KARST FEATURES IN THE MOTORWAY SECTION BETWEEN ČEBULOVICA AND DANE

KRAŠKI POJAVI V TRASI AVTOCESTE MED ČEBULOVICO IN DANAMI

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Tadej Slabe: Kraški pojavi v trasi avtoceste med Čebulovico in Danami

Pri načrtovanju in gradnji avtocest na krasu sodelujejo krasoslovci Inštituta za raziskovanje krasa ZRC SAZU. Na 14 km trase je bilo ob dveh že znanih jamah odkritih še 76 jam. Iz starih jam lahko razberemo več najstarejših obdobij razvoja vodonosnika. Nastale so v zaliti coni, nato bile preoblikovane s hitrejšimi vodnimi tokovi in zaradi znižanja vodne gladine v vodonosniku ostale suhe. V njih se je odlagala siga. Veliko jam so dosegle visoke poplavne vode in jih zapolnile z drobnozrnato naplavino. Priča smo torej zakrasevanju vodonosnika z nižanjem podzemeljske vodne gladine in njenemu občasnemu nihanju. Zaradi znižanja kraškega površja so mnoge jame, zapolnjene z naplavino, ostale brez stropa.

Ključne besede: krasoslovje, gradnja avtocest, slovenski kras

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Tadej Slabe: Karst features in the motorway section between Čebulovica and Dane

The karstologists of the Karst Research Institute ZRC SAZU are taking part at planning and constructing the new motorways over karst. The 14 km long laying-out where two caves were already known, revealed additional 76 caves. Old caves indicate oldest periods of the aquifer development. Caves developed in phreatic zone and were later transformed by faster water flows and due to lowering of water level in the aquifer remained dry. Flowstone was deposited in them. Many caves were reached by high flood waters and filled with fine-grained sediments. The karstification is due to underground water level lowering and its periodical variations. As the karst surface lowered many caves remained without roof.

Key words: karstology, motorway construction, the Slovenian karst

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INTRODUCTION

In Slovenia, an extensive part of the motorways is planned to be located in the karst. Denuding of the karstic surface and construction works for new roads reveal numerous karst phenomena. These are old karst caves which are hollow or filled up with alluvium, potholes with waters percolating from the surface into the ground, and various dolines. We, karstologists, take part in the planning of roads by making efforts to preserve characteristics of the karst landscape in the best possible way as well as taking part in the construction of these roads by surveying karstic phenomena, studying them and trying to suggest the ways for their preservation consistent with the safety of roads. The karstological control is carried out under a patronage of Zavod za varstvo naravne in kulturne dediščine Gorica (Institute of Natural and Cultural Heritage Protection Gorica) and financed by Družba za avtoceste RS (Motorways Company of Republic of Slovenia).

On this occasion I would like to present particularly the descriptions of the newly discovered karst features which should serve as the basis for more profound study of the formation and development of this part of the Slovenian karst. The recently discovered caves have been researched, surveyed and their plans completed. Some most typical samples of flowstone and deposits have been taken from the old caves. Different types of deposits have been systematically collected and prepared for mineralogical analyses by means of the Roentgen diffraction method as well as for microscopic, geochemical and pollen analyses. New perceptions will be of great help also in subsequent motorway construction.

THE KARST OF THE DIVAČA AREA

The Čebulovica - Divača road section (Fig. 1) runs transvers along the eastern edge of the karstic ridge, which extends from Štorje towards Čebulovica as far as the doline-pitted plain west of Škocjanske jame; between Divača and Dane the road section runs along the less karstified Divaško podolje around Divača (Melik 1960, 199).

