

FOURTH INTERNATIONAL CONFERENCE ON GEOMORPHOLOGY - Italy 1997

Guide for the excursion

CLASSICAL KARST

Meeting Ius 1997 in Italy, Postojna-Bologna, August 24-28

F. CUCCHI ⁽¹⁾, A. MIHEVC ⁽²⁾, F. FERRARESE ⁽³⁾ & U. SAURO ⁽³⁾

PREFACE

The field seminar is part of a symposium on Classical Karst organized in connection both with the International Congress of Speleology and with the International Conference of Geomorphology. Aim of the symposium is to give a chance for a debate on the state of the art of the knowledge and ideas about middle latitude karst environment and features with special reference with the Classical Karst region, that represents the «holotype» of karst. A schematic program of the meeting is outlined below:

Monday, 25.8.1997

Keynote: D. Ford: *Development of ideas about karst* and A. Kranjc: *Kras - Classical karst and development of karst science*.

Discussion and presentation of papers.

Excursion to Karst depressions of Matarsko podolje karst and surface morphology and caves of Skocjanske jame.

Tuesday, 26.8.1997

Keynote: P. Williams: *Hydrological processes and morphological development: the connection between process and form in the evolution of solution dolines*.

Discussion and presentation of papers.

Excursion to Karst poljes and caves of Ljubljana river basin.

Wednesday, 27.8.1997: Man and karst

Keynote: J. Gunn: *Problems of the karst resource management*.

Discussion and presentation of papers.

Excursion to Grotta Gigante cave and their epygean karst.

Thursday, 28.8.1997: Excursion to Montello karst in the Venetian Fore-Alps and transfer to Bologna.

GUIDE BOOK FOR THE FIELD SEMINAR CLASSICAL KARST

Classical Karst is a region situated between the Bay of Trieste and the Ljubljana moor, which name took origin from the root «Kras», that means «rock». Here early research and study started on «Karst type environment»; early models and theories about karst appeared and features such as karst polje and doline were described for the first time.

Classical Karst belongs to the catchment area of two large karst rivers, to Reka and to Ljubljana river and will be the subject of two short and one longer excursion.

MATARSKO PODOLJE AND BLIND VALLEYS OF BRKINI HILLS (Monday, 25.8.1997)

Main points of interest of the excursion are the Matarsko podolje corrosional plain at Markovscina, edge of Brkini hills, Odolina blind valley, Skocjanske jame cave and denuded caves above it and Risnik collapse doline.

(1) Istituto di Geologia dell'Università di Trieste.

(2) Institut za Raziskovanje Krasa, Postojna (Slovenia).

(3) Dipartimento di Geografia dell'Università di Padova.

F. Cucchi will lead the fieldtrip in the Grotta Gigante cave and their epygean karst, Andrej Mihevc will lead the fieldtrips in the karst depressions of Matarsko podolje karst, surface morphology and caves of Skocjanske jame, karst poljes and caves of Ljubljana river basin, F. Ferrarese and U. Sauro will lead the fieldtrip in the Montello karst in the Venetian Fore-Alps.

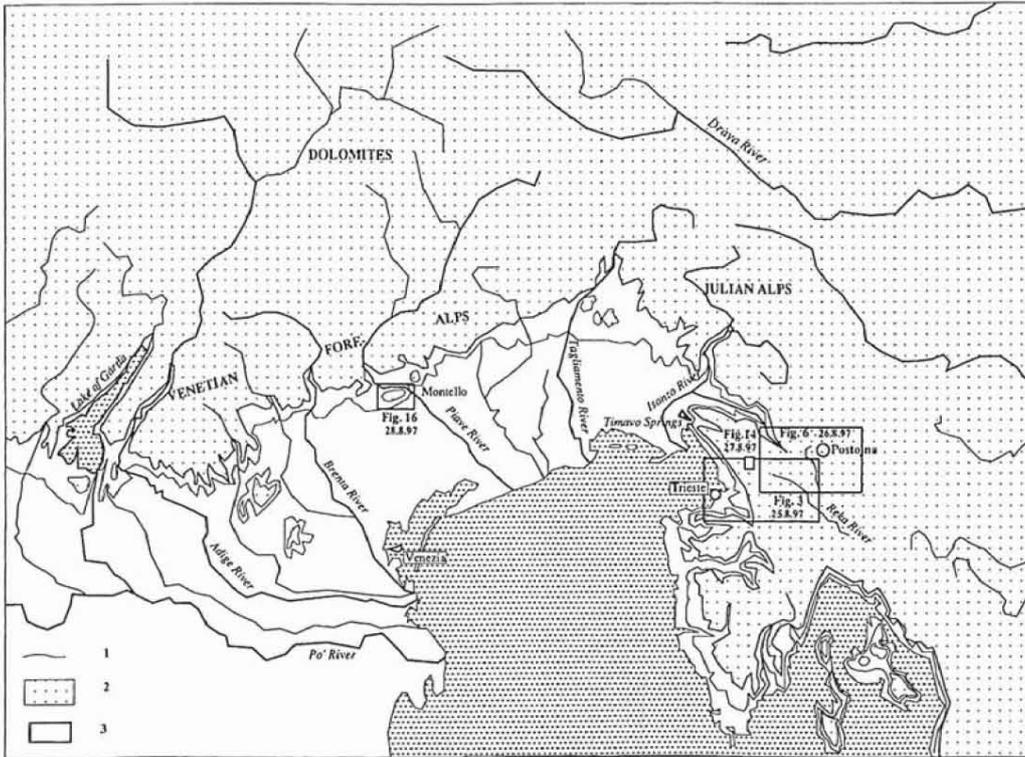


FIG. 1 - The Classical Karst Excursions routes (the sketch encompasses an area of about 400 x 300 km).

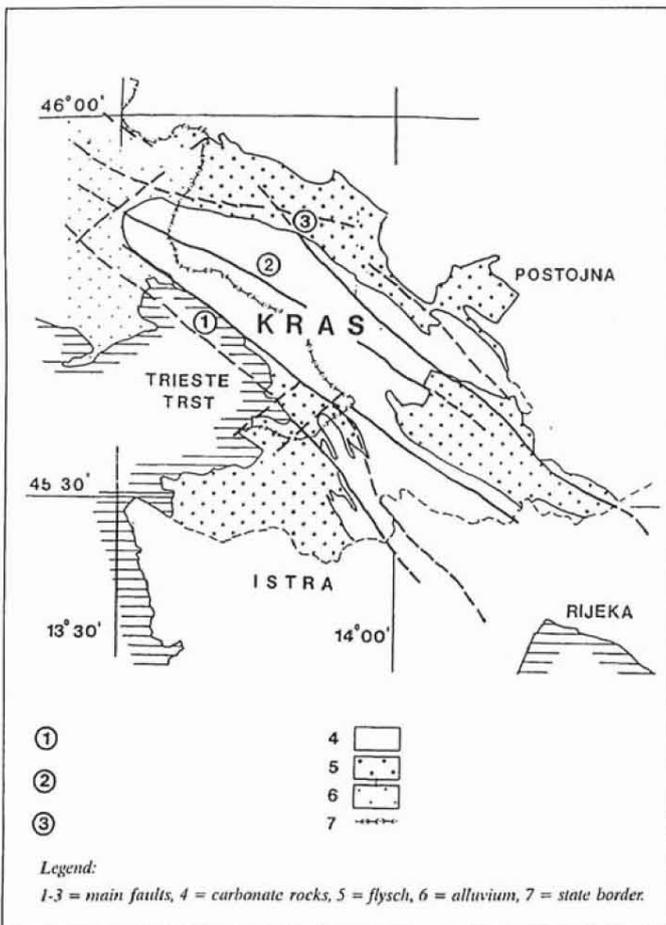


FIG. 2 - Location and position of Kras.

1a. KRAS

Kras is a limestone plateau, lying above the Trieste bay, the northernmost part of the Adriatic Sea. The 45° 45' N parallel and the 14° 00' meridian east runs through the middle of the Kras. Mediterranean influences are improved by its northern position and by the altitude.

