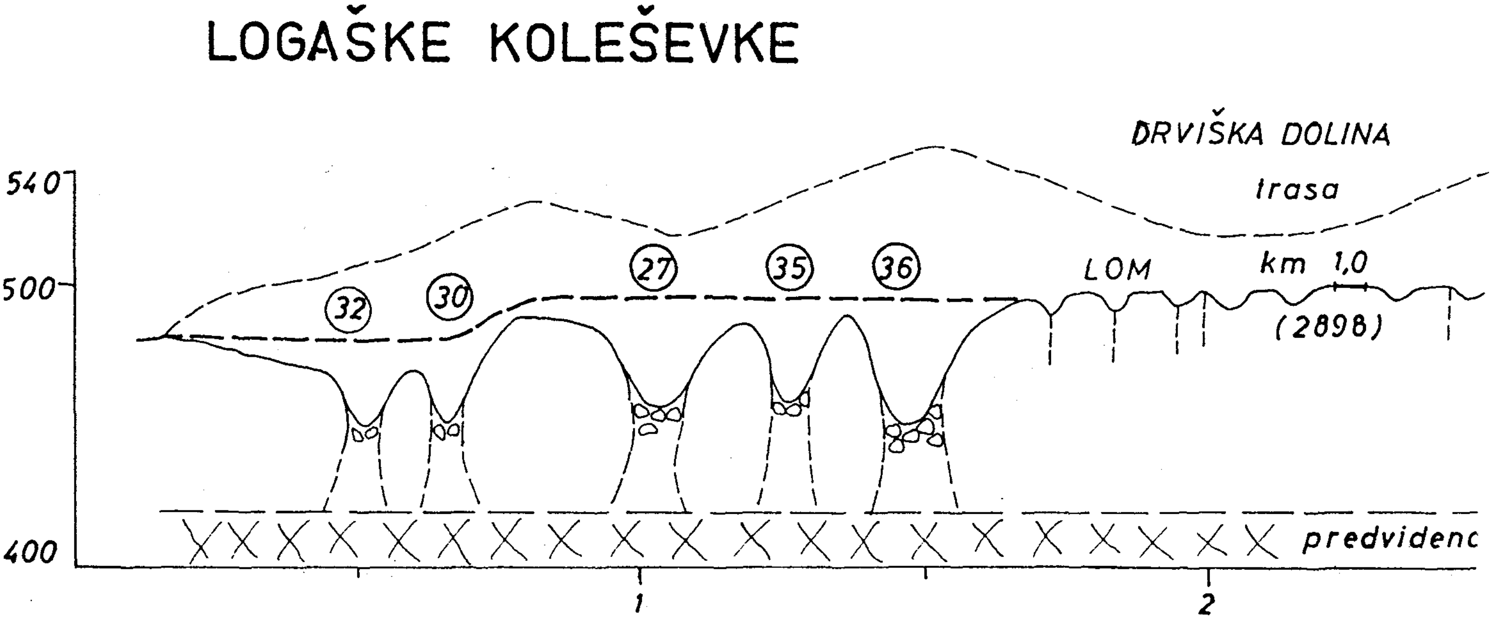


FIG.6: Logaške koleševke (the cross.section)