Karstologists have come to the conclusion that in the Kras, the traces of the primary surface run off of water towards the north-west are well preserved. Melik (1960, 201) made conclusions on the basis of the slopes of

the present surface, and Radinja (1972, 13) on the basis of the abandoned valleys and sediment remains on the karstic surface. In the past when carbonate rocks started to be denuded, the limestones must have been blocked and ground water held behind the barriers, which preserved the surface streams. The former surface run off from the area of Brkini across the Kras formed a longitudinal system of valleys between Divača and Brestovica (Habič 1974, 8). The study of the surface development between the poljes of Postojna and Cerknica by Gams (1965, 90) came to the conslusion that some morphological processes accelerated karstic dissection and the formation of doline-like features which were too often regarded as the remains of fluvial valleys. Relief characteristics of the Divaško podolje are also dependent on the structure and lithology as various lithostratigraphic elements and the main faults are directed from south-east towards north-west (Habič 1974, 8).

Near Divača the Palaeocene limestones (Fig. 1) of the Brkini syncline are in contact with Lower Cretaceous dark-grey bituminous dolomites along a distinctive Dinaric-directed fault (Habič 1974, 4). One part of the road section south of Divača is directed along the dark-grey bedded Cretaceous limestone alternating with the rudist Cretaceous limestone. Between Divača and Dane, that is along the Divača fault which is reflected also in the relief, there is a road section directed along the Palaeocene limestone (in smaller sections also along the Cretaceous limestone) and the dark-grey Cretaceous dolomite. Construction works for the road section revealed also tectonically fissured rock and numerous fault indicating the movement of the rock blocks into different directions. In the fault area the limestone is crushed into rubble and mylonite.

Characteristics of this part of the karst accord with the present hydrologic conditions. The present underground streams run at a depth of 200-300 m. South of Divača the river Reka, running from the sink at Škocjanske jame, is directed parallely to the road section, crosses it near Divača and runs beneath the Divaško podolje NW towards the sources of the Timavo. Precipitation waters reach the springs by vertical percolation. There have been warnings against the danger of pollution of underground waters which are being threatened due to karstic permeability. This fact can be proved also by studying the quality of waters which drain from the motorways (Kogovšek 1993) and by some experience in accidental spills of hazardous matters (Knez et al. 1994).

Regular karstological inspection has started relatively late. The major part of the road section had already been denuded, as well as vegetation and soil removed. Near Dane there is a hummocky rocky relief beneath the 0.5 m thick layer of brown soil. The two-metre wide, long rocky hummocks and fissures also, are rounded and smooth (Gams 1971). Individual thin layers of rock were crushed, and yellow rubble and red loam disclosed. Yellow rubble can be found also in some other fissured rocky zones of the road section.

