Speleological Association of Slovenia
and
Karst Research Institute ZRC SAZU

INTERNATIONAL KARSTOLOGICAL SCHOOL

Classical Karst

GUIDE-BOOKLET FOR THE EXCURSIONS

Lipica, September 20 - 23, 1993

Publisher: Inštitut za raziskovanje krasa ZRC SAZU, Titov trg 2, Postojna

Composed by: M. Knez, J. Kogovšek, A. Mihevc, F. Šušteršič

Translated by the authors and M. Kranjc

Produced by Desktop Publishing STEVE, P. Jakopin, realized by M. Kranjc

ŠKOCJANSKE JAME

September 20, 1993 at 14.00

450 ELAB

IZRK ZRC SAZU, Postojna, 2010

ŠKOCJANSKE JAME (The Caves of Škocjan)

The Caves of Škocjan (Škocjanske jame) present the biggest natural curiosity of the whole Classical Karst (Fig. 1) between Trieste Bay and Vipava valley. Together with blind valley of Vreme and Divača karst along the narrow ponor border of river Reka they make part of typical morphogenetical unit of contact karst, unique in Europe regarding its phenomena and dimensions.

THE HISTORY OF EXPLORATIONS

The virtual investigations in Škocjanske jame (Fig. 2) started in 19^{th} century. In 1819 Mahorčič explored the entrance, in 1823 Tominčeva jama was discovered and the stairs were built into Velika dolina. A. Schmidl discovered "Schmidlova dvorana" and passage to "Rudolfova dvorana". The time of systematic exploration and cave display in Škocjanske jame started around 1880. Mullerjeva dvorana, Dvorana ponvic, final siphon and Tiha jama were discovered between 1884 and 1904. In the same time the local cave workers constructed the footpathes and bridges. The main changes in after war period are electrification in 1959 and elevator from Velika dolina in 1986. Beside speleological exploration and underground discoveries the natural history science frequently went parallelly to explorations. The Brother Imperato water tracing belongs among the oldest in the world, as well as the tracing test with fluorescein in 1891. The studies of water connection, geological, mineralogical, sedimentological, and morphological studies occupied Morlot, Schmidl, Martel, Marinitsch, Timeus, Boegan, Gams, Gospodarič, Petkovšek ... The natural reserve Škocjanske jame and its vicinity was listed in 1986 as natural and cultural heritage at UNESCO as the example of the caves of extreme dimensions and karst landscape with rich history and interesting cultural tradition.

GEOLOGY AND MORPHOLOGY OF DIVAČA KRAS (CLASSICAL KARST) AND ŠKOCJANSKE JAME

Kras belongs to Outer Dinarids making part of Dinaric carbonate platform. The oldest rocks of Divača kras are limestones of miogeosinkline facies of Cretaceous age. They are followed by Paleocene limestones developed in miogeosinkline facies, too. Younger flysch rocks occur in eugeosinkline facies of Eocene age. The rocks of Lower Cretaceous developed as bituminous limestones and dolomites laterally passing to each other. Turonian age is dark grey, compact, bedded limestone alternating with rudist limestone. Senonian block is composed by lower and upper part. In lower part there are rudist limestones and in the upper part grey-brown, partly fresh water and partly marine limestones. Marl limestones and limestones of Paleocene age are shallow-sea and brackish rocks, developed in unequal depth.

Geological investigation evidenced that accessible channels of Škocjanske jame developed in Turonian and Senonian, mostly thick-bedded limestones with exception of Tiha jama, built in thin layered Cretaceous and Paleocene limestones (Fig. 3).

Hilly region on the east drained by Notranjska Reka is built by impermeable Eocene flysch. The contact with Paleocene and later Cretaceous limestone lies 4.7 km SE from Škocjan. The strata are oriented in the Dinaric direction (NW - SE), and belong to the SW wing of the anticline, of which the entire Trieste - Komen Plateau consists. In the cave the strata decline by 10 -20 SW wards. The faults run parallel with the strata, but also across them (NE - SW). The faults along the sliding plane are horizontal.

According to the shape and situation the collapse dolines (Fig. 4) were classified by I. Gams (1983) into four generations. The bottoms of the collapse dolines of the oldest phase are on average altitude 430 m, second and third phase on 355 m and the youngest fourth phase on 296 m.

Although the age of collapse dolines and ponor channels in Škocjanske jame and Divaški kras is not yet absolutely dated we infer by the geomorphological signs to Quaternary development. Valley incision and underground hollowing were followed because of climatical changes by filling up, and maybe tectonical movements have influenced the changes in the underground.

Big permeability of contact karst near Škocjanske jame, the volume of the biggest collapse doline Sekelak is more then 8.000.000 m^3, and the biggest hall Martelova Dvorana more than 1.500.000 m^3, is obviously the effect of favourable geological setting and big erosion and corrosion power of sinking Reka river in the contact area.

HYDROLOGY

Reka gathers the water from more than 350 km^2 of the surface, from it 60% are impermeable flysch while the karst background on Snežnik (1797m) and an the area of Slavensko - Košanski kras are not yet precisely defined. Two kilometers before the ponor under Škocjan approximatively Reka flows through 60 to 80 m deep narrow canyon. It is sharply cut into plain of Naklo terrace on 400 m a.s.l., its origin is not yet well explained. The actual Reka ponor lies under 108 m high wall of Škocjan (425 m). According to shape and situation it is relatively young as on the left and on the right of it older filled up steepheads are lying. The entrance passage is narrow and high developed along bigger fissure therefore the passages reach 50 to 80 m. The axis of Škocjanske jame is presented by 2.5 km long underground canyon wich has no lateral active water channels. There are several entrances to the underground. Between ponor and Mala dolina lies Brihta jama, under the natural bridge between Mala and Velika dolina is short passage called Okno. In Velika dolina there are two lateral dry passages, Tominčeva jama and Prunker, under precipiced west wall in Velika dolina lies on the right above the water channel Schmidlova dvorana, which is connected with Rudolfova dvorana, Svetinova and Müllerjeva dvorana. Through the last one Reka flows into Hankejev kanal.

Underground continuation of Reka between Škocjanske jame and Kačna jama is unknown on the distance of 1,5 km, but probably water flow avoids the collapse doline Risnik near Divača. Unknown is also the flow between Kačna jama and 30 km distant Timavo springs. Reka and other waters flow feeding the Timavo springs by 0,5 to 10 cm /s velocity. In average Reka needs for the way from Škocjanske jame to Timavo springs 9 days, its underground tributaries from Pivka border 2 months even at low waters.

Generations of cavers tried for more than 150 years to reach the underground flow between Kačna jama and Timavo springs from somewhere on the surface. They succeded in 329 m deep Labodnica near Trebče only and in no other among almost 1000 explored caves.

SEDIMENTS

In Škocjanske jame fluvial sediments as gravel, sand, loam and some rubbles and flowstone are preserved. In Tominčeva jama and Schmidlova dvorana the Holocene loam deposits are preserved. Czoernigova jama is filled up ponor channel with two accumulation phases from Younger Pleistocene. The rest of the same time deposits are preserved in shorter channels. Tiha jama is filled up by speleothems and fluvial sediments almost to the roof. Till now the flysch origin of fluvial sediments, conection of sediments and both morphological levels to accumulation terraces in ponor region of sinking stream and contemporaneous development of canyon waterchannel and both collapse dolines Velika and Mala dolina were proved. In Škocjanske jame development we can distinguish Holocene and Late glacial phases, Würm phases and Middle Pleistocene phase. Old Pleistocene phase is proved by sediments and galeries remins.

ARCHAEOLOGY

The Škocjan caves used to be a refuge of Paleolithic and Neolithic man; Bronze, Iron and Roman cultures are also represented. Paleolithic tools from Gravettien have been found in Roška špilja, a cave in the wall of Velika dolina. Tominčeva dvorana contains Neolithic objects and remains from younger cultures.

METEOROLOGY

Owing to its particular morphological structure, the cave in winter convectively cools down, and is through the prevailing part of the year cooler than its environs. The Reka water is always warmer than the air in the cave. Therefore, with major temperature differences, mist forms over the watercourse. In Velika dolina and Mala dolina the so-called temperature inversion, causing a particular air circulation and a special flora, was observed.

IMPACT OF HUMAN ACTIVITY ON ŠKOCJANSKE JAME
Mahorčičeva and Mariničeva jama

On the surface above the cave a small village lies, inhabitants cultivate the land, sewage system does not exist, thus the waste waters discharge directly into the karst. The cave ceiling is from 50 to 80 m thick. In the year 1992 the percolated water was analysed several times in order to find out the actual state.

In August, during drought, we did not succeed to take the samples and we explain the fact by small amount of the waste water. After the rainfall in June and October the drops on some places developed into abundant trickles indicating that the waste waters were strongly diluted by the rainfall.

In freshly infiltrated water we have measured up to 85 mg NO_3^- l^{-1} of nitrates, up to 5.5 mg PO_4^{3-} l^{-1} of phosphates, up to 53 mg SO_4^{2-} l^{-1} and up to 16 mg Cl^- l^{-1} of chlorides. The water had the COD up to 8.7 mg O_2 l^{-1}, and BOD did not surpass 2 mg O_2 l^{-1}. The measured values of the specific electric conductivity did not surpass 700 uS cm^{-1}, but the caught water in the solution cups indicated considerably higher values - more than 1000 uS cm^{-1} - and at the same time the highest values of nitrates (175 mgNO_3^- l^{-1}), sulfates (63 mgSO_4^{2-} l^{-1}), chlorides (49 mgCl^- l^{-1}) content together with high values of COD (24 mgO_2 l^{-1}) in comparison with freshly taken samples of infiltrated water.

The difference in quality among the particular trickles was registered (Fig. 5).