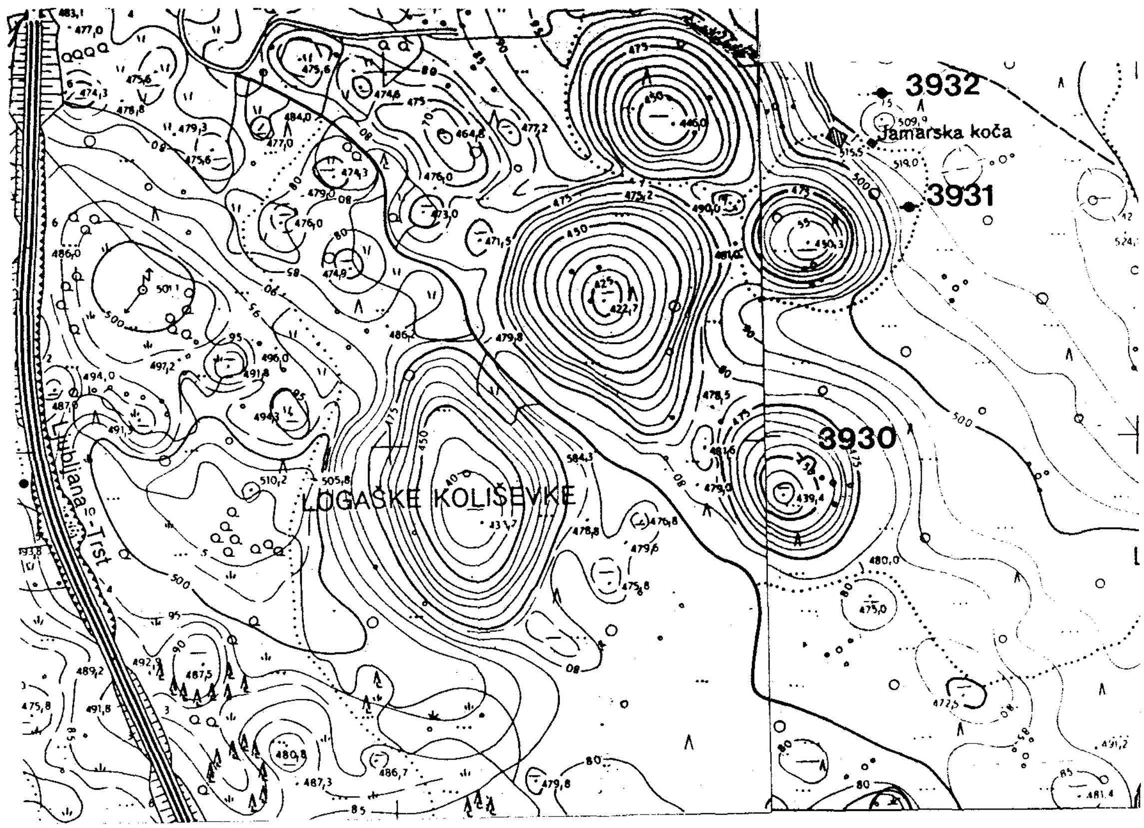


Fig.7: Logaške koleševke (1:5000)

4.The background of Ljubljanica springs

The springs of Ljubljanica are at the S part of Ljubljana moor in two sack valleys Močilnik and Retovje. In the background of these springs several large collapse dolines are situated (fig. 8). Bottoms of these dolines are just few meters above the Ljubljanica spring, therefore some of them are occasionally flooded, although the fluctuation of the watertable does not exceed few meters.

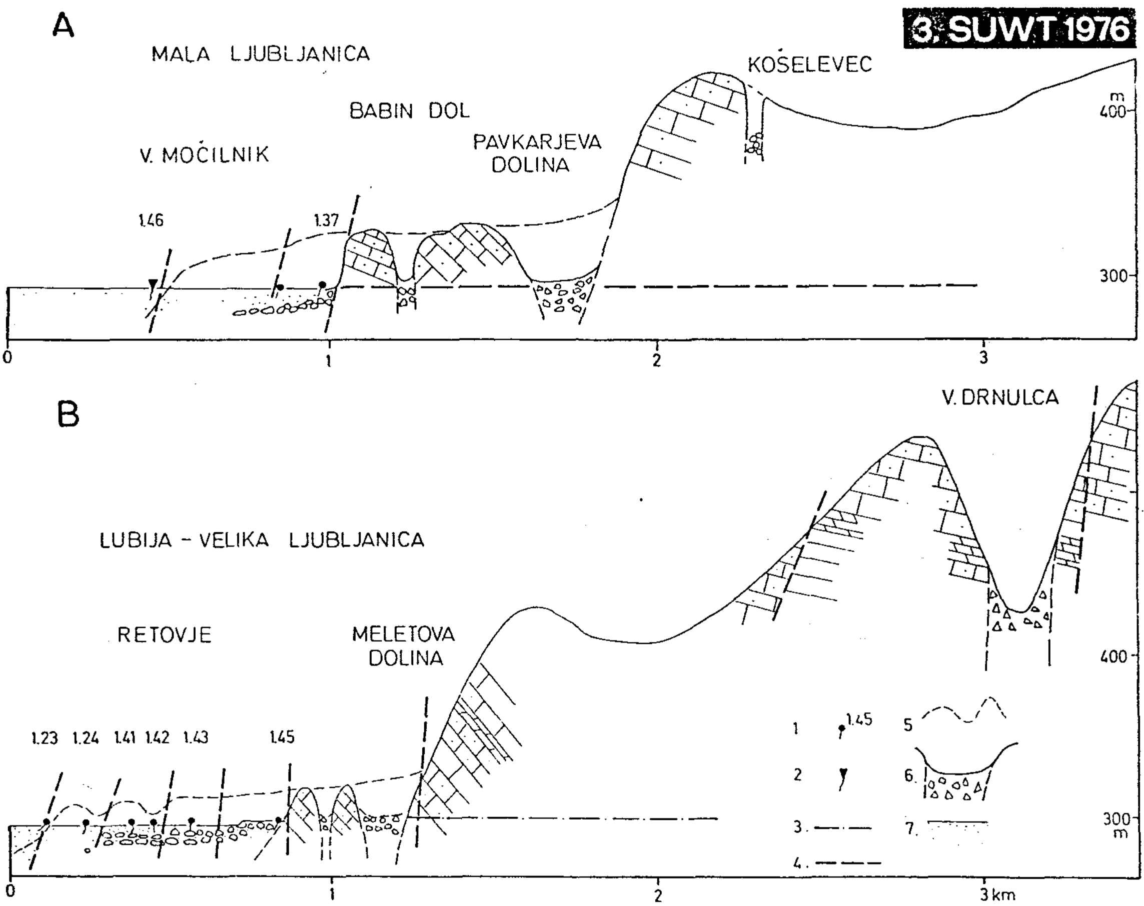


Fig. 4. *Ljubljanica springs restricted hinterland cross section, A-Močilnik, B-Retovje.* 1 — karst spring with number, 2 — thermal spring, 3 — karst water level, 4 — important fault, 5 — sketch of steephead, 6 — collapsed doline with breakdown rocks, 7 — Quaternary sediments on Ljubljansko barje.