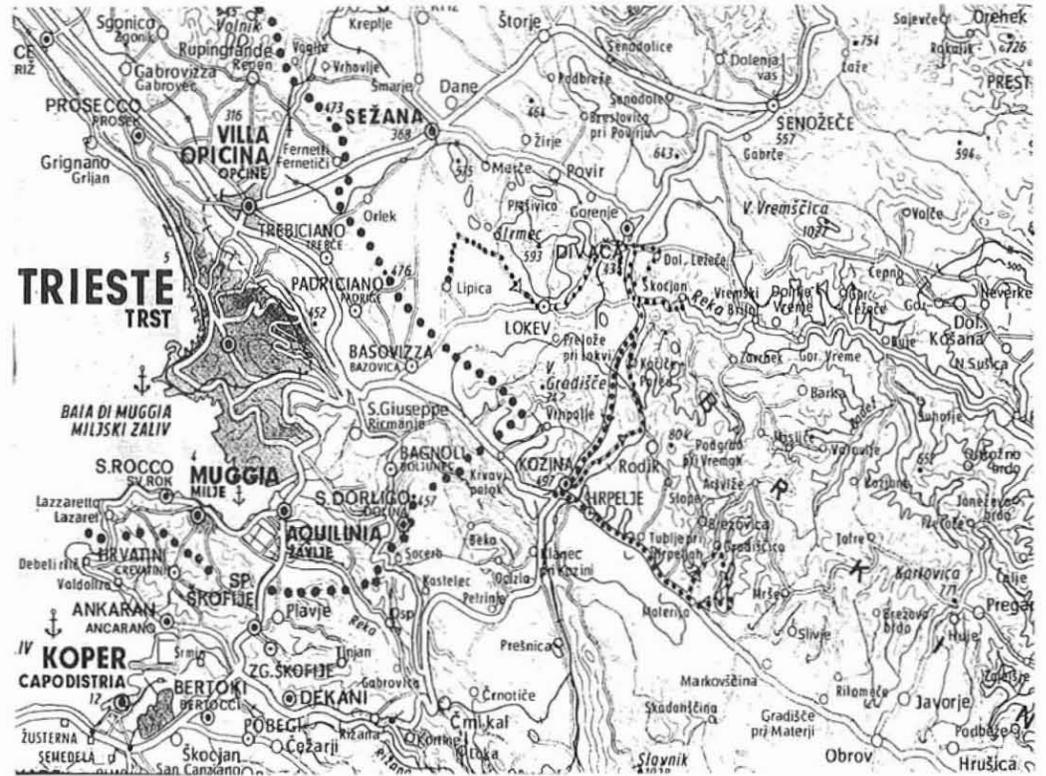
Kras (Carso) is physiographically well individualised regarding the surrounding regions. Trieste Bay and the low lying flysch (impermeable) country bound it at SW. To the NW it is surrounded by alluvial Friuli (river Soca - Isonzo) plain. Its NE side ends above the broad and low lying (100 m a.s.l.) alluvial and flysch Vipava valley. High (over 600 m a.s.l.) flysch relief separates Kras from the Pivka region. Towards SE the border of Kras can be well defined by flysch Brkini hills and Reka river valley, while towards the limestone ridges of Cicarija, Podgorski Kras plateau and Matarsko podolje valley the transition is less obvious.

Kras plateau is stretching in «Dinaric» direction (NW - SE), it is 40 km long and up to 13 km wide, covering about 440 km², sloping towards NW (Lokev to SE is 450 m a.s.l., Smartin - San Martino del Carso to NW is 168 m).

2a. MATARSKO PODOLJE

20 km long and 2-5 km wide corrosional plain Matarsko podolje gently raises from about 490 m on NW to 650 m on SE side. On the NE edge Palaeocene and Cretaceous limestone of Matarsko podolje are in contact with non-carbonate flysch rocks of Brkini Hills.

FIG. 3 - Excursion route Karst depressions of Matarsko podolje karst and surface morphology and caves of Skocjanske jame.



From flysch hills to the border limestone 17 separated sinking streams flow, draining 29.2 km² of the flysch area. Water basins of the sinking streams vary from 0.5 km² to the biggest 13.2 km². Some ponors allow to enter accessible caves ending by the siphons of captured water in the altitudes between 370 to 430 m. The deepest cave is 150 m deep, and the longest is 6 km long. There are more than hundred non active caves in the karst plain and in one cave only the water could be reached at the altitude of 350m.

Brooks developed blind valleys with bottom elevations between 490 to 510 m. As the karst plain is rising towards SE, the valleys lying more to the south are deeper, the deepest more than 200 m.

The development of the relief depressions along contact was controlled by the karst water level at altitudes of about 500 m. Bad permeability of the karst caused the deposition of the sediments in front of ponors and the deposits affected the planation and corrosion of the bottom of the blind valleys. The sedimentation was extremely intensive in the cold periods of the Quaternary and these deposits are preserved on the bottom of most of the blind valleys.

In actual conditions the karst water table stays deep under the altitude of the blind valley bottoms. The bottoms of the blind valleys are out of reach of the floods of the sinking streams in front of ponors and the gradient in the karst is so big that the old deposits from the surface are washed off into the karst by the suffosion processes.

3a. ODOLINA BLIND VALLEY

The blind valley was formed by the sinking stream draining 4.3 km² and having a discharge of about 15 l/s. Narrow fluvial valley on flysch widens on the limestone forming 1 km long and 300 m wide blind valley. Close to the contact it is 150 m deep and on the southern end it is deepened into the karst plain for about 60 m. The valley's bottom is covered by the alluvial sediments, gravel and sands. Flood plain is cut by some younger, up to 25 m deep alluvial dolines, ponors and sinkholes of the brook, sinking in the final part of the valley. In the sinkholes and in the riverbed the rocks are exposed having the relief below the sediments ranging up to 20 m.

During the normal water level the brook sinks in the riverbed immediately after the passage to the limestone, during normal water level it flows into 117 m deep ponor cave composed by potholes and shorter channels. The cave morphology is basically phreatic with strong traces of vadose transformation. It ends by the siphon of caught water on 370 m a.s.l.

4a. SKOCJANSKE JAME CAVES

Skocjanske jame were formed by the Reka sinking river in Palaeocene and Upper Cretaceous limestone. After reaching carbonate terrain from Eocene flysch, the Reka river (8.9 m³ mean discharge) incises in a 2 km long canyon and finally, under 100 m high, vertical limestone disappears

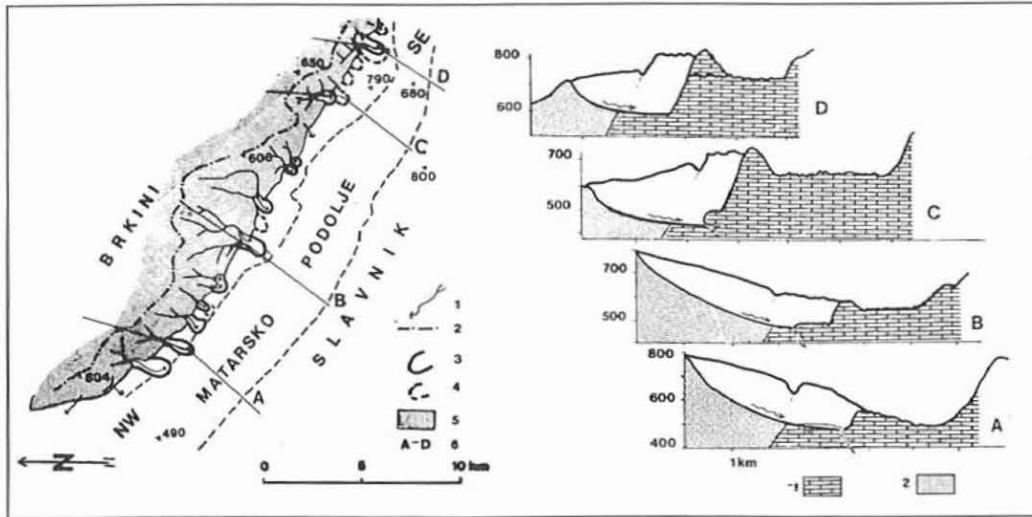


FIG. 4 - Matarsko podolje and blind valleys (Mihevc, 1993). Legend: 1) sinking river, 2) watershed, 3) edge of blind valley, 4) non active, high blind valley, 5) flysch, 6) cross sections over blind valleys.

underground in elevation of 317 m a.s.l.. After sinking Reka reappears in the bottom of two collapsed dolines, Mala Dolina and Velika Dolina. In the western slope of Velika the Reka finally disappears underground.

Main active cave is represented by elliptic, to 30 m wide passages in elevations of about 330 m and a 100 m deep gorge cut in it. After 2 km approx. the main passage ends by a siphon at elevation 214 m. Beyond the siphon the passage continues towards Kacna Jama, about 1,5 km far. In front of siphon lies the chamber Martelova dvorana. Its dimensions being 308 x 123 x 146 m and estimated volume of 2,1 million m³ it ranges among the biggest underground chambers in the world.

Škocjanske Jame is a very important cave from cultural and technical point of view. There are the remains from Mesolithic Period on. Škocjanske Jame were mentioned in antiquity already. The first attempt of water tracing is documented from 1599. In 1819 a part of the caves was displayed for tourist visit. In 1839 the underground water passage started to be explored; in 1890 the explorers reached the final siphon dived by the cavers only in 1991. In 1986 the caves were inscribed in the List of World's heritage of Unesco. From the last century the remains of pathways are preserved, a sort of technical monument. A good example are the rests Macja brv (Cat's Walk) spanning across the river at the height of 90 m.