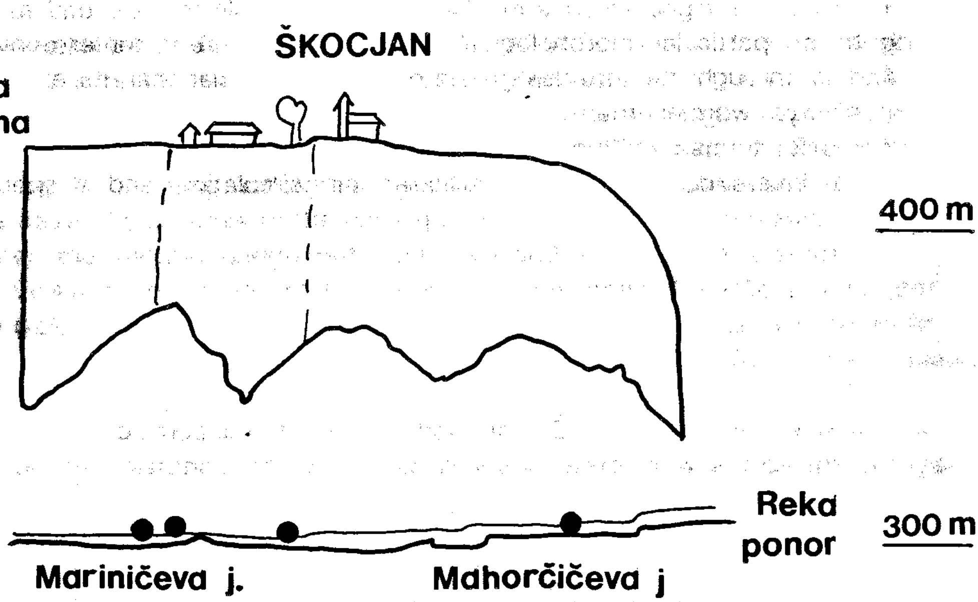


Fig. 5
Fig. 5
● observed trickles

BRKINI CONTACT KARST

September 21, 1993 at 14.00

CONTACT KARST OF BRKINI HILLS

One of the possible morphological karst classifications is the division according to the main morphological process. Karst relief formed by the influence of the allogenic flow could be designated by the term of the contact karst.

The term grows familiar in Slovenia on the Classical Karst where the karst contacts non carbonate rocks and marked relief forms developed. The term is reasonable as such karst essentially differs from the karst which surface was formed without such influence. In the international karstological literature such forms and phenomena are treated as karst influenced by allogenic flow (Ford & Williams, 1989).

Once the contact karst at the foot of Brkini was treated within the frame of cyclic geomorphological theory. The period of fluvial relief development should be followed by the karstification when the impermeable cover was removed. At the karstification beginning the superficial streams shortened and the last remains of this pre-karstic phase should be the blind valleys. Various forms of the blind valleys were later contributed to the climatical changes. Corrosionally widened and levelled bottom of the blind valleys and also bigger planations spread all over the Dinaric karst should be the result of the warm climate mostly. Cold periods in the Pleistocene accelerated the incision of the valleys, erosion and denudation in the water basins of the superficial rivers. Corrosion capacity of the sinking streams should affected the forms and dimensions of the blind valleys and it depends mostly on the aggressivity and quantity of the allogenic rivers.

GEOLOGICAL AND HYDROLOGICAL PROPERTIES OF THE TREATED AREA

Brkini Hills are built by flysch non-carbonate rocks of the Eocene age consisting of beds of marl, non carbonate sandstones and conglomerates. Flysch rocks build erosionally dissected hills which contact the karst plain on the south western side. This one is built by Paleocene and Cretaceous limestones dipping steeply below the flysch. The contact of flysch hills and limestones is 20 km long.

From flysch hills to the border limestones 17 separated sinking streams flow, draining altogether 29.2 km^2 of the flysch area. Water basins of the sinking streams vary from 0.5 km^2 to the biggest 13.2 km2.

The brooks sink in the altitudes between 490 to 510 m a.s.l.. Some ponors continue in the 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 vadose caves in the karst plain and in one cave only the water could be reached at 350 m of the altitude.

Water tracing showed the diversion of the sinking streams water into three groups of springs. The lowest are along the coast in the Kvarner Bay and the highest are the Rižana springs at 70 m a.s.l.

MORPHOLOGICAL PROPERTIES OF THE CONTACT KARST

Characteristical forms of the Brkini contact karst are blind valleys with corrosionally widened bottom. A characteristic example of such valley is Odolina blind valley.

The blind valley was formed by the sinking stream draining 4.3 km2 large water basin. The average discharge of the brook is about 15 l/s, but oscillations due to precipitation regime are frequent. The floods are rare and reach the narrow belt along the brook only. Periodical water hardness measurements indicated 111 mg of dissolved carbonates originating from the flysch marls.

Close to the brook's passage to the limestones the narrow fluvial valley widens. A valley, 1 km long and 300 m wide, developed on the limestones. Close to the contact it is 150 m deep and on the southern end it is deepened into the karst plain for 60 m.

The valley's bottom is covered by the sediments, gravels and sands. Flood plain is cut by some younger, up to 25 m deep alluvial ponors and sinkholes and riverbed 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 limestones, during higher water level it flows into 117 m deep ponor cave composed by potholes and shorter channels. The cave is basically phreatic with strong traces of vadose transformation. It ends by the siphon of caught water on 370 m a.s.l. (Fig. 6).

Beside some blind valleys where the brooks sink there are some fossil blind valleys with corrosionally widened bottom without existing brook. It was either captured by other brook or the brook formed clearly separated shorter blind valley with corrosionally widened bottom, as is it the case with Račiška dana blind valley (Fig. 7).

The Matarsko podolje is 20 km long and 2-5 km wide. Lowered surface is not a base-levelled plain, cross sections indicate that the bottom, disseminated by the dolines, is inclined southwestwards. In the longitudinal section the lowered surface gently raises from about 490 m on NW to 650 m on SE side. The lowered surface continues towards SE but from the highest point near the blind valley Brdanska dana it lowers on the distance of 2 km for 200 m.

The geomorphological sketch of the entire contact indicates a certain diversity of the forms of the brooks flowing from the flysch.

The first sinking streams in a series flow to the border limestones in the altitudes about 500 m in the lowest, NW part of the lowered surface. These brooks, for instance the brook Krvavi potok have deeply cut riverbeds in flysch but did not form the blind valley on the limestone. It sinks in his own riverbed on the levelled surface (Figs. 8, 9).

Most of the brooks namely developed blind valleys with corrosionally widened bottom. The bottoms of these valleys are situated between 490 to 510 m. As the valleys are incised in the border of the karst, uplifted towards SE, the blind valleys lying more to the south are deeper. The first deepened blind valley is cut for 50 m only while the deepest is the last one, deepened into border limestones for 250 m and its bottom lies 120 m below the bottom of the lowered surface.

CONCLUSIONS

The Brkini series of blind valleys with corrosionally widened bottoms with its situation along the karst plain, upraised lowered surface and some relief forms offer enough data to indirectly classify the sequence of the morphological events and dominant factors which were decisive for the formation of the actual relief forms.

The former shape along the ponors on the border of impermeable hills was karst corrosional plain. The water flowing on it had modest gradient in karst and was capable of the aplanation of the surface only.

The lowering of the piezometric level in the karst enabled the development of the relief depressions along the ponors. The deepening and the contemporaneous widening of the valleys followed the lowering of the karst water to the altitudes 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.

The blind valleys started to cut into the corrosional plain with small transverse and longitudinal gradient as in the contrary case the fluvial valleys should develop in them. They should be preserved on karst as dry valleys. The lowered surface is without such dry valleys, it is dissected by solution dolines and by some bigger collapse dolines only.

The corrosional plains along the ponors were entirely controlled by the piezometric level this is why they are on the northern part slightly deepened into the lowered surface, while in the SE part this incision is for 150 m. Stronger tectonic uplift in the SE part upraised the lowered surface above the impermeable flysch part and due to stronger uplift incomparable fossil blind valleys developed there.

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.

LITERATURE

Ford, D., & P., Williams, 1989: Karst Geomorphology and Hydrology, 1-601,London.

Gams, I., 1983: Škocjanski kras kot vzorec kontaktnega krasa.- Mednarodni simpozij "Zaščita Krasa ob 160-letnici turističnega razvoja Škocjanskih jam", 22-26, Sežana.

Gams, I., 1962: Slepe doline v Sloveniji, Geografski zbornik 7, 263-306, Ljubljana.

Gams, I., 1965: Types of Accelerated Corrosion. Problems of Speleological Research. Proceedings Inter. Spel. Confer. Brno 1964, Brno.

Gams, I., 1987: Škocjanski kras.- Man's Impact in Dinaric Karst, Guide-book, International Geographical Union, 101-115, Ljubljana.

Gospodarič, R., 1965: Škocjanske jame.- Guide-Book of the Congress Excursion through Dinaric Karst, 137-140, Ljubljana.

Gospodarič, R., 1983: O geologiji in speleogenezi Škocjanskih jam.- Geološki zbornik, 4, 163-172, Ljubljana.

Habič, P., Knez, M., Kogovšek J., Kranjc A. Mihevc A., Slabe T., Šebela S., Zupan N., 1989: Škocjanske jame speleological revue.- International Journal of Speleology, 18(1-2), 1-42, Trieste.

Krivic, P., M., Bricelj, M. Zupan, 1989: Podzemne vodne zveze na področju Čičarije in osrednjega dela Istre. Acta carsologica, 18, 265-284, Ljubljana

Melik, A., 1955: Kraška polja Slovenije v pleistocenu. Dela Inštituta za geografijo SAZU, 3, 1-163, Ljubljana.

Mihevc, A., 1993: Contact karst of Brkini Hills on the southern side of the Classical karst area in Slovenia.- Proceedings of the XI International Congress of Speleology, 5-7, Beijing

Radinja, D., 1985: Kras v luči fosilne fluvialne akumulacije. Acta carsologica, 14-15, 99-108, Ljubljana

Radinja, D., 1972: Zakrasevanje v sloveniji v luči celotnega morfogenetskega razvoja. GZ,13, SAZU, Ljubljana.

Roglič, J., 1957: Zaravni u vapnencima. Geografski glasnik 19, 103-134, Zagreb.

CLASSICAL DOLINES OF CLASSICAL SITE

September 22, 1993 at 14.00

THE SMALL SCALE SURFACE KARST AND SOLUTION DOLINES AT THE NORTHEASTER BORDER OF PLANINSKO POLJE

Summary

Since the Cvijić's monography Das Karstphänomen (1893) the opinion that the karst relief is in a way relic fluvial, deformed by karst shaping has dominated. The last decades research all over the world has shaken a lot the confidence to these ideas. Thus, an experimental polygon was erected near the northeastern border of the Planinsko polje, where geological, speleological and geomorphological investigations are in course. The latter investigations encompass both the general relief shaping as well as the small phenomena, solution dolines especially. This paper is an essay to present the first results of the geomorphological research, providing a preliminary information rather than a survey of the final conclusions.