FIG.8: The collapse dolines in the background of Ljubljanica springs

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ABSTRACTS OF THE PRESENTATIONS

SPELEOMOPHOLOGICAL CHARACTERISTICS OF THE AREA OF LIPNIK HILL (WEST CROATIA)

Neven Boćić
Speleological Society Karlovac - Croatia

Lipnik hill is situated in west Croatia, on right side of river Kupa (which is border between Croatia and Slovenia), about 15 km west from Karlovac. It is a part of Dinaridic mountain ridge, so it extand in direction NW-SE, in long of 10 km. Maximum width of Lipnik is 4.5 km. Exploring area extand 25.6 km^2. The highest peak of Lipnik is Goljak (481 m). Lipnik hill is made by limestone of low part of Createaceous period, with sinclinal structure.
At the exploring area 21 speleological objects are founded, explored and elaborated. The deepest one is 61 m deep, and the longest one is 146 m long.
Speleological object are classified in main morphological categories.
Microrelief forms made by corrosional-erosional proceses and made by sedimentation proceses (mechanical, chemical, organic) are observed.
Speleological object are formed in two litostratigraphic elements in Createaceous period (14 objects in neocomian limestones, 7 objects in barem-aptian limestones). This two litostratigraphic elements do not condition differences in morphological characteristic of objects. Dominants structure elements which are important for genesis of most objects are fractures which are diagonal on main structure direction (dinaric). Interbedded fissures are important in four objects. Hydrological conditions has influence on speleomorphological characteristic, too. There is suppose which object is the oldest, and which is the youngest. In analyse of Lipnik hill speleomorphology must be taken into consideration that speleological exploration are not still finished. It is real possibility of founding new speleological objects in future.

COLLAPSE STRUCTURES IN THE KONĚPRUSY AREA, BOHEMIAN KARST, CZECH REPUBLIC

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The karst developed in Lower Devonian (Pragian) skeletal limestones is characterized by numerous vertical and subvertical solution pipes with lithologically varied fill. Pipes (so-called karst depressions) are identifiable as „sinkhole-like“ forms on the surface. The intensive exploitation of limestones in huge quarries offers nice cross-sections through those karst forms. They are typically circular to ovate with diameter from 2-4 m up to tens of metres, sometimes they are divided by sharp ridges and cones. The walls are often overhanged and rarely they contain clear speleogens (e.g., niches, large-scale facets or phreatic half-copulas). The depth proved by geophysical measurements and drillings is several tens of metres. The bottoms of most of forms are still hidden in the depth. Some of them terminate by horizontal cave levels in the depth. This feature was typically observed in fifties and described by G.J. Kukla. At the present time, such features can be observed only rarely.
The pipes are filled with very complicated sequence of sediments in which collapse structures are visible. The sediments are represented by pre-Cenomanian weathering products in the lower part (varicoloured clays, sandy clays, etc.). The Cretaceous is represented by the Peruc Member (freshwater fluvial and fluvio-lacustrine deposits, Cenomanian), Korycany Member (marine sequence with glauconite, Cenomanian) and by the Bílá Hora Formation (marls, spiculites, sandstones, Lower Turonian) and locally also by Jizera Formation (sandstones, Middle Turonian). Cretaceous ages are proved by some paleontological finds and by lithological correlations. Cretaceous and pre-Cretaceous sequences are disconformably overlain by Tertiary sequences. The boundary of both units is often marked by paleosoil horizons. Tertiary sediments are composed of variegated and multicoloured sands, clayey sands and sandy clays, often intercalated by grey clays resembling weathered volcanic

tuffs. The Tertiary age has not yet been proved by any paleontological evidence. The youngest fill is reprezented by Quaternary screes, solifluction horizons and soils.
The origin of solution pipes is connected with the hydrothermal activity most probably during Paleogene to Miocene, when the surface of limestones was still covered by slightly eroded cover of Upper Cretaceous platform sediments. Hydrothermal karst forms developed up to the surface of limestones as the piezometric level was situated within the Cretaceous cover. After the lost of buoyancy support of water, sedimentary cover started to collapse down. Internal structures of the fill indicate multi-phase collapses. Cretaceous and pre-Cretaceous deposits are often subvertical with chaotic internal texture. In the centre of some of pipes, there are traces of younger collapses, most probably induced by continuing karstification and suffosion in the depth. Tertiary deposits overlay the Cretaceous ones disconformably, they show gentler centripetal inclination, but, in places, they fill the central parts of collapsed fill. Quaternary covers fill only very shallow structures.