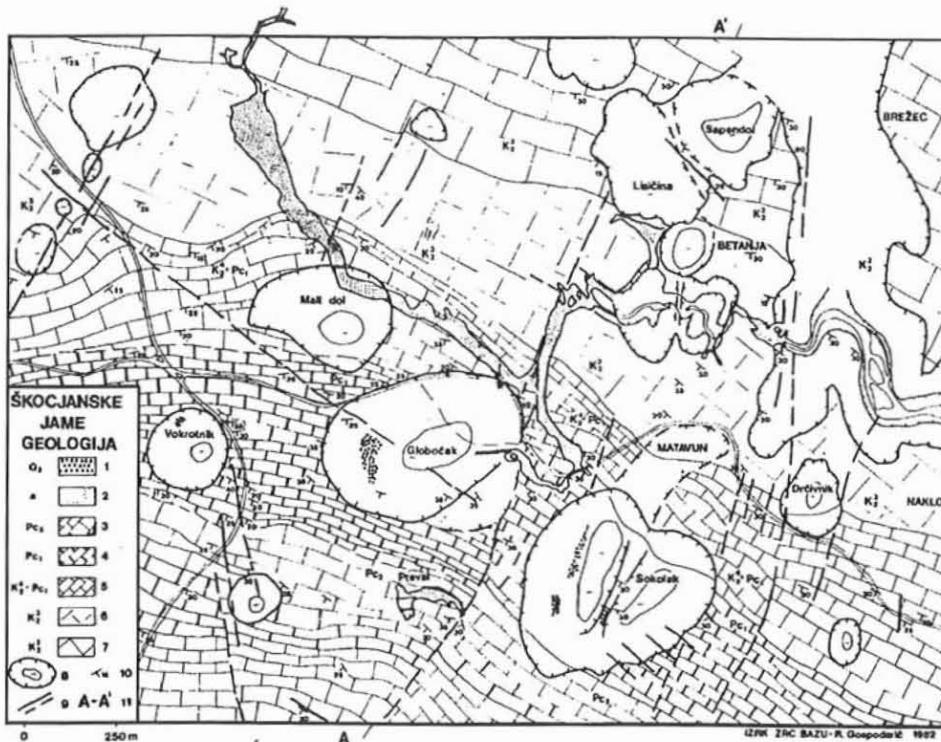


FIG. 5 - Geology and main surface and underground features of Škocjanske jame caves (Habic & alii, 1989).

5a. UNDERGROUND FLOW OF REKA RIVER

The surface Reka river discharge vary from 0,16 m³/s the medium 8,95 and the highest above 387 m³/s. After sinking in Skocjanske jame it flows for 41 km underground and appears in on surface as Timavo river.

In Skocjanske jame we can follow the underground Reka for about 3 km, from 317 m to 214 at the terminal sump. Only 1000 m NW, in the cave Kacna jama Reka flows in galleries at 182 m and disappears in a sump at 156 m. During floods, the piezometric levels rise of about 90 m.

In the Trebiciano cave, 13 km from the entrance to Skocjanske jame the Reka appears at 12 m reaching during floods the elevation of 115 m. Further downstream, 5 km from the springs we can reach the piezometric level at 4 m elevation respectively. In the Timavo spring area, several caves reach the saturated zone at the same elevation of the springs which are 2 m above sea level.

6a. KARST SURFACE ABOVE SKOCJANSKE JAME

The mainly planated karst surface stands at the elevation of about 430 m and is dissected by numerous dolines and collapsed dolines.

Usual dolines are 50-100 m in diameter and are about 10 m deep; there can be more than 200 dolines per km². Volume of dolines vary between some thousand m³ to several tens of thousand m³.

Larger dolines are supposed to have been originated by collapse phenomena. They are all situated in vicinity of the course of the underground Reka river. In the area there are 15 large collapse dolines, having an overall volume of more than 38 millions m³. Their mean depth is 55 m and mean diameter 200 m. Largest one, Globocak has 4,8 mill. m³, smallest one, Risnik has 1,4 mill. m³ of volume.

On the surface it is possible to recognize several remains of cutted caves. The largest is the remain of a 20 m wide gallery in Lipovih dolinah, above Skocjanske jame cave. Gallery floor is in elevation of 430 m a.s.l., and it is possible to be recognized for a length of about 550 m by the large speleothems and fluvial cave sediments. The ceiling of the cave is missing, cave volume was transformed to elongated dolines. In them we still find fluvial sediments, which were used as a proof of prekarstic surface river sediments by some older morphologists.

KARST POLJES AND CAVES OF LJUBLJANICA RIVER BASIN (Tuesday, 26.8.1997)

Excursion will stop in upper part of Pivka basin and on the high karst Javorniki plateau; in Cerknica polje at bottom and edge ponors; in Rakov Skocjan valley at natural bridges; on the Planinsko polje at springs and sinking points; in Postojna cave and lower part of Pivka river basin.

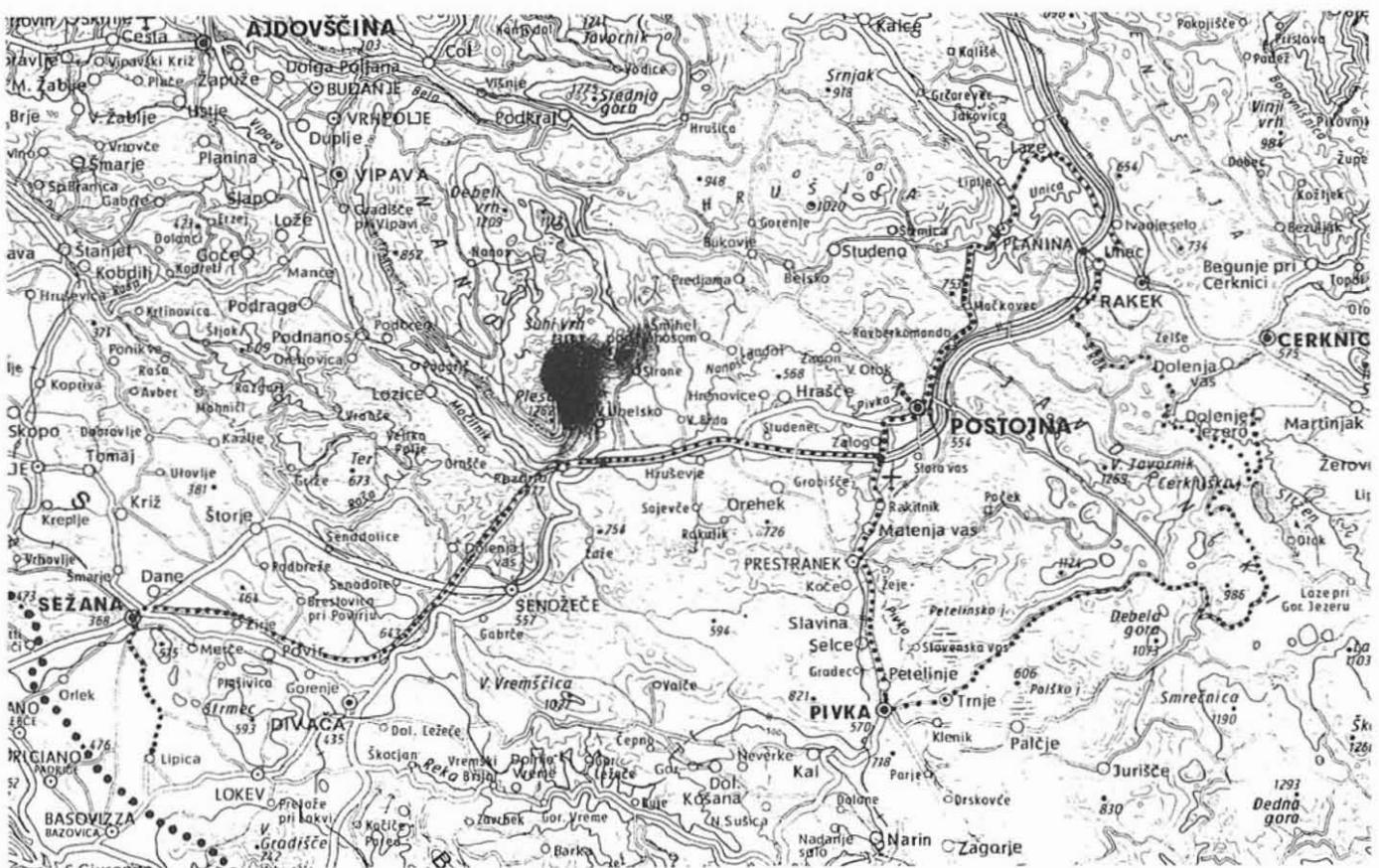


FIG. 6 - Excursion route Karst poljes and caves of Ljubljana river basin.