The present paper encompasses the general relief morphology, and the spatial distribution of dolines, and the proper dolines shaping. The discussion possible is added to every chapter, whilst the guidelines to further research are collected in the final chapter.

The research area was planned in such a way that it encompasses the surface above the most important outflow caves of the Planinsko polje (Logarček and Najdena jama), and covers the contact between lythologically quite different lower and upper Cretaceous limestones. The area is one of the most speleologically studied in Slovenia (I. Gams, 1963, F. Šušteršič, M. Puc, 1970, R. Gospodarič, 1982) and it offers ample possibilities to compare geological, geomorphological and speleological findings.

At first a detailed geological map on the scale 1 : 5000 (J. Čar, 1982) was done and some morphometrical analyses performed. The last showed in several ways that fluvial elements in the present relief may not be expected. So, the following geomorphological mapping was designed in a flexible way, the legend being not fixed in forward. It was oriented to geometry and factography, avoiding the genesis. Special concern was given to the dolines. In 150 m wide stripe, directed parallelly to the dip was destinated for detailed studies of dolines and 20 of them were measured in a special way (F. Šušteršič, 1985). A computer program pack was developed to process the field data. Filtered doline shape, its volume, the direction and the amount of the doline surface slope can be computed. In such a way one can distinguish which semiprofiles are not biased and numerical taxonomy operations can be executed upon them.

The field works started in 1980, being concluded in 1983 in general lines. The theoretical work, including development of computer software lasted up to the end of 1986.

DOLINES DISTRIBUTION

All the dolines in the studied area were mapped on the scale 1 : 5000. The collapse ones were excluded from further processing and no classification among the presumably solution ones was done. The whole territory covers 3,77 km², 0,25 km² being affected by collapsing. This share is omitted in the further discussion. The total number of mapped solution dolines is 918, and the overall density is 260,8 dolines/km². The density varies with lythology and 212,2 dolines/km² were established on lower cretaceous limestones, while the density 352,5 dolines/km² holds for upper cretaceous. The number of doline centres was counted in circles of the average doline influence area. The rough count data were smoothed by a conical filter and a continuous (density) plane was computed (Fig. 1/c).

To check the relations towards the corrosion shafts all the known caves of the kind in the area were processed in the same way. The total number of them is 70, the average density being 19,9 shafts/km² (Fig. 1/d). These data were related to doline data, obtaining correlation $r = 0,42577$ (0,1 % significance level).

Another question bound to the doline density is percentage of surface, affected by dolines. During motorway construction works a great deal of the area was surveyed on the scale 1 : 1000. These data were used to compute the average share of the affected area. The average is 64,03 %, ranging from 29,5 % to 85,5 %, calculated over 10 000 m² areas.

Some basic statistics concerning distribution of dolines were performed. The quadrat statistic showed that the null hypothesis of random distribution may be received at 5 % significance level, but it must be rejected at 1 % level.

The nearest neighbour analysis yielded: $R = 1,22578$ (for total), $R = 1,24381$ (for lower cretaceous), and $R = 1,21667$ (for upper cretaceous) at the 0,1 % significance level. The Donnelly's correction is not considered (discussion in Slovene text).

The immediate neighbours were determined by constructing symmetrals among nearby dolines. The average number of neighbours is 5,84. Nevertheless, it does not imply that the arrangement is hexagonal, as any quadrangular pattern being not rectangular too, produces the same effect. A side or two are short compared to the others then, and just this effect is very common in our case.

The H. Mc Connell and J. M. Horn's (1972) method was used too. The negative binomial distribution fits the best the square count data. It means, that the uneven distribution of dolines on lower and upper cretaceous limestones did not affect the statistics, probbably due to proper proportions of the both populations. If one may explain the negative binomial distribution in such circumstances at all, it seems that the best interpretation is that the basic distribution is the Poisson one, but its parameter is Gamma distributed. Such cases are very ofen in ore mineralization spatial distributions and it means that the doline distribution follows a very general geological structure, i. e. tiny fracturation.

The previous statistical findings can be summarized in a few general conclusions. Dolines appear more frequently on the thickly stratified, pure micritic upper cretaceous limestones, rather than on partly dolomitized lower cretaceous limestones, being somewhere thinly stratified or even laminated. On the other hand lythology does not control the pattern of spatial distribution, which appears to be governed by structural factors.

DOLINES SHAPING

The dolines considered in this chapter are generally named solution dolines, but this expression just implies such a genesis, which remains in several ways still enigmatic. The usual doline morphometry knacks proved not to be very effective (F. Šušteršič, 1985), another, more general access has been designed (o. c.). Twenty dolines in the experimental polygon were measured in this way bringing about a number of interesting data. Anyway, in this paper only two of them are presented, in order to show the method, rather then to start a discussion about their formation.

Doline LV 75 is an example of a simple doline. In its ground plane (Fig. 2/a) three concentrical zones can be perceived. In the outermost the slopes are not very centrically oriented, but they apparently try to follow some structural lines. The effect becomes more evident on the Fig. 2/b where the isoplethes connect the points of equal slope direction. Fig. 2/c shows that the inclination of the slope is relatively gentle in this area.

The middle area is characterized by centrical slope orientation and extremes in the gradient. The absolute gradient maximum is in the southwester quadrant, probably due to the combined dip angle and insolation (in fact shaddow) effect.

The central zone is rough in small scale, but as it is just the top of the sediment fill it is of no further interest.

On the eastern slope of the doline sharp changements of the slope direction were detected. Those lines of discontinuity (in the mathematical sense) were named sutures. Sutures are found in all the measured dolines and they apparently follow local structural directions. Further study of the proper sutures meaning is in course, alluding them to be connected with the master voids.

The direction of the maximum slope decline more or less from the ideal, centrical direction. On the Fig. 3 the amounts of deviation (ordinate) are plotted against the actual direction (abscissa). The figurative points are clustered near two very distinct directions, i. e. 20° and 170°, the deviations being maximal there too. It means that those directions are very dominant, extending their influence quite far around. This effect is common to all measured dolines (excluding the most complicated ones) and is well related to dinaric structural directions. (The internal pattern of the clusters is induced by scanning and has nothing to do with the doline shape).

On the other hand a small, isolated cluster is in the western direction. This being the dip direction, it is easy to explain it by the slope instability, induced in such a way.

The mentioned deviations may be transformed to their cosines and the correlation of any point in the doline, with the ideal shape is obtained. Having no proper experience, the value 0,9000 was arbitrarely decided to be the treshold between proper and biased doline shape. So, the semiprofiles, computed over proper slope regions only are informationally valuable. The correlation plot of the doline is shown on the Fig. 2/d. A simplified version of it is Fig. 2/a, where one may see that only a small part of the doline is regular enough to obtain proper semiprofiles. Some of them are drawn on both sides of the same figure.

It was found that the first three harmonics of any semiprofile contain more than 95 % of the total semiprofile variance and in most cases 99 % too. Thus, the fourth harmonic may be omitted without important lose of information. The first three may be interpreted as components of vectors in threedimensional space and the cosines of the mutual angles are measures of correlation (similarity). Any geometrical shape satisfactorily represented by the first three harmonics can be treated in the same way. So, the three most usual doline model shapes (cone, semisinusoidal and quarter-sinusoidal rotational bodies) were expressed in the same way. The harmonics vectors were normalized and a plane, perpendicular to the resultant defined (U, V). Any semiprofile representant vector transfixes the U, V plane in a point. The distances among these points are approximative measures of the similarity.

Any semiprofile in the doline can be computed and their representative points in the U, V plane form a closed curve (Fig. 4/b). Asterisks represent the three standard shapes and the heavy line the proper semoprofiles. Though they lie in two different parts of the doline they are quite similar, while all the rest are situated in various places of the U, V plane.

The proper semiprofiles differ from the standard ones a bit and it is a sign that up-to-date formalization of the dolines shaping has not been very effective. The proper semiprofiles express again the three well known concentrical stripes, permitting some more insight into the very geometrical relations.

The doline LV 70 is much more complicated, but more representative too. Its ground plane and additional maps (Fig. 5) express several foci of mass removal. Anyway, Fig. 6 shows that the influence areas of foci nr. 1 and 3 are not logically situated. This may be an effect of quite arbitrary organization of the central, loamy part of the doline, or just an effect of the computative algorhytm. Anyway, the focus nr. 2 is not doubtful and a bedrock barrier separates it from the others.

The same taxonomical procedures as before were performed. It is not surprise that the semiprofiles, running over two foci differ a lot from others, but it is a little unexpected, that the rest of them are practically the same as in the former doline. It gives a hope that the proper semiprofile basic shapes are few only, that will facilitate a lot the further studies. Other properties of the doline are visible on the Fig. 5 and no further comment is needed.