REVIEW OF PALEOMAGNETIC DATA FROM CAVES IN SLOVAKIA AND SLOVENIA

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Since 1997 the Institute of Geology of the Academy of Sciences of the Czech Republic has been studying paleomagnetic properties and magnetostratigraphy of selected caves in Slovakia and in Slovenia. Although not representing the absolute (numerical) method, the paleomagnetic research appeared to be a good tool to decipher age of cave fills. The Brunhes/Matyuama boundary (0.78 Ma) is a principal correlation level.
The palaeomagnetic research in Slovakia brought important results changing up to date ideas on the age of the speleogenetical process in the most important cave systems of Slovakia. The research in the *Demänovská jaskyňa Slobody* followed the uranium series dating of speleothems in the whole cave system. Correlation of obtained magnetostratigraphic results, radiometric dating and river terraces of tributaries of the Váh River indicate definitively that there are both no real correlations of cave levels and river terraces as supposed earlier or river terraces of the Váh River have different age that interpreted up to now. The speleogenetical process was much older than supposed earlier. The research in the *Belianská jaskyňa* indicated the most complicated magnetostratigraphic structure. Sediments are substantially older than Brunhes/Matuyama boundary. Sediments are clearly older than the top of Olduvai zone (1.77 Ma). Therefore, the age of sediments is Early Pleistocene at least. The speleogenetical process had to be older. The research in the *Domica Cave* is only in beginning.
The application of the magnetostratigraphy to cave sediments of the Classical Karst (Slovenia) represented first dating attempts in relict and paleokarst caves. Sediments in them showed no paleontological content and the age of sediments was over the range of numerical dating. Dating of sediments in *Trhlovca Cave* and *Divaška jama* indicated Brunhes/Matuyama boundary and Jaramillo zone (1.07 Ma). Newly published data from *Postojenska jama* indicate the occurrence of reverse polarized sediments, too. Dates from *Divaška profile* and *Kozina profile* in the road cut of highway indicate that sediments magnetization is dominantly within reverse polarized zone with two normal polarized zones. Magnetostratigraphy of the *Černotiče profile* is even more complicated. We correlated those profiles as older than top of the Olduvai zone (1.77 Ma). Obtained magnetostratigraphic data older than Brunhes/Matuyama boundary clearly show the age of speleogenesis cannot be connected with Pleistocene climatic cycles and it is older. Fills of paleokarst caves are clearly older than about 1.7 Ma. The speleogenesis of fossilized caves was probably connected with very intensive paleokarst and speleogenetic phase related to the Messinian crisis and the fossilization with post-Messinian sea-level rise in the Mediterranean region.
The studies were interesting also from theoretical point of view deciphering some principal problems of magnetostratigraphy application in cave fills. Sedimentary fills of all studied profiles were separated into individual sequences and cycles divided by numerous evidences of breaks in deposition. Some breaks were expressed by erosion features (cut down of channels, intercalations of clays in speleothem sequences) and/or precipitation features. Some of magnetostratigraphic zones start or finish on such manifestations of unconformities. Such features prove enormously complicated deposition dynamics with numerous breaks in deposition and erosions caused that parts of original profiles can be missing; whole caves and cave systems can be even several times completely filled and exhausted. Therefore, unconformities within sedimentary profiles can hide a substantial geological time. The velocity of deposition cannot be calculated in such profiles. The time duration of individual magnetozones cannot be calculated, the geometric character of obtained magnetostratigraphic picture cannot be compared with standard scales, and the abundance of detailed internal division and scarcity

of fossils make the correlation of obtained magnetostratigraphic picture with standard palaeomagnetic scales problematic.

THICKNESS OF GYPCRETE, AN IMPORTANT FACTOR IN THE MORFOGENESIS OF SALT KARST

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South Iran (Zagros Mts., near the port Bandar Abbas) has been known for the occurrence of numerous salt plugs. They occur at different altitudes and in a different state of development (active, passive, ruins). The diversity of their environments is very favourable for the evaluation of the importance of morfogenetical factors. Three plugs were studied in detail, the plug on Hormoz Island (low activity), Namagdan plug on the Queshm Island (passive plug) and the Khurgu (high activity). It has been proven that irrespective of the plug activity and type of environment, specific karst forms are connected to a certain thickness of gypcrete (under the term "gypcrete" we include also semi-consolidated sediments covering the surface of salt plugs). We can distinguish four classes of different thickness of gypcrete, each with its special form of superficial and underground karst:

1) Salt outcrops without sedimentary cover

Rock salt outcrops occur only on steep (more than 50°) or vertical slopes and also at the bottom of steep canyons and gullies, where the residuum from salt dissolution has been washed out by precipitation. In salt outcrops, there is only superficial outflow. Sharp rillenkarren are typical for this environment.

2) Thin gypcrete (thickness 0.5-2 m)

Thin ferruginous gypcrete occurs on moderate to flat slopes from which thicker deposits were removed by erosion. This gypcrete is the result of current salt dissolution. The runoff is collected in small funnel-shaped dolines (diameter 2-8 meters) terminating in vertical solution pipes developed in rock salt. Hundreds of these dolines cover the whole area. Dolines are concentrated in flat uvala-like depressions (diameter 100-500m). After a short path through the underground, water re-emerges on the surface. The caves are short (length 10-300 m), with a small cross-section, and mostly there also are superficial bypasses several meters above the current cave level.

3) Gypcrete of moderate thickness (5-30m)

The gypcrete thickness of more than 2 m is mostly a result of a previous fluvial and marine activity (teracess, subrosion). The dolines have a similar shape as in the previous case, but they are noticeably larger (diameter about 20 - 50m) and their density is considerably lower. Small blind valleys occur.

4) Gypcrete of large thickness (more than 40 m)

In areas formed by thick gypcrete, karst forms are generally absent. The outflow is almost completely superficial. However, scarce but huge ponors (blind valleys with catchments about 0,5 - 2 km^2) occur. The largest caves in south Iran explored to date are all connected with such huge ponors (Ghár-e Daneshyu Cave -1909 m, Tří Naháčů Cave - 5010 m).

There is an important difference between classes 1-2 and the other classes, which considerably affect karstogenesis: In case of classes 3 and 4, the runoff is collected outside the contact with rock salt. Then the concentrated flow is moving quickly into the salt environment with nearly no NaCl dissolved. On the contrary, in cases 1 and 2, the flow down the salt walls on the surface and in solution pipes in dolines reaches saturation with NaCl very quickly.

Thin gypcrete enables the corrosion of salt and produces a dense network of smaller dolines. Massive and thick gypcrete enables water circulation only where disturbed. Places of infiltration are not so common, resulting in a more concentrated water flow from large catchment areas.