1b. LJUBLJANICA KARST RIVER BASIN

The peculiarities of Ljubljana basin such as karst poljes with regular floods, large karst depressions, sinking rivers and many caves were described by numerous natural scientists starting in 17th century. Need for abolishing periodical floods in 19th century and 20th century, or to use poljes for accumulation basins, suitable for energetic and other purposes gathered a large knowledge about the Ljubljana river and its karst.

Ljubljana karst river is right Sava affluent and a part of Black Sea water basin. The river basin, hinterland of karst springs near Vrhnika measures about 1200 km². The mean annual precipitation is 1300-3000 mm, during 100 to 150 rainy days. The one day maximal amount to 100 mm, in extreme cases even 300 mm.

Most of the basin is formed on the Mesozoic rocks, mostly limestone. On these rocks the water of precipitation infiltrate directly into the karst and there are no surface rivers. Triassic dolomite is allowing some surface flow, forming bottoms of some karst poljes or forming hydrologic barriers. There are some smaller areas on the non carbonate rocks with surface waters sinking on the contact with limestone.

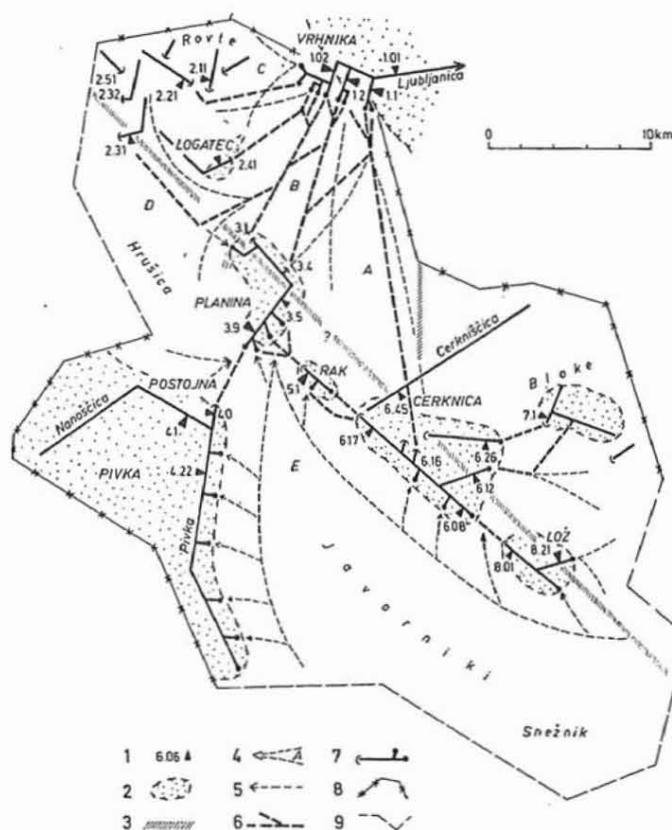


FIG. 7 - Schematic review of superficial and underground waters in Ljubljana Karst river Basin. Legend: 1) important gouging stations, 2) karst polje with sediments, 3) central hydrogeologic relative barrier, 4) intake areas of permanent karst springs, 5) periodic karst water discharge, 6) underground water connections, 7) superficial stream with springs and ponors, 8) superficial watershed, 9) supposed karst watershed. (Gospodaric & Habic, 1976).

Major part of the basin are karst mountains and plateau above 700 m, with a belt of lower karst surface along the Idria fault line in the altitude between 450 to 600 m. In it karst poljes are distributed in levels, presenting the deepest and largest relief depressions. On the poljes surface rivers appear only. After sinking several times they all appear at the springs at Vrhnika as Ljubljana with mean annual discharge of 24.8 m³/s.

2b. PIVKA BASIN

Pivka is an 150 km² large flysch and karst plain in the elevation between 500 m and 600 m. From all the sides it is surrounded by higher karst plateau: Nanos Mts. (1313), Hrusica Mts. (1264), Javorniki Mts. (1268) and Snesnik Mts. (1796). The central part of the Pivka basin belongs to the Pivka river mostly. Its karst springs are in the most SW part near Knesak and Zagorje. Lower parts of flat surface with shallow karst depressions are regularly flooded in this part of basin. At the end of its 26 km long periodical surface stream Pivka sinks into Postojna cave. It continues there its underground course towards Planinsko polje.

Mean annual discharge of Pivka river is 6,04 m³/s. River can be followed trough the lower galleries of Postojnska jama and Pivka jama. After sumps it appears in Planinska jama, where is underground confluence with the Rak river coming from Rak valley and Cerknisko polje.

3b. POSTOJNA CAVE

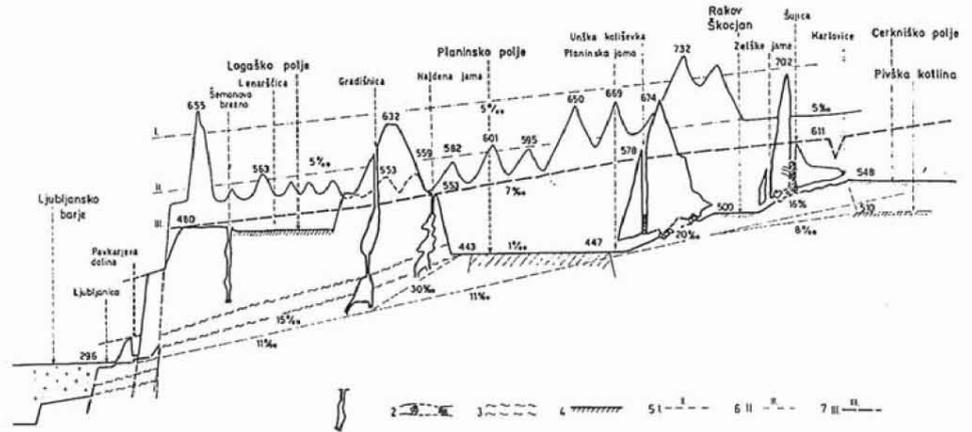
Postojna cave is one of the oldest and one of the largest tourist caves of the world. Important tourist development of the cave started in 1818, although cave was known for visitors in 13. century already. Between the years 1818 and 1992 it was visited by 26.000.000 people, in 1990 only by 989.084 visitors. Later because of the wars in vicinity number decreased dramatically.

Cave lies on the northern side of the Pivka basin in where Pivka river flows into it at 511 m above sea level. Above the river sinking in a sump there is one of the historical entrances, the others are scattered on the flat surface above the cave itself. Together these cave system comprises 19 km. From the last sump in Postojnska jama there is still more than 2500 m of unexplored underground course of the underground Pivka to the sump in Planinska jama cave at the edge of Planinsko polje.

The cave lies in the upper Cretaceous limestone. All cave galleries lie in the Postojna anticline ridge of Dinaric direction (N.W.-S.E.). Most of the galleries are in the steeper south-western wing. The difference of altitude between higher and lower levels of the cave galleries is about 20 m. Several large collapses above the old galleries formed large collapse dolines like Vodni dol, Jersanave doline and Stara apnenica.

The ceiling above the cave is up to 120 m thick. Intensive growth of sinter in the cave is due to high annual precipitation, about 1700 mm, and high mineralization percolating water.

FIG. 8 - Longitudinal cross section of the central part of the Ljubljana karst river basin. Legend: 1) active cave or pothole, 2) unknown parts within known active caves, 3) the supposed zone of former active caves between Planisko polje and Ljubljansko barje (Ljubljana Moor), 4) karst poljes bottom, 5) Gradisce relief level, 6) Bodiski vrh relief level, 7) dolina relief level. (GOSPODARIC & HABIC, 1976).



The Cave contains two kinds of alluvia. Grey, prevalently flysch loam, sands and gravel, which had at first filled the rooms up to the ceiling, after the erosion phase remained mostly in blind galleries and buried under collapsed rocks. More recent sediments - reddish loam at the entrances, mixed up with debris, and in the interior heavily coated with sinter, which grow, according to speleothem data-tions, during warmer periods of Quaternary. Faunal remains and stone tools from the last glacial and the more recent epoch have been found.

4b. CERKNISKO POLJE

The polje of Cerknica, often called just Cerknisko Jezero (the Lake of Cerknica) is well known karst polje because of its regular floods or karst intermittent lake. Its hydrological properties caused that already in the beginning of New Age scholars from all round Europe were attracted to it. Still more known became the lake through the Valvasor's description (1689).

Catchment area of Cerknisko polje covers about 475 km² altogether. The bottom of polje itself covers 38 km² in elevation of about 550 m. Inflows are on E, S, and partly on W polje's side. There are some small superficial tributaries to polje, the largest is Cerkniscica, with about 45 km² of hinterland mostly dolomite. The principal karst waters take their springs in SE polje's corner which are flowing to river Strsen directly from Losko polje and Javorniki Mts.