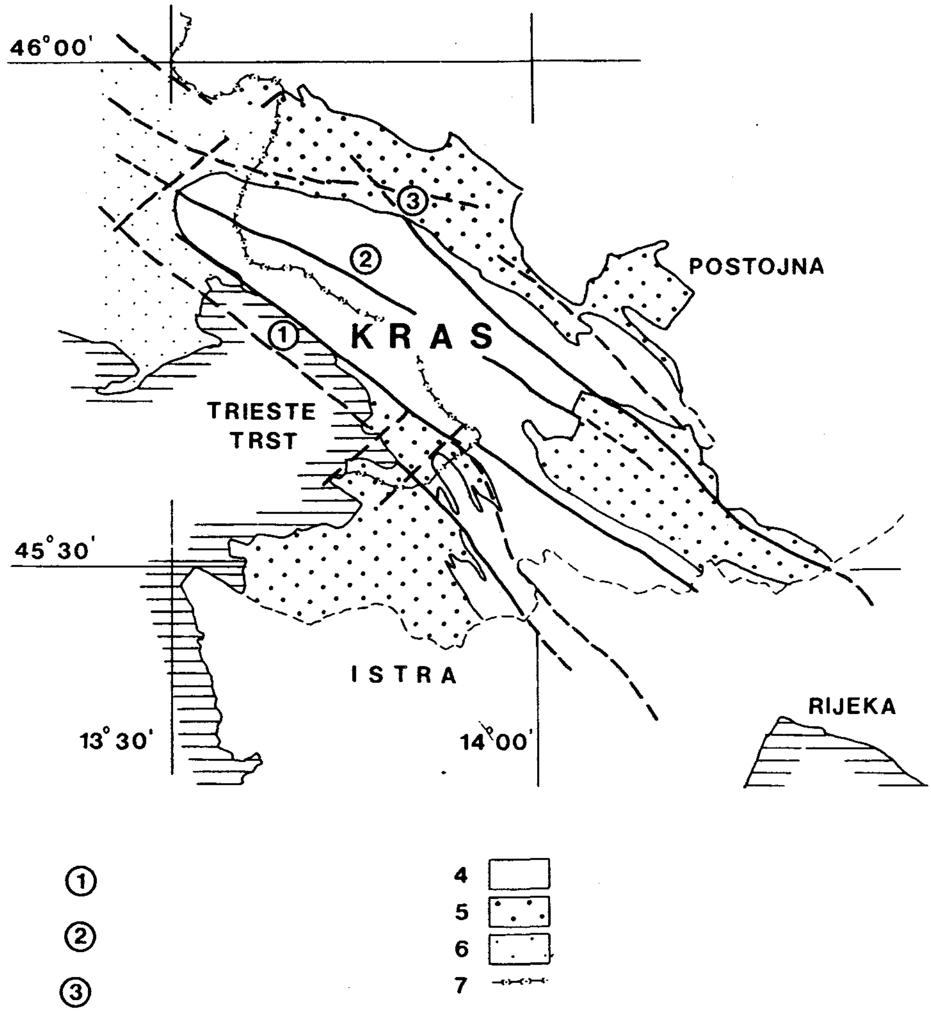
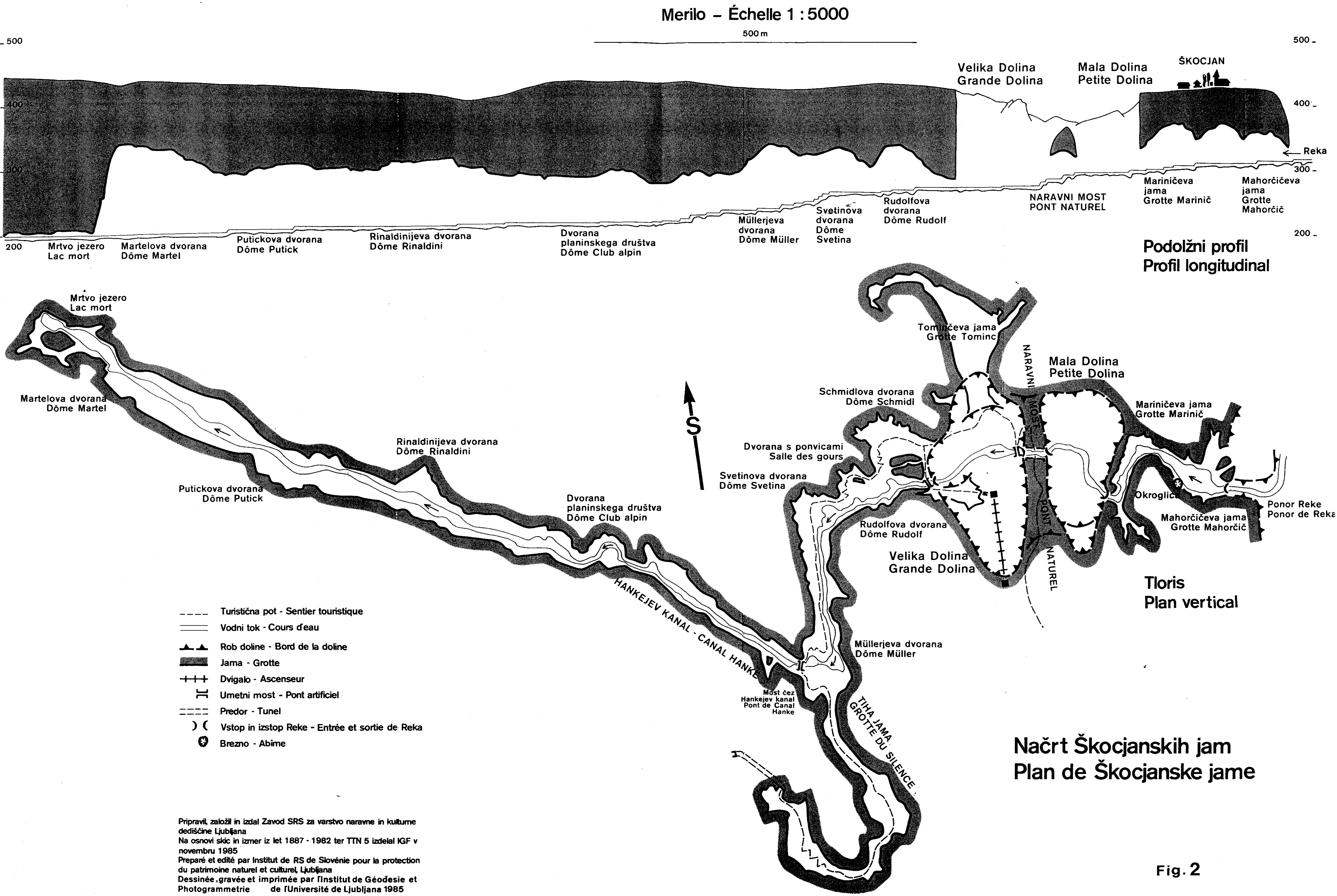


Fig. 1 Structural sketch of Karst. From Habič, 1983

1. Trieste fault
2. Divača fault
3. Raša fault
4. Carbonate rocks
5. Flysch
6. Alluvial sediments
7. National border



Merilo - Échelle 1 : 5000
500 m
500
400
300
200
Velika Dolina
Grande Dolina
Mala Dolina
Petite Dolina
ŠKOCJAN
Reka
Mrtvo jezero
Lac mort
Martelova dvorana
Dôme Martel
Putickova dvorana
Dôme Putick
Rinaldinijeva dvorana
Dôme Rinaldini
Dvorana
planinskega društva
Dôme Club alpin
Müllerjeva
dvorana
Dôme Müller
Svetinova
dvorana
Dôme
Svetina
Rudolfova
dvorana
Dôme Rudolf
NARAVNI MOST
PONT NATUREL
Mariničeva
jama
Grotte Marinič
Mahorčičeva
jama
Grotte
Mahorčič
Podolžni profil
Profil longitudinal
Mrtvo jezero
Lac mort
Martelova dvorana
Dôme Martel
Rinaldinijeva dvorana
Dôme Rinaldini
Putickova dvorana
Dôme Putick
Dvorana
planinskega društva
Dôme Club alpin
S
Tominčeva jama
Grotte Tominc
NARAVNI MOST
PONT NATUREL
Mala Dolina
Petite Dolina
Schmidlova dvorana
Dôme Schmidl
Mariničeva jama
Grotte Marinič
Dvorana s ponvicami
Salle des gours
Svetinova dvorana
Dôme Svetina
Okroglica
Ponor Reke
Ponor de Reka
Mahorčičeva jama
Grotte Mahorčič
Rudolfova dvorana
Dôme Rudolf
Velika Dolina
Grande Dolina
Tloris
Plan vertical
HANKEJEV KANAL - CANAL HANKE
Müllerjeva dvorana
Dôme Müller
Most čez
Hankejev kanal
Pont de Canal
Hanke
TIHA JAMA
GROTTE DU SILENCE
Turistična pot - Sentier touristique
Vodni tok - Cours d'eau
Rob doline - Bord de la doline
Jama - Grotte
Dvigalo - Ascenseur
Umetni most - Pont artificiel
Predor - Tunel
Vstop in izstop Reke - Entrée et sortie de Reka
Brezno - Abîme
Načrt Škocjanskih jam
Plan de Škocjanske jame
Pripravil, založil in izdal Zavod SRS za varstvo naravne in kulturne dediščine Ljubljana
Na osnovi skic in izmer iz let 1887 - 1982 ter TTN 5 izdelal IGF v novembru 1985
Preparé et edité par Institut de RS de Slovénie pour la protection du patrimoine naturel et culturel, Ljubljana
Dessinée, gravée et imprimée par l'Institut de Géodesie et Photogrammetrie de l'Université de Ljubljana 1985