COLLAPSED DOLINES AS A CONNECTION BETWEEN THE KARST SURFACE AND UNDERGROUND (EXAMPLES FROM CROATIA)

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In the Croatian Karst there are a lot of examples of collapsed dolines. In the cases of four selected caves in different Croatian Karst areas (Dolačina mama cave – Žumberak Mt., Tamnica cave and Mrgića pećina – Kordun and Jama na Sredi cave – Cres Island) some geomorphologic elements and features of collapse process were analyzed (the influence of geological conditions and cave's stage of development, the morphology of collapse dolines and cave passages beneath them). The analysis confirms that a collapse is a significant component of cave development and that formation of collapsed dolines is an important indicator of Karst evolution.

CAVES BELOW COLLAPSE DOLINES - CASE STUDY OF THE TISOVA JAMA

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The cave Tisova Jama (-235 m) is located on Beljanica Mountain (Carpatho-Balkanides, Eastern Serbia). Its entrance pit is situated at the bottom of a great collapse doline (dimensions 180 x 160 m), below which there is a chamber with greatest surface (11 374 m2) and volume (approx. 170 000 m3) among so far known Serbian caves. Such dimensions can be explained by the presence of strong underground stream in the unreachable part of the cave. Removal of the material disrupts the stability of the rock below the doline, which leads to breakdown and deepening of the doline.
Key words: collapse doline, cave chamber, Beljanica, Carpatho-Balkanides

LARGE COLLAPSE DOLINES IN PUGLIA (SOUTHERN ITALY): THE CASE OF "DOLINA POZZATINA" IN THE GARGANO PLATEAU

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The paper deals with the description of the largest doline of Gargano (Puglia) in Southern Italy (675 m long, 440 m large, 130 m deep); aiming to suggest an interpretation of its origin and development, the surrounding karst forms and other large dolines of Puglia are described too.

GYPSUM-KARST COLLAPSE AND HYDROLOGIC EFFECTS IN THE NORTHERN BLACK HILLS, SOUTH DAKOTA, USA

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Gypsum and anhydrite are found in four stratigraphic units in the Black Hills of South Dakota and Wyoming, USA: in a large part of the Minnelusa Formation of Pennsylvanian and Permian age; in several horizons in the red beds of the Opeche and Spearfish Formations of Permian and Triassic age; and in most of the Gypsum Spring Formation of Jurassic age. Dissolution of gypsum in the Spearfish and Gypsum Spring has resulted in collapse and formation of many sinkholes in several areas that are presently undergoing urban development in the northern Black Hills. Dissolution of anhydrite in the Minnelusa at depth has produced a regional collapse breccia, many sinkholes, extensive disruption of bedding, and breccia pipes and pinnacles, some of which extend more than 300 m (1,000 ft) into overlying strata. Removal of anhydrite in the Minnelusa probably began soon after the Black Hills were uplifted (early Tertiary) and continues today. Recent subsidence is evidenced by sinkholes more than 60 ft (18 m) deep opening up within the last several decades, collapse in water wells and natural springs resulting in sediment disruption and contamination, and fresh circular scarps surrounding shallow depressions. Some of the sinkholes in the Spearfish Formation might be too large to be accounted for by dissolution of the relatively thin gypsum beds within the lower 200 ft (60 m) of that formation. They were more likely produced by the removal of much thicker anhydrite layers in the Minnelusa Formation, approximately 500 ft (150 m) below. Much of the calcium sulphate in the lower part of the Spearfish has been dissolved, many of the beds are contorted because ofexpansion due to hydration of anhydrite to gypsum, and many gypsum veinlets extend down from parent gypsum beds along random fractures. Thus, a secondary porosity and permeability has developed in the lower part of the Spearfish Formation, and contrary to present hydrologic interpretation, it is an aquifer, at least locally. Several sinkholes are sites of resurgent springs. These springs support fish hatcheries and are used for local agricultural water supply. As the anhydrite dissolution front in the subsurface Minnelusa moves downdip and radially away from the center of the Black Hills uplift, these resurgent springs will dry up and new ones will form as the geomorphology of the Black Hills evolves. Abandoned sinkholes and breccia pipes, preserved in cross section on canyon walls, attest to the former position of the dissolution front. Mirror Lake, which is expanding northwestward in a down-dip direction, is a local analog of a migrating dissolution front.

SHAFTS AND COLLAPSE DOLINES IN THE CONGLOMERATE KARST OF MONTELLO HILL (VENETIAN FORE-ALPS)

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The paper deals with the dolines resulting from collapse or from surface intersection of underground cavities in the messinian age conglomerates of the neotectonic morfostructure of Montello hill. The spatial distribution of these forms are also discussed and compared with the degree of karst development.

DOLINE DEVELOPMENT PROCESSES IN THE GLOBAL VIEW

Ivan Gams

In the globe dolines are dense mostly in the climatic temperate zone where precipitation prevails over the potential evapotranspiration and thus the doline depth development over the slope creeping processes. Inside of this belt the density of the doline decreases with the surface inclination. They are nearly absent where the slope inclination is above the angle of repose where the mass of unconsolidated material is less stable (32 - 38o) and where the slope processes prevail over the doline depth processes. After the first phases of doline development (subsoil doline, funnel-like doline) based on the local accelerated corrosion and drainage concentration in the more fractured rock, the larger bowl-like doline form prevails with the exceeded soil/rock interface in the "mantle"(of the geometric turned upside cone-form) over the area of plain surface inside of its upper rim. This doline development becomes the primary and normal and the collapse the secondary process. The deepening of the doline weakened with the getting the bottom soil in the pit thinner.
The speed of solution of different size of grains of carbonatic rock in rain and acid river water was simulated in the labour. Modifications of these basic postulates based on the main solution occurred by the soil moisture in the soil-rock interface are dealt with, too.