Flattened bottom of Cerknisko polje is regularly flooded for several months in autumn winter and spring time, at floods it alters to spacious karst lake. Principal ponor caves and swallow holes are disposed at NW polje's border. The highest waters run off through the caves Mala and Velika Karlovica, where more than 7 km of passable channels are known. Lower waters are sinking mostly in marginal swallow holes and in numerous ground swallow holes and estavellas, which are disposed in central polje's bottom.

During the last two centuries a lot of plans for the hydromelioration of polje has been made, but not any one was realised. In 1965 it was proposed to make the Cerknica polje permanent lake. In the years 1968 to 1969 the entrances to the main ponor caves, Velika and Mala Karlovica were closed by concrete walls, and 30 m long tunnel was made to connect the surface with the Karlovica cave, but small effect of retention in dry period and less moistened years were assessed.

5b. RAKOV ŠKOCJAN

A very specific karst depression, the about 1,5 km long and 200 m wide valley of the Rak river, is situated at the elevation of 500-510 m at the northern foot of Javorniki,

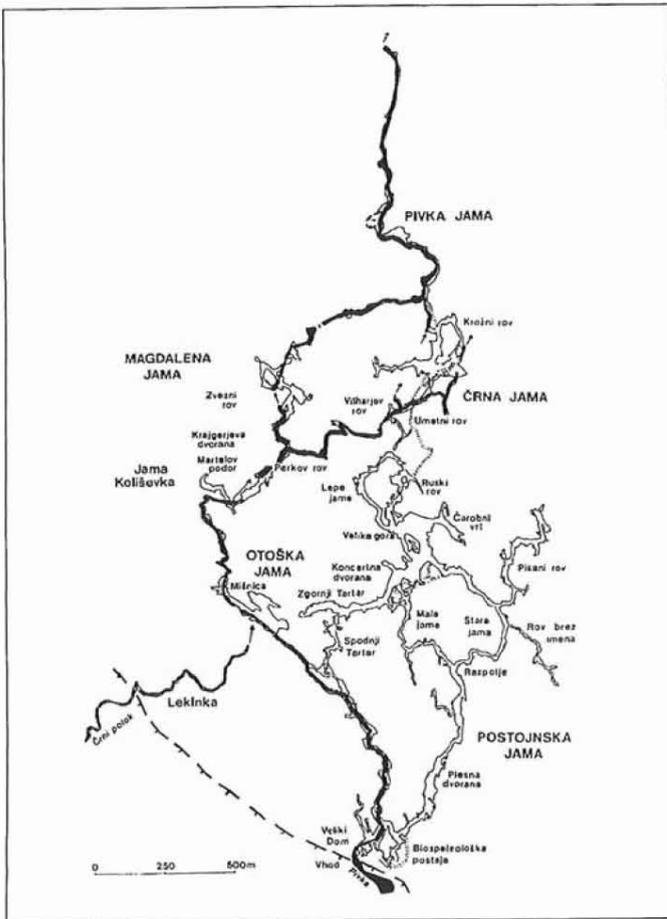
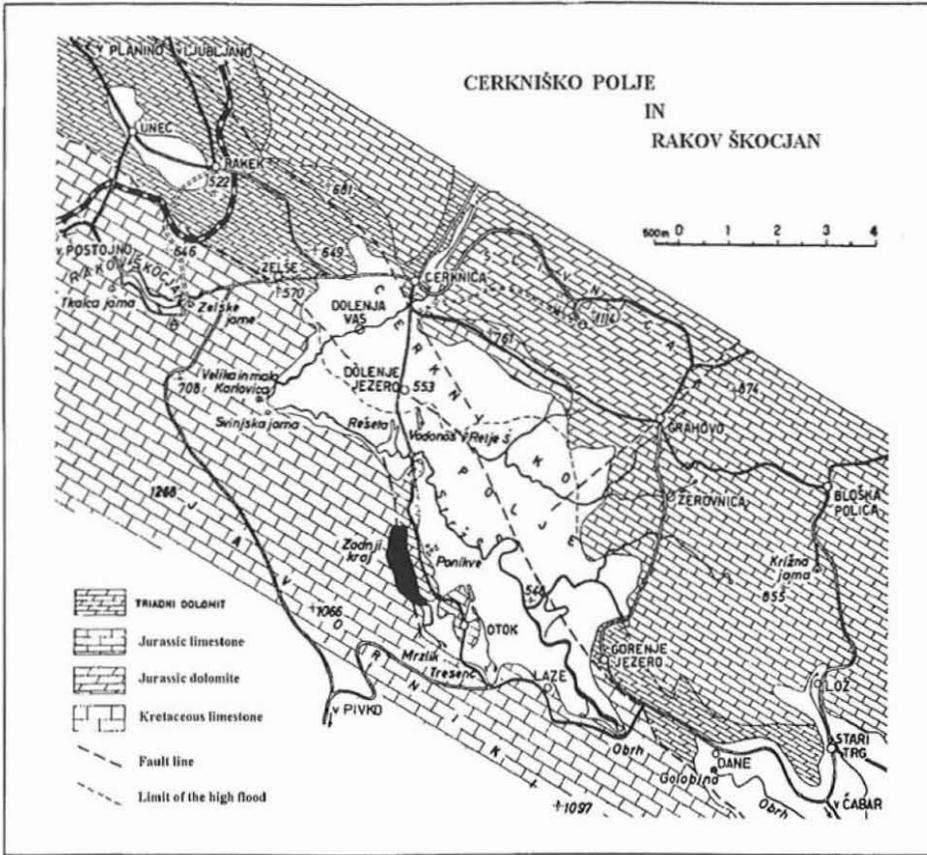


FIG. 9 - Plan of Postojnska jama cave.

FIG. 10 - Cerkniško polje and Rakov Škocjan.



somewhere in the middle between the Planinsko and Cerkniško polje.

At the eastern, spring side, the valley is canyon like. The Rak river springs up from the Zelske jame, bringing waters from Cerknica. Numerous collapse dolines are situated around the entrance to the cave. Downstream valley widens and several small karst affluent join Rak from south. Important spring is Kotlici, bringing water from the Javorniki mountains. The wide flat along the lower course of the Rak is concluded after 800 m by the Great Natural Bridge and after Rak sinks into Tkalca jama. The distance from this point to the springs at Planinsko polje is about 4 km.

The water regime in the Rak valley is intimately bound to the regime in Cerkniško polje. When the Cerknica lake

dries up, the course of Rak dries up too. The connections of Rak with the Cerkniško jezero and with the Unica springs at Planinsko polje are proved by water tracing.

6b. PLANINSKO POLJE

Planinsko polje is overflow polje, of rectangular shape, 6 km long, 2 km wide, with two narrow pocket valleys on SW part, 50 m deep, with 16 km² flat surface at height of 450 m. Its wider surrounding is built by Upper Triassic dolomite, Jurassic and Cretaceous limestone. The development of closed karst depression is result of accelerated corrosion, controlled by a geological structures.

It presents the most important water confluence in the river basin of Ljubljana. Tectonically crushed and almost

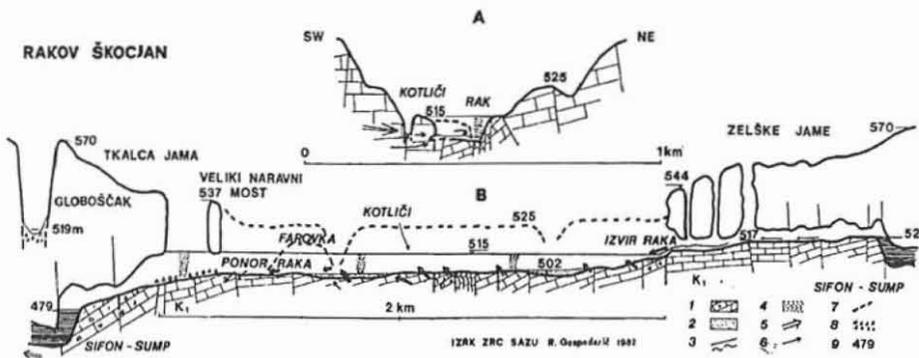


FIG. 11 - Rakov Škocjan depression - cross section (R. GOSPODARIC, 1983). Legend: 1) rocky bottom, 2) alluvium, 3) faults and structure zones, 4) flood high on January 4, 1982, 5) karst spring, 6) water flow direction, 7) terraces, 8) collapse heaps, 9) altitudes a.s.l.

impermeable dolomite barrier along the Idrija wrench 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 they can sink into the underground again. The principal Unica springs, with mean annual discharge $24 \text{ m}^3/\text{s}$ (min. $0,3 \text{ m}^3/\text{s}$, max. $100 \text{ m}^3/\text{s}$) are situated in the southern polje's part in Cretaceous limestone, where the confluence of waters from Cerknica, Javorniki Mt. and Pivka is located. Periodic effluents are situated also in NW polje's part, below the Grcarevec village, where the high waters from a part of Hrusica plateau, and perhaps also from Hotenka, are flowing.