Fig. 2

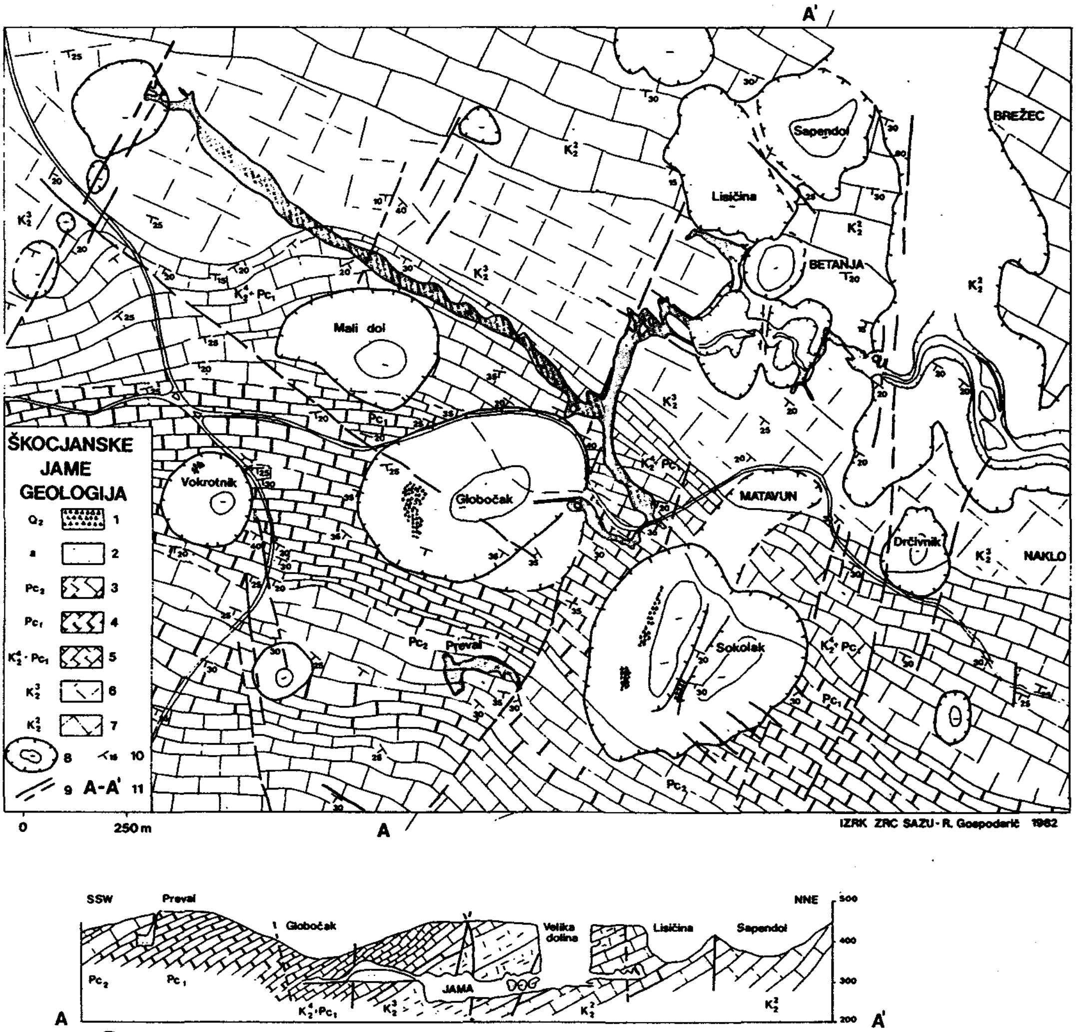
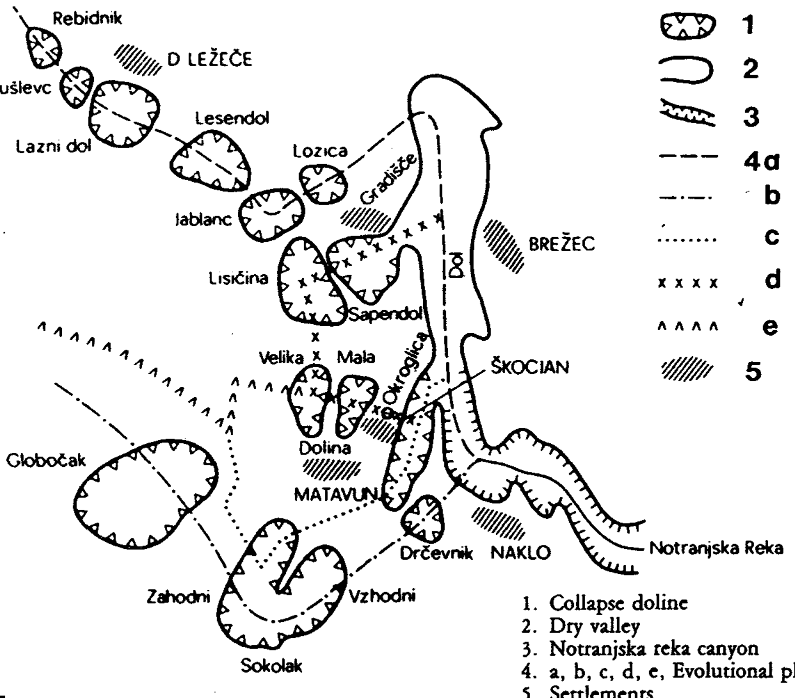


Fig. **3** Geologic Map of Škocjanske Jame Karst.



1. Collapse doline
2. Dry valley
3. Notranjska reka canyon
4. a, b, c, d, e, Evolutional phases
5. Settlements

From Gams, 1983, 26.

Fig. **4** Contact forms of Škocjan karst

Fig. 6.: Morhological sketch of the Odolina blind valley

Legend: 1. surface on flysch, 2. blind valley bottom - flat corrosion widened surface covered with sediments on limestone, 3. surface on limestone, a. Matarsko podolje karst plain, with solutional dolines as dominant form, b. surface with dominant conical hills, 4. watershed, 5. contact flysch - limestone, 6. brooks with ponors and ponor caves, 7. slope of blind valley, 8. slope formed along the lithological contact, 9. ponor steephead, 10. alluvial dolines and sinkholes, 11. solutional dolines , 12. edges of alluvial terraces in the bottom of blind valley, 13. conical hill.

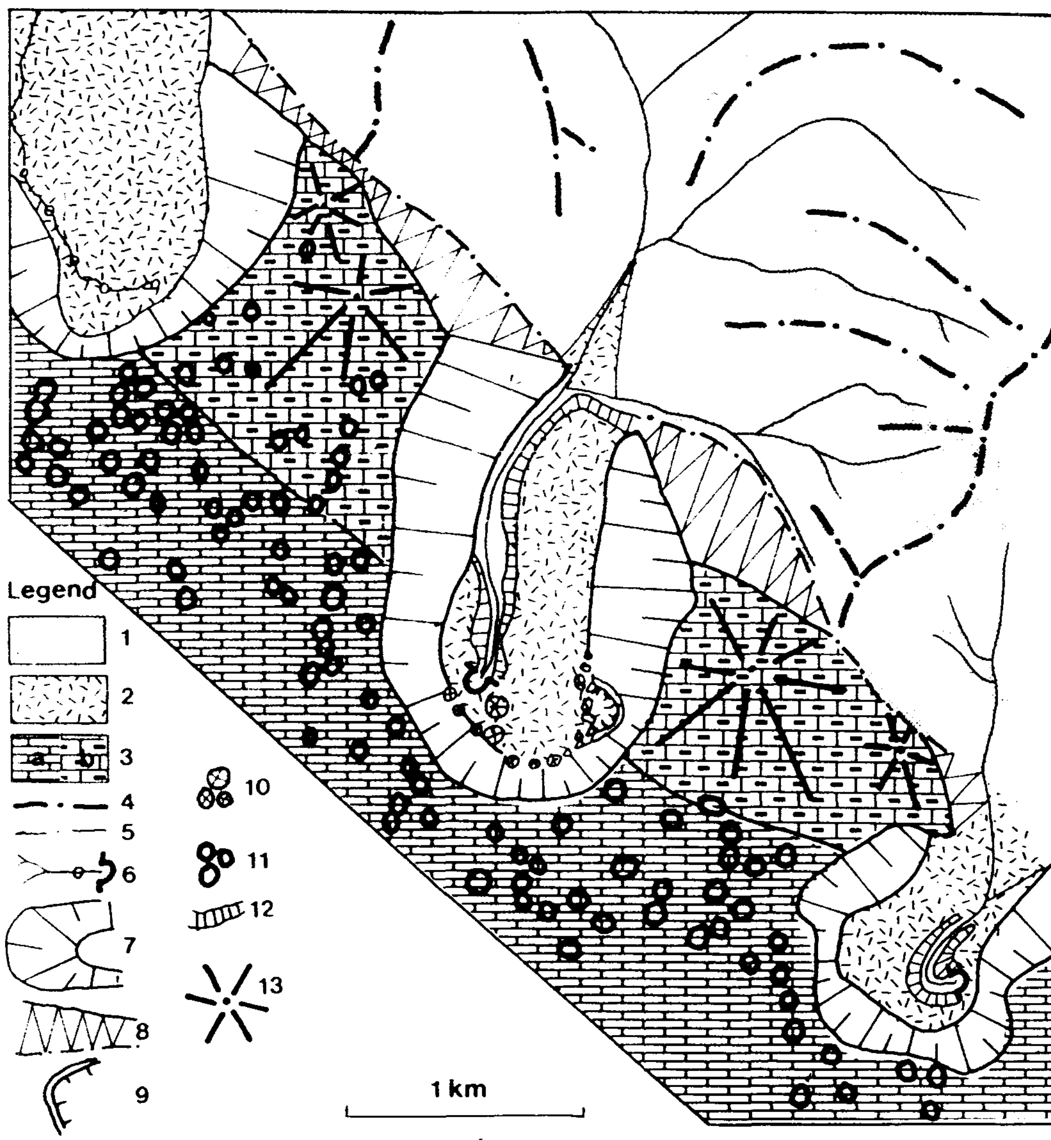


Fig. 7.: Morhological sketch of the Račiška dana valley

Legend: 1. surface on flysch, 2. surface on limestone- Gradine, 3. limestone surface of Matarsko podolje, 4. Bottom ob fossil blind valley, 5. sediments in the bottoms of blind valleys, 6. watershed, 7. contact flysch - limestone, 8. brooks with ponors and ponor caves, 9. slope betveen Gradine and Matarsko podolje, 10. slope formed along the lithological contact, 11. Blind valley of Zavnja brook, 12. blind valley of Račiška dana, 13. ponor steephead, 14. dry valley of Zavnja, 15. wall in the ponor steephead, 16. collapse doline, 17. *solutional dolines*, 18.*aluvial sinkhole*, 19. edges of alluvial terraces in the bottom of blind valley, 20. conical hill.