PATTERNS OF COLLAPSE CHAMBERS IN THE ENDOKARST OF MALLORCA (BALEARIC ISLANDS, SPAIN)

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The Majorcan endokarst is significantly characterized by a very wide extent of breakdown and collapse phenomena. Several types of endokarst-collapse features occur, both in the massive and micritic Jurassic limestones of the mountains as well as in the very porous Miocene calcarenites of the southern and eastern coast of the island.
Many well known caves in Mallorca are constituted by single breakdown chambers, open to the surface trough ceiling collapse or slope recession. But many others are the result of a progressive coalescence of breakdown voids connected randomly by mechanical failure. Such strings of large rooms and vault-like passages show wandering and erratic trends, rather than straight hydrological and tectonically guided ones (as could be expected).
In the first group some cenotes can be included, as the Cova de sa Gleda entrance pit and Cova des Serral, together with a few huge open-ceiling breakdown domes, like Avenc de Son Pou and Cova des Drac de Santanyi. Furthermore, several large macrochambers, difficult to recognize before surveying, due to the growth of speleothems that create partitions and smaller pseudochambers, also belong to this group; this is the case of Cova de Can Sion and Covota de sa Penya Rotja.
In the second group the great majority of Majorcan caverns can be included, like, among many others, Cova des Pont, Cova dets Ases, Coves dels Hams, Cova des Coll, Coves de Campanet, the celebrated Coves del Drac and, last but not least, Cova de sa Campana, the deepest cave system in Mallorca (-304 meters).
Endokarst collapse patterns can be described, studied and eventually explained on the basis of accurate cave-surveyings, because breakdown piles, sloped boulder floors, vault profles, dome structures and coalescence areas could be detected easily when mapped. Morphometrics of specific collapse features found in caves needs more additional work as a fundamental contribution to the knowledge of speleogenetic processes and endokarst evolution over time.

MECHANISMS AND KINEMATICS OF COLLAPSE DOLINES FORMATION AND DEVELOPMENT: THE STATE OF THE ART

Jerzy Liszkowski

Collapse of surficial materials into subterranean voids of any origin is the most catastrophic and hazardous type of subsidence, i. e., of ground surface deformations. Strongly localized and accidental, they may cause buildings and other engineering structures to failure, land to be removed from use and lost of life.
However, note that collapse is the final, surficial expression of a long-term continuous-discontinuous subsurface process of rock and/or soil failure only, which may persist hundreds to millions of years. Also the mechanisms of void formation and development may be very different even if we limite the discussion to natural collapses in karstic terrains, i. e., to sinkholes or collapse dolines.
Based on published data and authors own experiences, the paper discuss the mechanisms of sinkhole formation, the modes of cavity formation and enlargement, typical strain-time curves of the whole process of rock and/or soil failure and the possibilities of their prognosis and risk evaluation. Also the many factors, which influence or determine the geometry and kinematics of void enlargement up to the final sinkhole formation at Earth's topographic surface are listed and commentated.

SOME EXAMPLES OF COLLAPSE DOLINES IN THE APULIAN MURGE (SOUTHERN ITALY)

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The paper deals with some examples of collapse dolines in Apulia, southern Italy; the study area is located in the Alte Murge, a karst plateau which rises up to 686 m a. s. l. Following a geomorphological introduction to the area, the underground karst and the related surface landforms, the latter with particular reference to large-sized dolines, are treated. A review of the previous studies regarding karst landforms in the area is also presented. Then, the most important dolines, such as the Altamura Pulo, the Molfetta Pulo, and the Andria Gurgo, and the related caves as well, are described. The paper is intended to provide the first data on the Murge dolines; detailed study of surface and subterranean karst morphology, together with analysis of the local geologic and structural setting, will be the next steps of the research, aimed at a better understanding of the processes leading to genesis and evolution of the dolines.

COLLAPSED DOLINES IN REGIONS OF THE NORTH-EASTERN ALPS OF AUSTRIA.

Karl MAIS, Vienna

Collapsed dolines are remarkable features of the karst surface, they form the shape of the landscape. Their morphology and their development are mainly connected with fractured layers and the breakdown of huge cavities in the underground. Examples are given mostly from the classical Karst of Slovenia, even so in speleological books published in German such as KRAUS 1894, KNEBEL 1906, KYRLE 1923, TRIMMEL 1968, but also in BÖGLI 1978. In these publications the development of the phenomenon is described and illustrated with reference to »classical« objects and not to examples from the eastern Alps. Therefore we try to show some collapsed dolines from this region, describe their pecularities and point out the problemes of their development during time.

Examples are given from Dürrenstein, NÖ, Dachstein-Region, Totes Gebirge and also from the limestone Alps of Salzburg. The glacial overforming of the landscape, huge cave chambers in the underground and the further development of the karst morphology are discussed. Our aim is to find aspects for further fieldwork on alpine karst features as well for detailed reviews of previous studies. Another goal is the impelentation of the results with state of the art cartography.