The principal Unica swallow-holes are disposed at northern edge, where mostly medium and high waters are sinking. At low waters the whole Unica is disappearing in swallow-holes at eastern polje's border. The water is sinking directly from Unica bed through the polje's bottom across more than 150 swallow-holes and impassable fissure. Only at Dolenje Loke and in skofji lom, up to 160m long ponor caves are known, but there are several horizontal caves in vicinity of the polje, where water oscillations can be observed. Tracers from this part of polje were detected in springs of Ljubljana. The velocity of tracers to 10 -13 km distant and 155 m lower springs were between 2.4 - 6,8 cm/s.

Planinsko polje is flooded several times in a year. The minimum inflow to the polje amounts to $1,5 \text{ m}^3/\text{s}$; mean $23 \text{ m}^3/\text{s}$, maximal was estimated to $100\text{-}120 \text{ m}^3/\text{s}$, the total ponor capacity being about $60 \text{ m}^3/\text{s}$. 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.

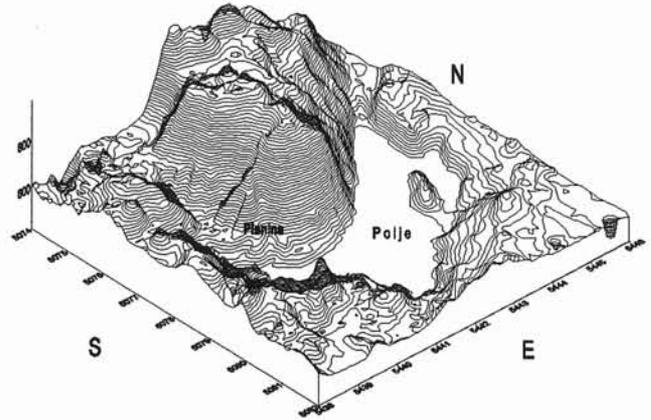


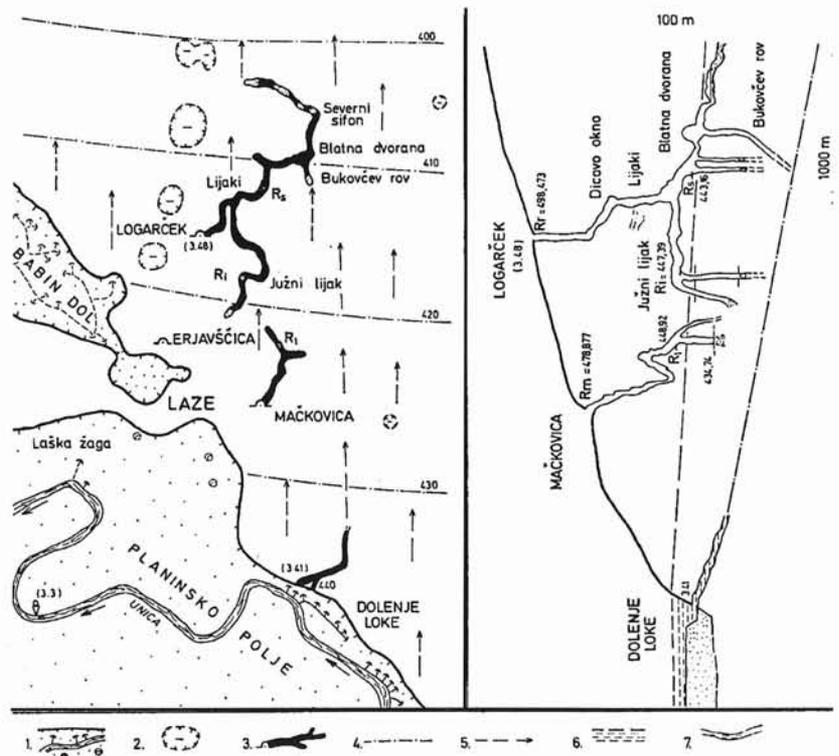
FIG. 12 - Dem of Planinsko polje.

GROTTA GIGANTE CAVE AND THEIR EPHYGEAN KARST (Wednesday, 27.8.1997)

1c. THE GROTTA GIGANTE CAVE

The Grotta Gigante (Giant cave), one of the most important and well-known Italian touristic caves, is basically formed by a single large room. A steeply sloping tunnel joins this hall with the entrance located at 265 meters a.s.l., near the homonym village, a few kilometres from Trieste. Its plan is sub-elliptical and the room, 114m deep from the

FIG. 13 - Ponors at the eastern side of Planinsko polje (GOSPODARIC & HABIC, 1976). Legend: 1) karst polje's border with superficial river bed and swallow-holes, 2) collapsed dolines, 3) simplified caves ground plan, 4) lowest known karst water level hydrocontour lines, 5) direction of karst water outflow, 6) the floods altitude on polje and in caves, 7) the pools of caught water in the cave. Right side: simplified cave's cross section.



ground surface, is about 160m long and almost 65m wide; the maximum height of the roof extends up to 107m and its volume occupies about 600.000 m³. The cave is built in very pure fossiliferous (essentially entire or fragmented rudists) Cretaceous limestones.

Stratification, 15°-23° deep direction southwards, is, usually sharp, varying from 80 to 5; fractures, normally sub-vertical or steeply sloping, are not large and the prevailing rocky unitary volumes extends up to 1 m³. Arrangement and frequency of discontinuity surfaces cause a rapid hypogean percolation along very sloping flow lines (permeable thickness ranges from 45 m to about 90 m), with limited horizontal movements and a slight southward resultant due to strata. The hypogean percolation catching basin, therefore, is only found in the area surrounding the cave.

2c. THE SURFACE LANDSCAPE

From the geomorphological point of view, characteristics of the surface area are those typical of the Classical Karst represented by a slightly undulating flat surface with local dolines having steep slopes and *terra rossa* at the bottom. Outcropping or suboutcropping rocks prevail and are characterized, on the head of the strata, by all possible epigeal karst phenomena (*karren*, *rillenkarren*, *grikes* etc.). Thin detrital soils covers are also easily recognisable where vegetation, mainly oaks and beeches, has taken place. Graze fields alternate with gardens, orchards, vineyards and areas covered by buildings as well as asphalt roads and open squares (fig. 14).

In this area, with an extension of only two hectares, percolating waters show different and not constant chemical concentrations. On the basis of the comparison among the size of each parameter, the considered trickles may be divided into two groups: the northernmost, corresponding to salter waters (for instance with about 230 mg/l) and the southernmost area, where points present lower salinity (for example about 150 mg/l).

Furthermore, the relationships among chemical elements concentrations, such as Na and K, may discriminate the waters of the two groups. Chemistry variations are probably due to slightly different drainage paths followed by waters percolating through soil and rocks. It is supposed that they assimilate the main part of the elements in the most superficial layer of the soil.

As evidence of the research, trickles parting seems to depend on high karst dissolution processes and on mankind's activities. Percolating waters coming from lands not subjected to anthropogenic influences (*terre rosse*, detrital soils and *Karrenfeld*) are poor in chemical elements. Instead those waters whose drainage basin has been modified throughout the years by human and agricultural utilisation of the territory (buildings, asphalted or country roads, gardens, fields), show a higher level of mineral concentrations.

Finally, some chemical parameters, such as sodium, chlorine, sulphates and nitrates, present concentrations according to time. This is mainly evident for those trickles

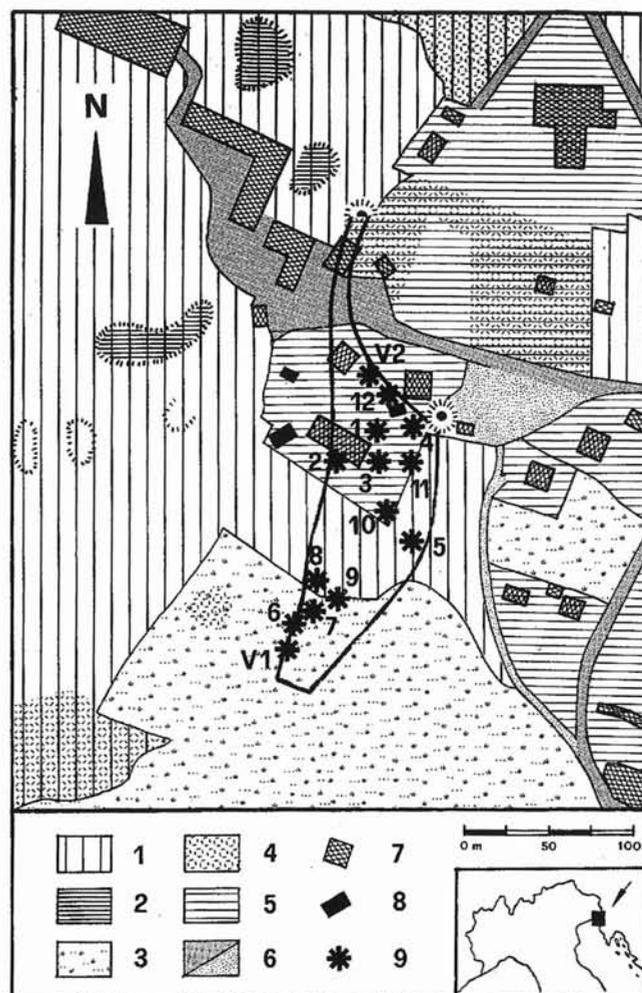


FIG. 14 - land use map.: 1 = outcropping or sub-outcropping rocks; 2 = *terra rossa*; 3 = meadows; 4 = trees; 5 = gardens, orchards, vineyards; 6 = asphalted and country roads; 7 = buildings; 8 = swimming pools; 9 = sampling station in the cave.

presumably affected by particular situations on the surface such as swimming pools, gardens of country houses, Imhoff irrigation water tanks, vineyards, etc.