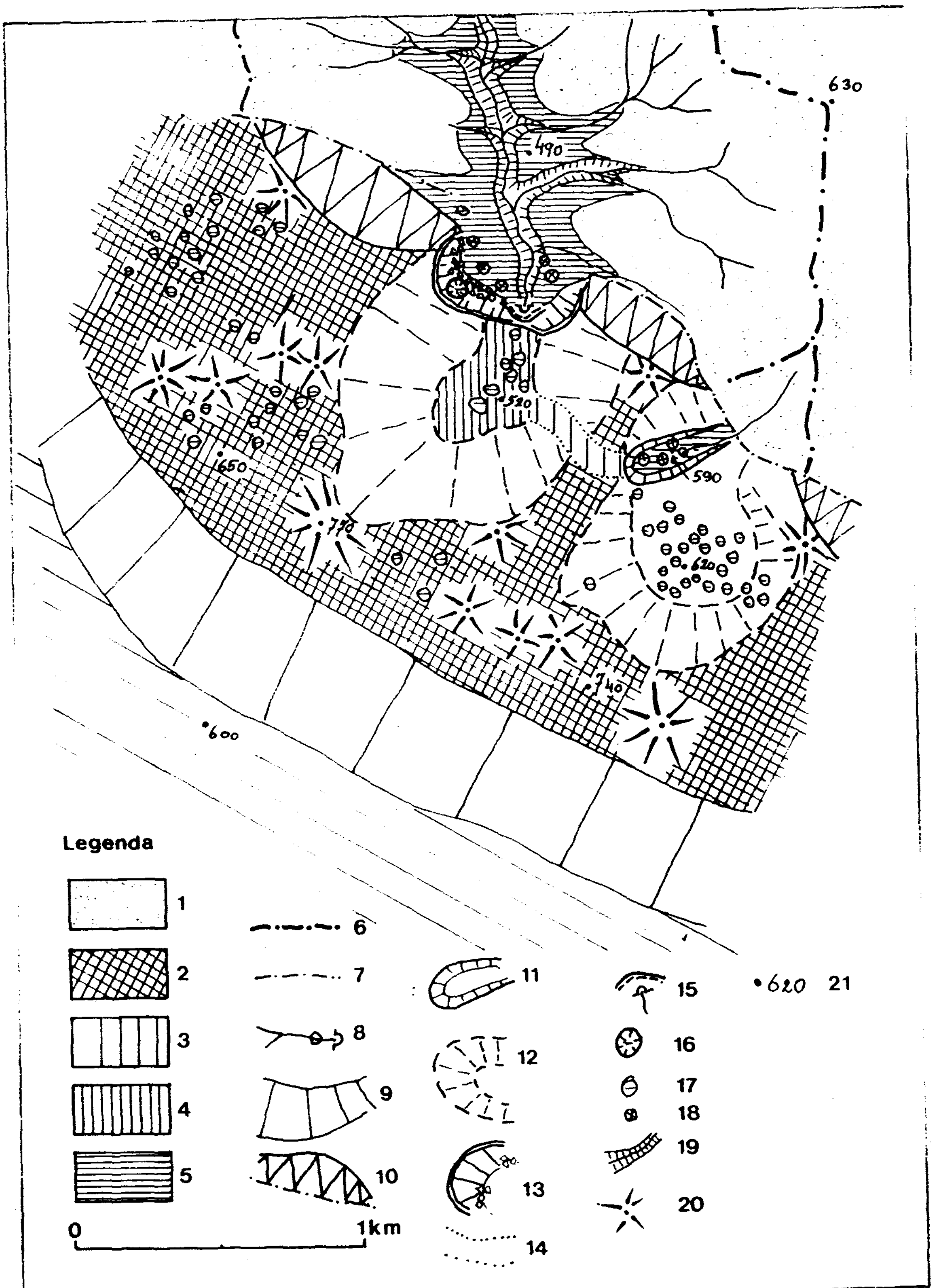


Fig. 8.: Geomorphological sketch of the contact karst at the foot of Brkini.Between Brkini hills and corrosion plain Matarsko podolje is narrow belt of higher relief formed in limestones.

Legend: 1. Brook with sinkhole,2. watershed, 3. blind valley, 4. fossil blind valley, 5. flysch, 6. cross section over blind valleys.

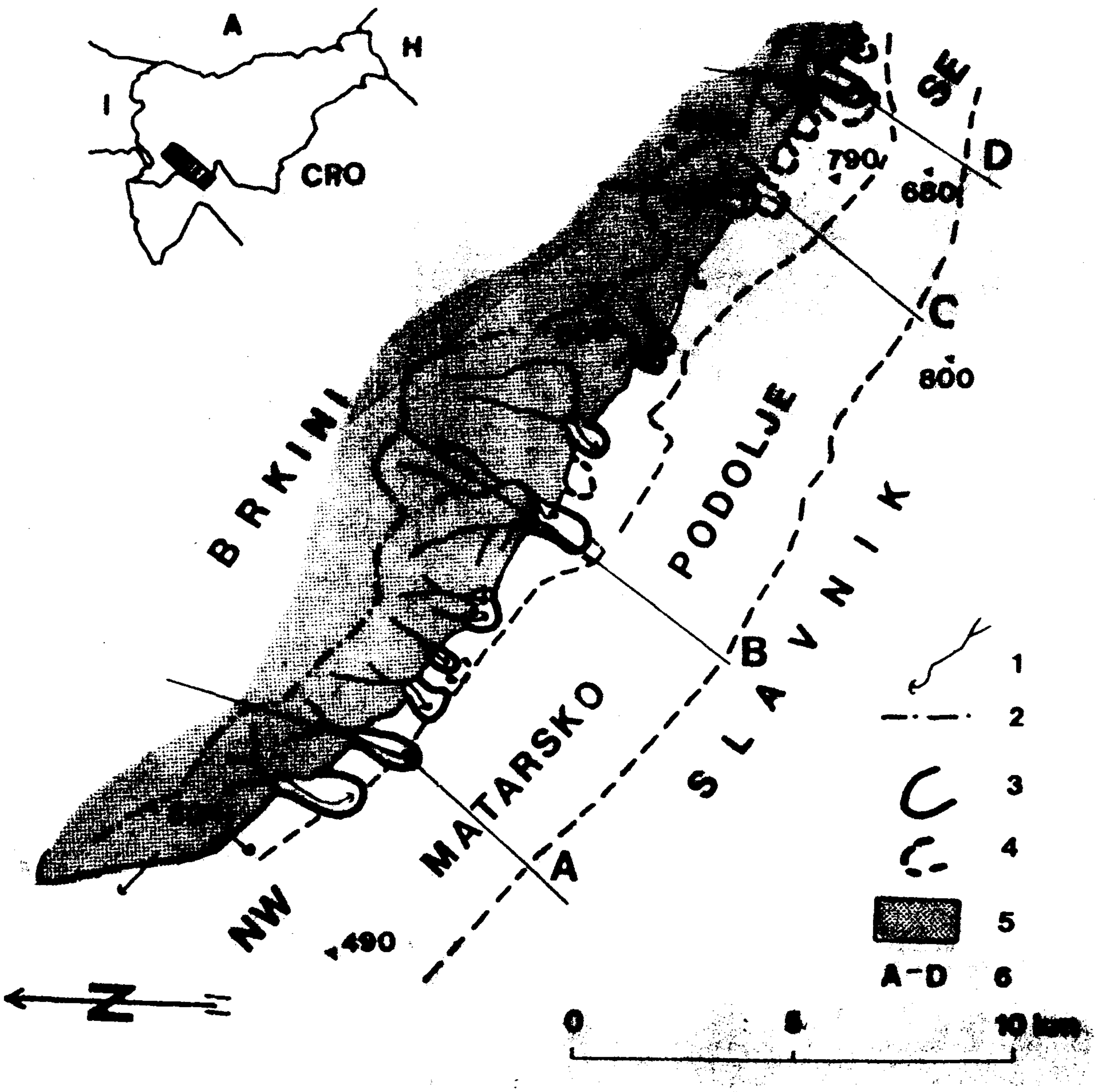
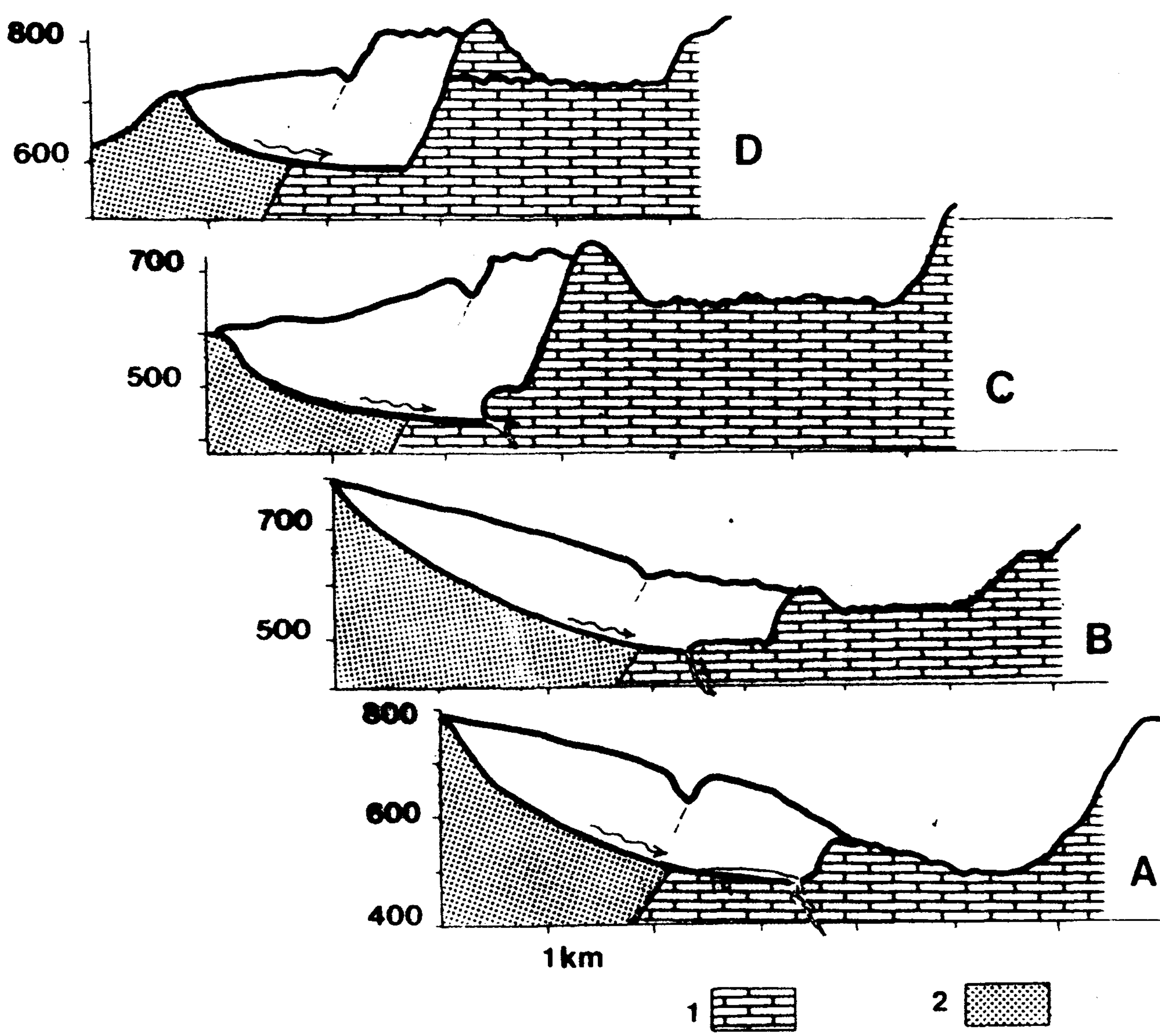
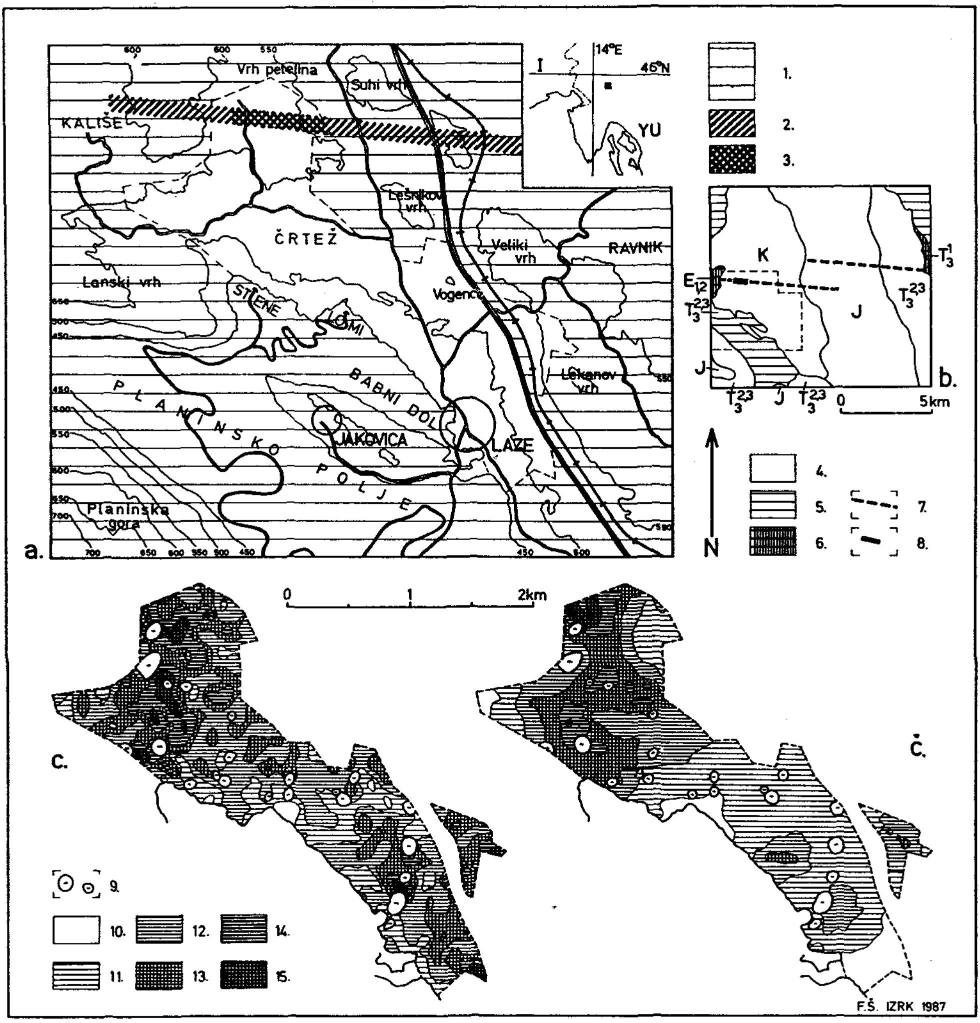