COMTRIBUTION TO THE MORPHOGENESIS OF COLAPSED DOLINES ACCORDING TO HUNGARIAN AND CARPATIAN EXAMPLES

Janos Moga

In my paper I give a summary of the morphogenetical and morphometrical researches of some collapsed dolines found in the Carpathian range. With the help of structural-geological, tectonical, morphological and hidrogeological research I drow the development processes of the measured collapsed dolines (Udvarkő – Bükk mountain, Lednice szakadéka, Horpota – Gömör-Torna karst and the Csodavár (Cetatile ponorului) – Bihar mountain). With the help of the morphometrical measurements of the collapsed dolinas I show the most characteristic formal qualities as well as the role played by the crumbling and other denudation processes in the development of collapsed dolinas.

USING GEOGRAPHIC INFORMATION SYSTEM (GIS) TO DETERMINE GEOLOGIC CONTROLS ON THE DISTRIBUTION OF SINKHOLES IN THE OZARKS OF SOUTH-CENTRAL MISSOURI

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In an effort to understand the geologic controls on the distribution and development of sinkholes in the Salem Plateau of the Ozarks Plateaus Province, south-central Missouri, various statistical analyses, using a Geographic Information System (GIS) platform were performed to test hypotheses related to randomness, lithostratigraphy, geologic structure, topographic position, and slope. Area and point data for 2.613 sinkholes in two 30'x60' quadrangles were compiled on a 30 m grid. To understand the relationship to lithostratigraphic units, the percent area of sinkholes was calculated for five units, and it was determined that the Lower Ordovician Roubidoux Formation has the highest percentage of sinkholes with a slightly lower percentage in the overlaying Jefferson City Dolomite. A focal sum neighbor analysis was performed to see if the distribution of sinkholes had any clustering or linearity. A northwest trend to the Bolivar-Mansfield fault zone in south-central Missouri. In this area the Jefferson City Dolomite has a higher percentage of sinkholes relative to the Roubidoux Formation. Topographically, most sinkholes occur on the plateau areas and on gentle slopes (less than 3 degrees). Although sinkholes usually develop in the Roubidoux Formation on the plateau areas intense fracturing near regional fault zones may enhance their development in other units. A better understanding of the karst system in this area is important for land-use management including conservation of natural resources, ground-water management, and environmental protection. The study area includes potential economic lead and zinc mineralization within the Mark Twain National Forest.

PALEOMAGNETIC RESEARCH OF FOSSIL CAVE IN THE HIGHWAY CONSTRUCTION AT KOZINA (SLOVENIA)

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The construction of highway from Divača to Črni Kal (SW Slovenia, Classical Karst) uncovered a number of fossil caves and unroofed caves. One of them was situated near Kozina *(detailed situation to be completed)*. The fossil cave was roofless with rests of collapsed roof only in the upper part. It formed mild depression in the field. The sedimentary profile in cave was more than 4 m high. It was composed mostly of sandy sediments of light brown to ochreous color. Clayey and silty intercalations occurred, too. Sediments contained dynamic structures and textures (lamination, cross-lamination, etc.). Erosional surfaces divided the profile into individual sequences.

Totally 38 samples were taken from the profile, only one from them was cemented. Samples were demagnetized by alternating field (AC) at 10 to 1,000 Oe. The cemented one was demagnetized by gradual thermal process from 80 to 560 °C in the MAVACS apparatus. Individual components of remanent magnetization after the demagnetization by alternating or thermal field were detected by multi-component analysis by the Kirschvink method. Detected remanent magnetization in a natural state varies between 95 and 36,470 pT, values of volume magnetic susceptibility are from 55 to 998.10^{-6} SI. Rocks are low or medium magnetized. Normal and inverse polarization was detected after demagnetization. Some samples showed expressive viscose component (up to 90 %); the primary component of magnetization and resulted polarity could not been stated therefore. The profile contains

inverse and normal polarity magnetozones. The character of distribution of magnetozones is similar to the previous locality of Divača profile (fossil cave in road cut at Divača). The age of the profile at Kozina is older than Bruhnes/Matuyama boundary (0.78 Ma). According to arrangement of individual magnetozone, it could be stated that sediments are older than the top of Olduvai chron (1.77 Ma), as the magnetostratigraphic profile at Kozina terminates by reversed polarized magnetozone and contains two normal polarized zones.
The profile can be correlated with the Divača profile, not only from the paleomagnetic point of view, but also from lithological point of view. We suppose, similarly as in Divača, that the cave is a result of Messinian speleogenetic epoch and its fossilization was connected with rapid base level uplift after refilling of the Mediterranean basin by water. If this hypothesis is close to reality, the fossilization process can be dated from about 5.2 Ma up.