In the Gigante Cave seismographs of O.g.s. (Osservatorio Geofisico Sperimentale, the well-known research centre in theoretical and applied seismology) and horizontal pendulums for the crust movements studies are located. Near the cave a field laboratory to study limestones degradation in natural conditions is placed. The measurements taken from 1979 up to the present by micro-erosionmeter indicate that on the Carso of Trieste, where the average annual rainfall is 1350 mm, the average surface degradation levels is between 0.01 mm and 0.03 mm per year. Of course, some lithotypes lose more volume, while others have extremely slow levels of dissolution. In any case, the extent of dissolution is in the order of hundredths of a millimetre per year.

INTRODUCTION

In the Southern Alps the Montello ridge is one of the most singular sub-alpine groups, a kind of low plateau comparable to a turtleback about 13 km long in the WSW-ENE direction, 5 km wide and with an average elevation of about 100 m (maximum of 280 m) above the surrounding plain. It is situated in the high Venetian Plain, about 50 km north of Venice.

This morphostructure is the expression of the up-arching of a tectonic wedge delimited on the SSE side by an overthrust (Aviano line) and on the NNW side by a backthrust (backthrust of Montello) (fig. 15).

The geological formation, which constitutes this relief, is a nearly 2000 m thick conglomerate (Montello Conglomerate), formed mostly by limestone pebbles bound by a carbonatic cement. It is part of a messinian age (late Miocene) delta fan, showing in its upper part also alluvial deposits. The accumulation of this delta fan may be correlated with the main uplifting phase of the south alpine chain during the Neogene.

So this morphostructure has begun to bulge very recently, from no longer than 5 million years. During its history, the erosion has removed no more than a few hundred metres of rocks. Due to its gradual upsurge, the morphostructure has been exposed to the erosional processes first of all by the rivers and secondarily by karst denudation. The uplifting prevailed upon erosion and a hill was formed, the surface of which is a step of erosional surfaces of increa-

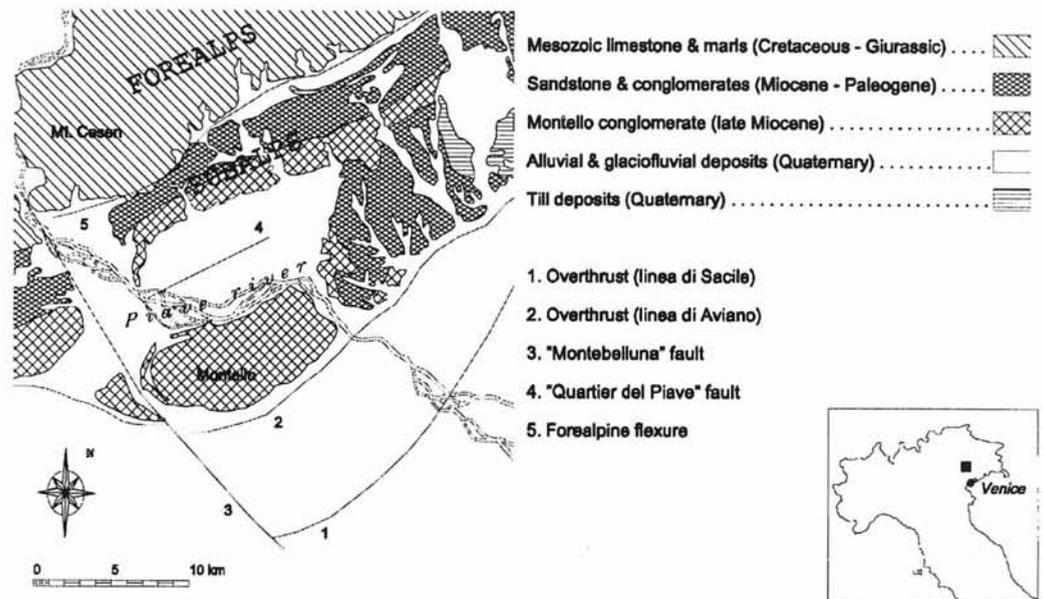


FIG. 15 - Geological sketch of the Montello area.

sing ages, from the lowest to the top one. In general the hill summit is comparable to a low plateau with a high density of karst dolines: in total there are 2070 dolines on a surface of 60,8 km², for an average density of 34 dolines per km².

The detailed analysis of the digital images let us recognise morphological sub-units originated by fluvial erosion, with character of wide rock cut terraces modified in different ways by karst morphogenesis.

1d. VAL POSAN

Val Posan (Posan valley) is a large karst depression of «uvala» type originated by the coalescence of more karst dolines. This complex form is the expression of the advanced stage of karst evolution of this part of the morphostructure. Inside the depression it is possible to recognise

smaller features and in particular some collapse pit dolines. The greatest of these dolines shows a maximum diameter of 40 m and a depth of 18 meters. On its bottom a brook is flowing fed by a spring cave and disappearing in a swallowing cave; so this doline is a true «karst window» connecting the surface with the underground karst.

2d. TAVARAN GRANDO CAVE

Tavaran Grando Cave is a spring cave situated on the NE side of the Montello. It represents a typical example of cave in conglomerate developed mostly in «sature environment». Probably, during its first development, the cave was the feeding system of a «valclusian» type karst spring. The cross sections of the galleries are circular and the bottom shows only a few modifications by the late vadose circulation, in forms of potholes and pans. On the roof there

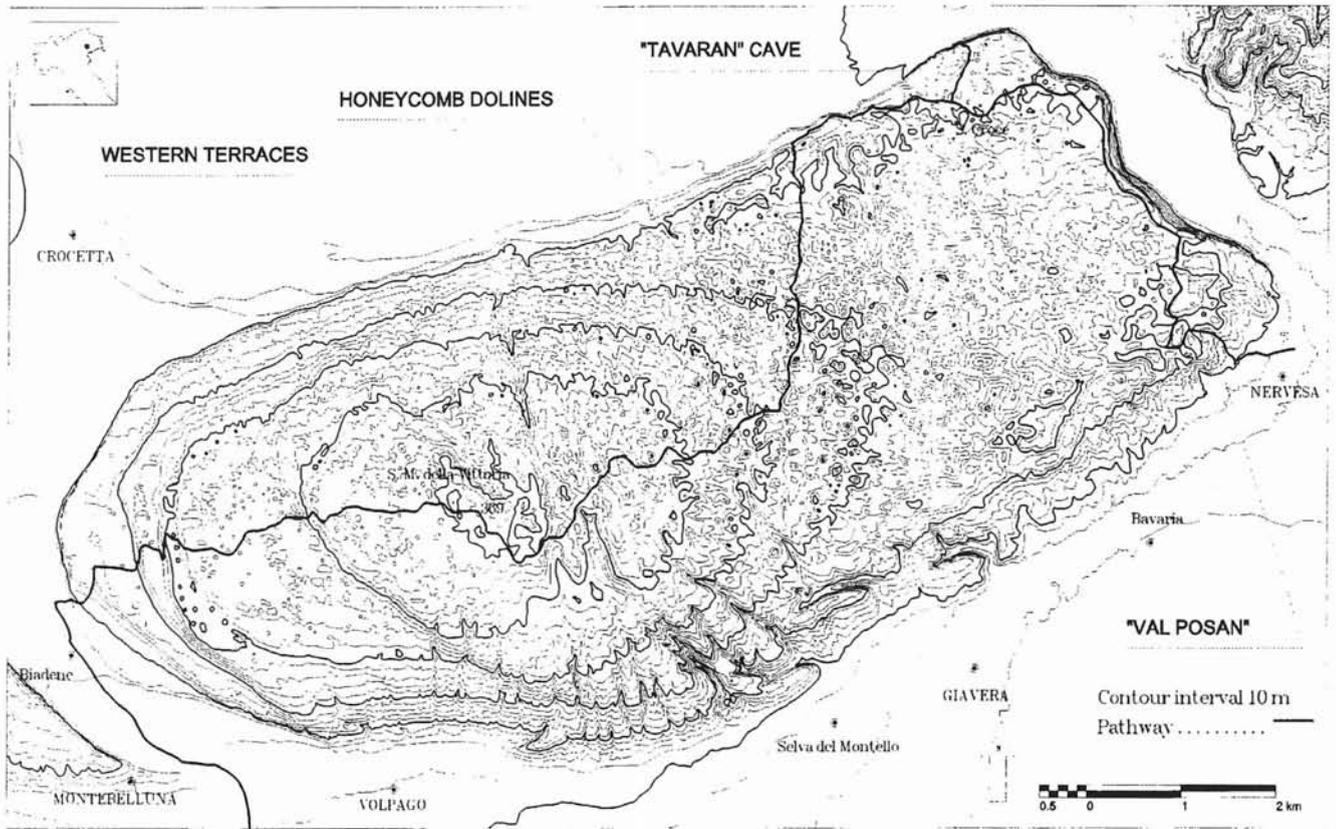


FIG. 16 - The Montello Karst excursion route: 1. Val Posan, 2. Tavarano Grand Cave, 3. Central Plateau, 4. Western Terraces, 5. Biadene depression and Montebelluna hill.