Fig. 9: Cross sections over the catchment areas of the sinking streams on flysch, blind valleys of the sinking streams and the bottom of Matarsko podolje. Blind valleys: A Odolina, B Jezerina, C Račiška dana, D Brdanska dana

Legend: 1. limestone, 2. flysch





Sl.10 a) Pregledna karta obravnavanega ozemlja.
1. Ozemlje, ki ni bilo vključeno v raziskave.
2. Načrtovani pas podrobnih meritev vrtač.
3. Ozemlje z izvršenimi podrobnimi meritvami vrtač.

b) Pregledna geološka skica.
4. Karbonatne kamnine.
5. Aluvij.
6. Nekarbonatne klastične kamnine.
7. Načrtovane podrobne meritve vrtač.
8. Izvršene podrobne meritve vrtač.

c) Število vrtač na hektar.
9. Udornice.
10. Ozemlje brez vrtač.
11. 0—1,5.
12. 1,6—3,0.
13. 3,1—4,5.
14. 4,6—6,0.
15. 6,0 <.

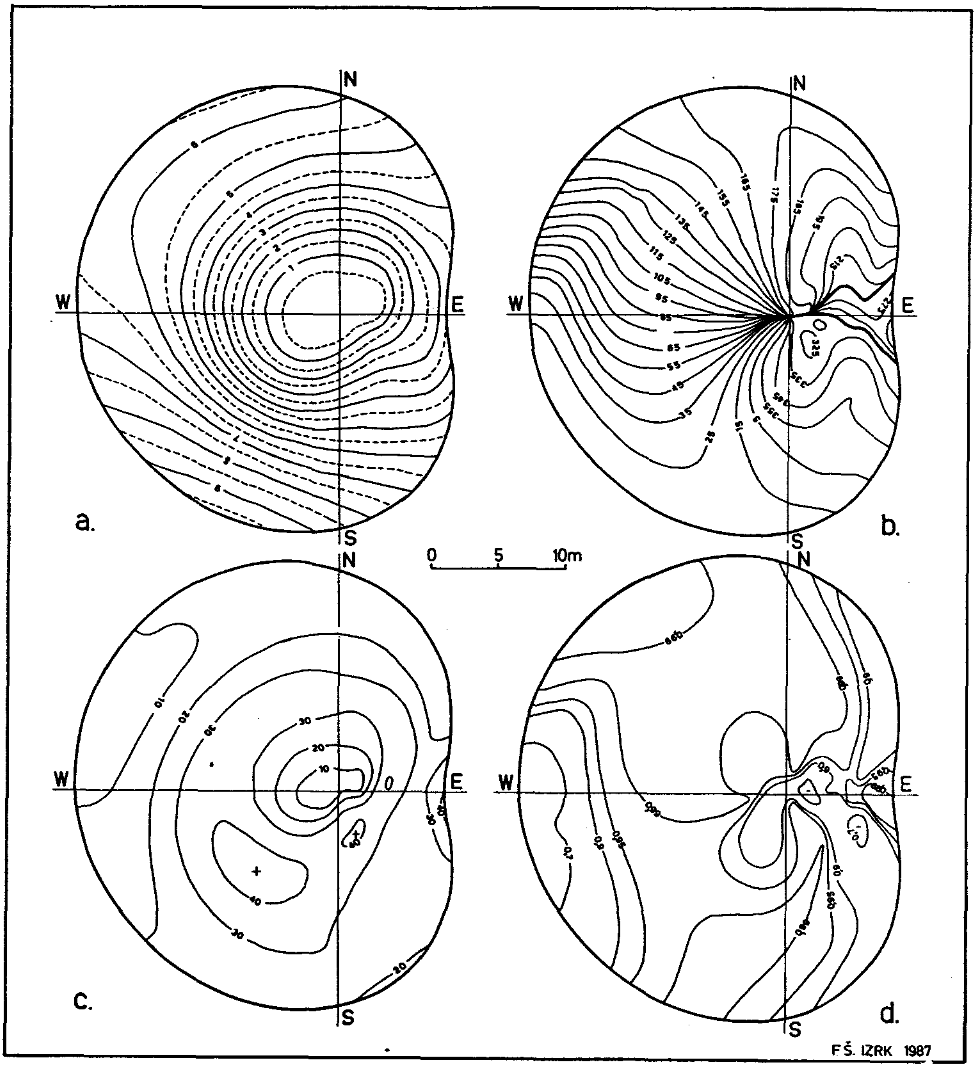
č) Število korozijskih brezen na km².
9. Udornice.
10. Ozemlje brez brezen.
11. 0—15.
12. 16—30.
13. 31—45.
14. 46—60.
15. 61 <.

Fig.10 a) Survey map of the studied territory.
1. The areas being not included into present work.
2. The stripe of the planned detailed dolines measurement.
3. The area of achieved doline measurement.

b) Survey geological sketch.
4. Carbonate rocks.
5. Alluvium.
6. Noncarbonate clastic rocks.
7. Planned dolines measurement stripe.
8. Achieved dolines measurement area.

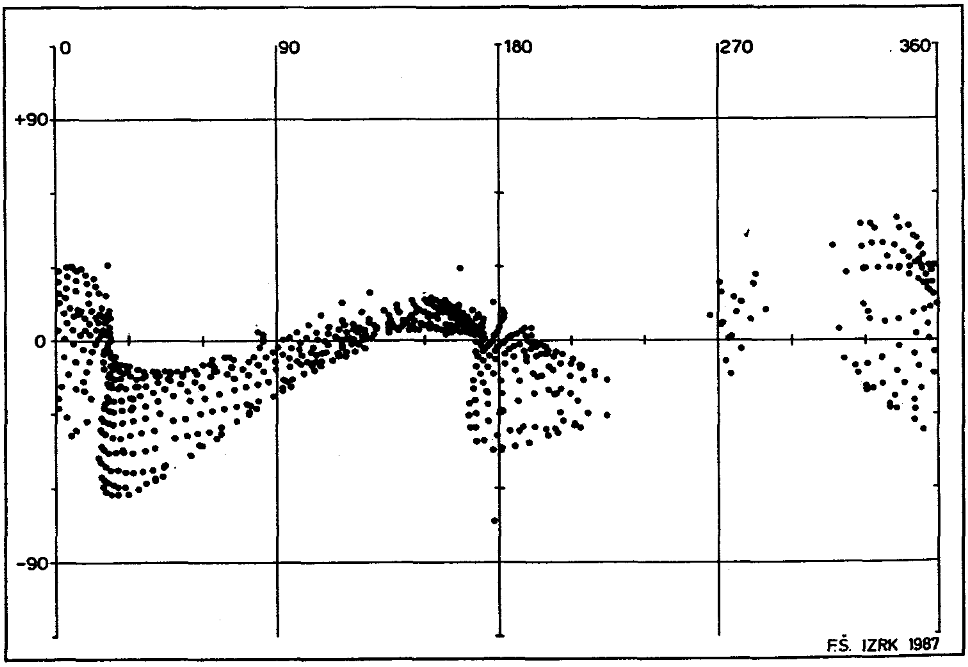
c) Number of dolines per ha (10 000 m²).
9. Collapse dolines.
10. Areas without dolines.
11. 0—1.5.
12. 1.6—3.0.
13. 3.1—4.5.
14. 4.6—6.0.
15. 6.1 <.

č) Number of corrosion shafts per km².
9. Collapse dolines.
10. Areas without corrosion shafts.
11. 0—15.
12. 16—30.
13. 31—45.
14. 46—60.
15. 61 <.