COLLAPSE STRUCTURES GENETIC MODEL OF MALLORCA UPPER MIOCENE

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Miocene carbonates (Upper Tortonian-Lower Messinian) in Mallorca Island, are composed of reefal (Reef Complex) and shallow carbonates (Santanyí Limestones) that prograded across platforms sourronding paleoislands. The contact between the Reef Complex and the Santanyí Limestones is a subaerial erosion surface with Paleokarst features. The shallow-water carbonates beds both the lagoonal beds of the Reef Complex and basal beds of the Santanyí Limestones, are affeted by V-collapse structures produced by roof collapse of caverns developed in the underlaying Reefal Complex. Recent work on these carbonate platforms allows to propose a genetic model to explain the origin of these V-structures, that are related to early diagenetic processes induced by high-frequency sea-level fluctuations, the same sea-level fluctuations that controlled the facies arahitecture of the carbonate platforms.
During sea level lowstands cave system developed at the water table near the subaerial surface. During subsequent rise of sea level, the roof of the cave collapsed as result of increse of loading by aggradation of the overlaying shallow-water carbonates. This collpase produced V-incasion structures when these beds were not completely consolidate collapsed in the cavity. The cave system developed by preferential dissolution of aragonita (mainly corals) in the reef facies and coral patches existing in the outer lagoonal beds of the Reef Comoplex.
Key words: Collapse structures, Upper Miocene, Santanyí Limestones, Palleokarst, Coral reef.

EXAMPLES OF RECENT KARST COLLAPSES IN THE VENETIAN FORE-ALPS

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The paper deals with models of solution and collapse dolines applied to some typical morphostructural settings of Monti Lessini and other fore-alpine mountain groups; some recent collapses are described.

(No title)

Szabolcs Leel-Ossy

Paper presents speleological, mineralogical and other features of crystal caves which were exposed in a limestone quary in the souther Hungary.

IS VELIKA JERŠANOVA DOLINE A COLLAPSE DOLINE ?

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The Velika Jeršanova doline (a.s.l.=535 m) is situated on the surface above the Postojnska Jama cave system. Its deepening disconnected the continuation of Pisani rov (a.s.l.=535,5 m) towards North. The Velika Jeršanova doline doesn't have a typical shape of collapse doline. Regarding its gentle slopes it's better to call it collapse doline with gentle slopes, although it's collapse doline due to the formation. The crest of Postojna anticline runs in Northern edge of Velika Jeršanova doline. Strike and dip of thin

bedded Turonian and Cenomanian limestones are disorderly on anticline's crest. Limestones are dipping for 5-20^0. Principal tectonic structures are Dinaric oriented.
The upper edge of the collapse doline includes the area of 325x300 m. The highest edge is at the altitude of 575 m, what is 40 m higher than its bottom. Slope gravel covers the SW slope of collapse doline. The bottom of collapse doline is covered with thick red clay sediments. The formation and shaping of Velika Jeršanova doline is directly connected with the formation of collapse chamber Velika gora and with collapse in the passage of Čarobni vrt.
One of the causes for untypical collapse shape of Velika Jeršanova doline is its formation in thin bedded clay rich limestones what causes less expressed morphological shapes and more gentle slopes. The difference between collapse doline and collapse doline with gentle slopes is in the degree of tectonically crushed rocks. The most intensive formation of collapse dolines is due to the lowering of underground water.

REMARKS ON COLLAPSE AND COLLAPSE-LIKE FORMS IN CARBONATE KARST (ON BASIS OF ABISSO DI TREBICANO AND GROTTA GIGANTE IN CLASSICAL KARST AND PALAEOKARSTIC FEATURES IN POLAND)

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Based on fundamental studies of denuded caves made by A. Mihevc and co-workers and speleodestructive processes in caves made by F. Šušteršič on Classical Karst, as well as author's experiences from caves in Italy and palaeokarstic sites in Poland the problem of collapse and collapse-like forms origin is discussed. Examples of Trebicano Abyss and Grotta Gigante in the Trieste Karst were examined to explain the transformation of big cave chambers to the part of surface morphology – collapse-like forms in shape, without or with small participation of cave breakdown processes. The presence of big cave chambers, as in the Grotta Gigante, in zone of influence of epikarstic processes may testify possibility of development on surface forms with shape similar to collapse doline but resulted of continuous destruction of speleologenetic space and denudation. In some places of mentioned chamber well-defined epikarstic features occur and they are placed on phreatic forms.
The basic aim of the paper is to present the role of denuded caves and shafts, filled by cave internal sediments and covered by glacial and fluvio-glacial sediments in the development of collapse-like dolines in several areas of the Silesian-Cracow Upland in Poland. The top layer of the Triassic carbonate rocks of this region is one of a good example of the polycyclic denudation surface, mostly covered by Quaternary sediments. Main attention has been paid to the areas affected by mining and water exploitation, where induced collapse and collapse-like forms created. Processes of subrosion and suffosion as well as rare observed breakdown of cave fillings within the carbonate massif are one of possible way of collapse-like features origin.
Contribution to the morphogenetics of collapsed dolines according to Hungarian and Carpathian examples

THE REGULARITIES OF COLLAPSE DOLINES FORMATION UNDER THE CONDITIONS OF SULPHATE/CARBONATE COVERED KARST (BY THE EXAMPLE OF DZERZHINSK REGION, RUSSIA).

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In Dzerzhinsk region sulphate (P_1) and carbonate (P_2) rocks are buried at a depth range of 30 to 70 m beneath the ground surface. Above them there are clay (P_2) 0...20 m in thickness and alluvial sands (Q) 20...60 m in thickness. The main karst failures on the ground surface are collapse dolines. The regularities of their formation and development are investigated during more than 50 years.
In the process various methods are used: field inspection, laboratory modelling of karst collapse, probabilistic methods. It is emerged that the sinkholes quantity distribution in time follows the Poisson's law but sinkhole diameters distribution is close to normal or lognormal law. On this basis collapse danger for building and exploitation of structures is estimated in most cases. By the mechanism of collapse formation three types of collapses are differentiated: collapsing, piping, collapsing/piping.