are ceiling channels expression of at least one phase of filling of the outer sector of the cavity. Some chimneys are the proof of the water percolation from the overlying

epikarst zone. The lowering of the morphological outer surface has favoured the opening of a second entrance and the forming of a natural bridge.

TAVARAN GRANDO
69 V TV
Nervesa della Battaglia

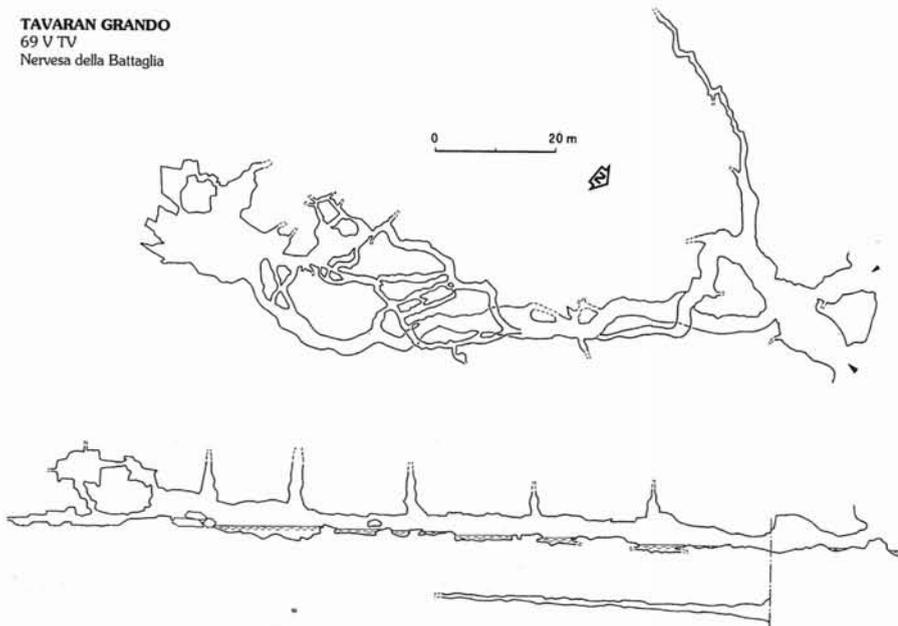


FIG. 17 - Plan of Tavarano Grand cave.

3d. CENTRAL PLATEAU

East of the highest point of Montello Hill (Collesel Val dell'Acqua, 371 m a.s.l.) there is a plateau characterized both by systems of dry and blind valleys which cross the hill with N-S and NW-SE direction and, more eastwards, by honeycomb patterns of dolines which cover more than 80% of the total area. Most of these dolines are partially coalescent with the contiguous ones, constituting complex forms.

4d. WESTERN TERRACES

In the west section of the hill where, west of the highest point, there is a sequence of seven terraces which mark the transition from the alluvial plain to the top of the hill. The surfaces of these terraces present a different degree of development of the karst dolines which are missing on the lower terrace, are shallow in the second terrace and in general are better developed in the highest terraces.

The most significant parameter to compare the degree of karst evolution of the terraces is not the density of dolines (dol./km²) but the karst volume (VCAR = average volume of the karst depressions/km²). VCAR values point out that the karst relief is more evolved on the highest terraces, which correspond with the oldest fluvial erosional surfaces.

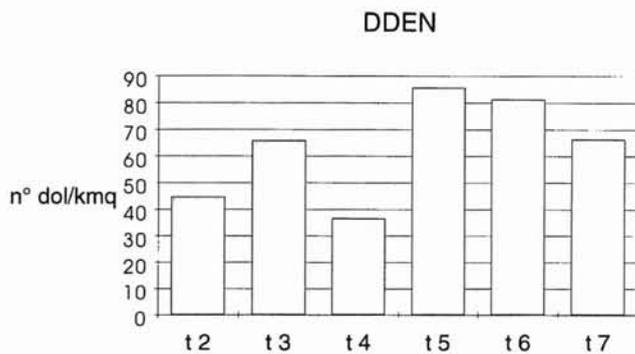


FIG. 18 - Density of dolines in the seven terraces.

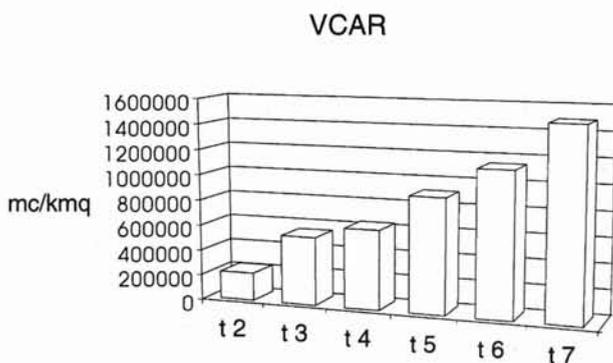


FIG. 19 - VCAR (m³/km²) in the seven western terraces grows with regular trend.

5d. BIADENE DEPRESSION AND MONTEBELLUNA HILL

West of Montello rises the Montebelluna hill (Capo di Monte, 195 m a.s.l.), which represents the continuation of Montello morphostructure. Between the two units there is a depression which could be interpreted as a segment of dead valley and in particular as an entrenched meander of a paleo-river. In fact it is easy to hypothesize that in the past a river (a «paleo-Brenta» and/or a «paleo-Piave», according with the hydrographical rearrangement in the Southern Alps during the Pleistocene) was cutting an entrenched antecedent valley inside the active morphostructure of the Montello. Due to the gradual upsurging of this morphostructure the river course shifted to the west and a step of seven rock cut terraces were shaped. Only during upper Pleistocene the river course changed and this valley segment become dead.

CONCLUSIVE REMARKS ABOUT THE MONTELLO KARST

Montello karst is an active morphostructure with some karst features similar to those of Classical Karst. in particular it is characterized by a high density of dolines. Nevertheless it is a very a recent structure and it is in conglomerate rock unit, and because of this its study is interesting to understand the karst landforms evolution in time and to make comparison with different morphokarstic structures. The different morphological sub-units of Montello express particular aspects of the karst relief: this seems to diversify according to the age of the surface, to the presence of systems of fractures and to the slope.

In the morphodynamical context of the Montello the dolines began to develop as large and shallow forms and their vertical development (depth) was controlled by the geological structure, by the morphological position and by the time.

The degree of development of karst basins, of doline type (sink-holes), depends on the age of the surfaces: we aim to point out, on the basis of the characters of the karst forms, in particular those of dolines, the main differences among the populations of the different morphological sub-units. Such differences supply interesting indications both on the evolution of karst landforms and on the geodynamic history of the whole morphostructure.

The sub-unites of the hill can be divided into two main groups: the north-west group of Montello - with the hill in Montebelluna (NW group) and the south-east group (SE group). The former group has typical morphological features as the presence of extended subhorizontal surfaces and a narrow range of sizes of dolines. On the contrary, the SE group is generally marked by bigger dolines, even if it shows a wider range of morphometric values. The main sub-units inside the groups are: the seven western terraces and the northern ones in the NW group; the subsummit plateau, the middle south and the south east zones in the SE group.

The surfaces of the western terraces (t2-t7) present growing ages from the bottom upwards. That's why in the first terrace the karst process had little time to perform, so that the development of the karst forms turn out to be scarce while in the highest terrace the karst relief is more highly developed.

The Vcar values point out that the karst relief is more evolved on the oldest terraces according to their relative altitudes. However, we can unexpectedly notice how the density of dolines decreases on the highest surfaces (t6 and t7). Even the 4th terrace (t4) has an anomalous density, which is definitely low compared to the others: the dolines are few but big, as is also shown by the high values of planimetric extension, depth and volume.

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