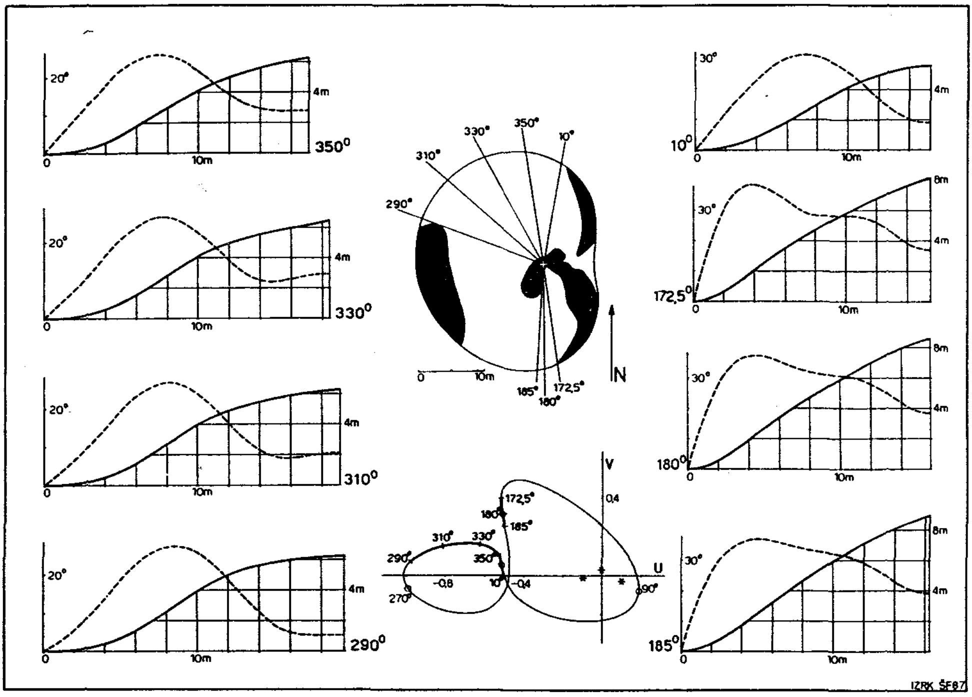
Sl.**11**. Vrtača LV 73.
a) Tloris.
b) Smeri največjega strmca pobočij.
c) Iznosi največjega strmca pobočij.
d) Korelacija z idealno obliko.

Fig.**11** Doline LV 73.
a) Ground plan.
b) Directions of the greatest slope.
c) Values of the greatest slope.
d) Correlations with the ideal shape.



Sl.**12** Vrtača LV 73. Primerjava smernih odklonov z dejanskimi smermi največjega strmca pobočij.

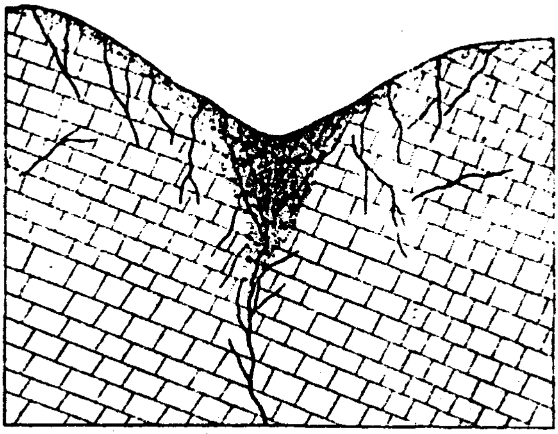
Fig.**12** Doline LV 73. Plot of the directional deviations and the actual greatest slope inclination directions.



Sl.**13** Vrtača LV 73.
a) Območja sprejemljivih in spačenih polrezov.
b) Primerjava dejanskih oblik polrezov z etalonskimi. Zvezdice: gornja: pravilni stožec, leva: vrtenina polovice sinusoide, desna: vrtenina četrtine sinusoide.

Fig.**13** Doline LV 73.
a) Proper and biased semiprofiles regions.
b) Correlation of the actual semiprofiles to standards. Asterisks: upper: regular cone, left: half sinusoide rotation body, right: quarter sinusoide rotational body.

Die bloßgelegten, angeschnittenen Dolinen geben einen vollständigen Aufschluss über die Zusammensetzung ihres Untergrundes und alle Beobachtungen, welche darüber vorliegen, zeigen nur, dass die kleinen typischen Dolinen Oberflächengebilde sind. Ich habe solche angeschnittene Dolinen in dem zweiten Eisenbahneinschnitte südlich von Unterloitsch in Krain beobachtet. (Siehe Profil.) Unter denselben kommen keine Höhlen vor, der Schichtverband ist nirgends gestört; von dem Dolinenboden setzen sich aber zahlreiche Klüfte durch eine Zone verwitterten Kalksteines fort und sind bis in das frisch aussehende, wenig zersetzte Gestein zu verfolgen, welches die Unterlage bildet und ebenfalls entblößt ist.



Durchschnitt einer 8 m tiefen Doline mit Unterlage. Unterloitsch in Krain.

fig.14

LJUBLJANA
BREZOVICA
DRAGOMER
VRHNIKA
LOGATEC
x3
x4
x5
x2
x1
PLANINA
RAKEK
CERKNICA
POSTOJNA
PIVKA
ILIRSKA BISTRICA
SENOŽEČE
IDRIJA
ŽIRI
VIPAVA
BOROVNICA
ŠKOFLJICA
IG
STARI TRG
LOŽ
KNEŽAK
PRESTRANEK
HRPELJE
PODGRAD
KLANA
Snežnik
Javornik
Nanos
Ljubljanica

INTERNATIONAL KARSTOLOGICAL SCHOOL

LIST OF PARTICIPANTS

1.Dr. Ivan BALAK
Sprava Chranene krajinne oblasti Moravski kras
Sadova 2
67801 BLANSKO
Česka republika

2.Dr. Branka BERCE-BRATKO
AREA
Cesta 4. maja 51
61380 Cerknica
Slovenia

3.Dr. Pavel BOSAK
Czech Speleological Society
Slezska 19
120 000 Praha 2
Česka republika

4.Ga. Martina BRNOT
Rozmanova 5
61240 Kamnik
Slovenija

5.Ga. Anica CERNATIČ-GREGORIČ
ZVNKD Gorica
Delpinova 16
65000 NOVA GORICA

6.Prof. Dr. Dora CROUCH
Rensselaer Polytechnic Institute
739 Yale St. 6B
CA 93060 Santa Paula
USA

7. Dr. Franco CUCCHI
Istituto di geologia e paletnologia dell'Università degli studi
Piazzale Europa 1
34132 TRIESTE
Italia

8. Mr. Andrej G. FILIPPOV
Vost. Sib. NIIGGIMS
st. Dekabrskih Sobitiy 29
664062 IRKUTSK
RUSSIA

9. Dr. Fabien HOBLEA
14 rue de Bel-Air
01140 THOISSEY
France

10. Ga. Maja JAKIČ
Kunaverjeva 1
61000 LJUBLJANA
Slovenija

11. Mag. Janja KOGOVŠEK
Inštitut za raziskovanje krasa ZRC SAZU
Titov trg 2
66230 POSTOJNA
Slovenija

12. Dr. Andrej KRANJC
Inštitut za raziskovanje krasa ZRC SAZU
Titov trg 2
66230 POSTOJNA
Slovenija

13. Ga. Maja KRANJC
Inštitut za raziskovanje krasa ZRC SAZU
Titov trg 2
66230 POSTOJNA
Slovenija

14. Dr. Jurij KUNAVER
Oddelek za geografijo, FF
Aškerčeva 2
61000 LJUBLJANA
Slovenija

15. Ga. Barbara LAMPIČ
Grablovičeva 32
61000 LJUBLJANA
Slovenija

16. Prof. dr. E.P. LÖHNERT
Westfälische Wilhelms-Universität,
Geologisch-Paläontologisches Institut
Corrensstrasse 24
4400 MÜNSTER
Germany

17. Mag. Andrej MIHEVC
Inštitut za raziskovanje krasa ZRC SAZU
Titov trg 2
66230 POSTOJNA
Slovenija

18. Ing. Matjaž MLINAR
AREA
Cesta 4. maja 51
61380 CERKNICA
Slovenija

19. Mr. Jiri Robert OTAVA
Czech Geological Survey
Leitnerova 22
658 69 BRNO
Česka republika

20. Ga. Urška PETJE
61355 POLHOV GRADEC 104
Slovenija

21. Ga. Metka PETRIČ
    V. Mohoriča 4
    65280 IDRIJA
    Slovenija

22. Dr. Simon PIRC
    Oddelek za geologijo FNT
    Aškerčeva 12
    61000 LJUBLJANA
    Slovenija

23. ~~Mr. Michal PIŠKULA~~
    ~~Czech Speleological Society~~
    ~~Ondrova 23~~
    ~~63500 BRNO~~
    ~~Česka republika~~

24. ~~Mr. Matjaž PUC~~
    ~~Aškerčeva 15~~
    ~~61000 LJUBLJANA~~
    ~~Slovenija~~

25. ~~Gospod Daniel ROJŠEK~~
    ~~Rutarjeva 4a~~
    ~~65000 NOVA GORICA~~
    ~~Slovenija~~

26. ~~Prof. dr Ugo SAURO~~
    ~~Dipartimento di Geografia~~
    ~~Via Del Santo 26~~
    ~~35123 PADOVA~~
    ~~Italia~~

27. ~~Ga. Martina SELJAK~~
    ~~Smoljevo naselje~~
    ~~61386 LOŽ~~
    ~~Slovenija~~

28. Sg. Margherita SOLARI
University of Padova
Vicolo del Portello 3/7
35129 PADOVA
Italia

29. Ga. Martina STUPAR
ZVNKD Gorica
Delpinova 16
65000 NOVA GORICA
Slovenija

30. Ga. Suzana SVETLIČIČ
Inštitut za raziskovanje krasa ZRC SAZU
Titov trg 2
66230 POSTOJNA
Slovenija

31. Dr. Leoš ŠTEFKA
Sprava Chranene krajinne oblasti Moravski kras
Sadova 2
67801 BLANSKO
Česka republika

32. Dr. France ŠUŠTERŠIČ
FNT - VTOZD Montanistika, Odsek za geologijo
Aškerčeva 2
61000 LJUBLJANA
Slovenija

33. Mr. Andzej TYC
Katedra Geomorfologii, Uniwersytet Šlaski
Ul.Bedzinska 60
41-200 SOSNOWIEC
Polska

34. Ga. Mojca URANKAR
Glavičeva 18
61234 MENGEŠ
Slovenija

35. Ga. Mimi URBANC
Goriče 24
64204 GORIČE
Slovenija

36. Gospod Marko VRABEC
Šipkova 8
61240 KAMNIK