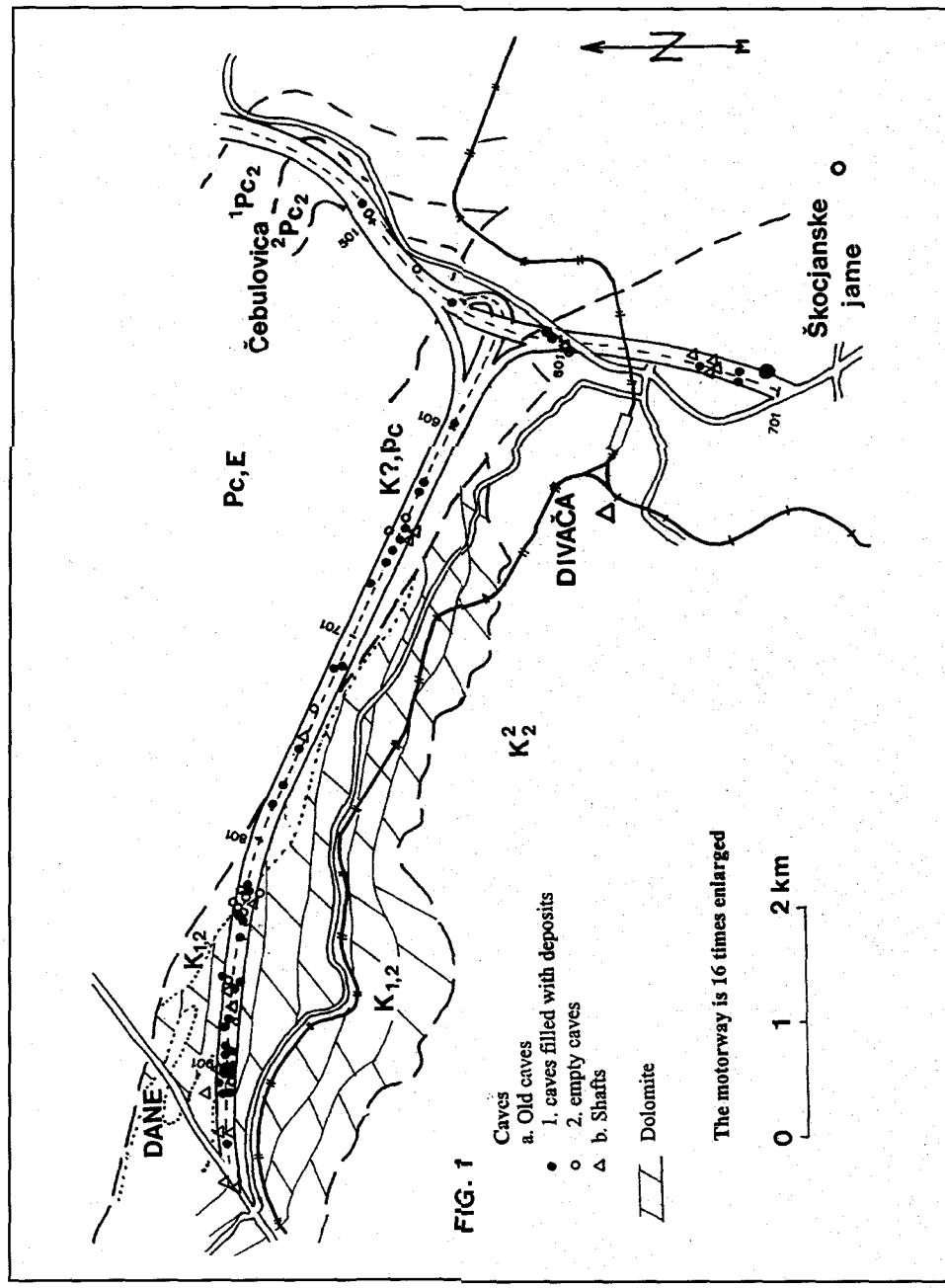

Fig. 1: Caves in a motorway
Sl. 1: Jame v trasi avtoceste

DOLINES

Due to their shape, dolines in the highway section were divided by Habič (1974, 6, 7) into funnel-shaped dolines from which loam is mostly rainwashed, bowl-shaped dolines with an extensive loam surface at the bottom, and shallow infilled dolines with slightly permeable loam at the bottom. The filled up dolines often contain water. Near Divača there are 11 dolines per km of the road section, and between Divača and Sežana only 5. In the southern motorway section of Čebulovica-Divača there are in the Cretaceous limestone large funnel-shaped dolines with only a little loam. Bowl-shaped and filled up dolines prevail in the limestone of Divaško podolje. The latter are small, 30 to 50 m in diameter and 5 to 15 m deep. The greatest depth of the doline, established by means of drilling, was 27,5 m (Habič 1974, 5). Red and brown karst loams prevail in the dolines. The loam is rainwashed from the doline slopes onto the rubble base which was formed by weathering of the rocky bedrock. Some dolines contain also flysch sand and gravel as well as yellowish and layered silt which is probably alluvium left behind by the former watercourses (Habič 1974, 6). By means of drillling Habič (1987) studied one partly excavated doline near Sežana. Small and rarely pitted filled up dolines etch into a hummocky dolomite surface which is covered by a thin layer of soil. The upper layer of the doline fill consists of brown soil, 1,5 m below the surface there is red loam.

The motorway construction works demanded removing the alluvium from the filled up dolines. The results obtained during the previos research by means of drilling into the doline alluvium were thus confirmed. The dolines often consisted of a considerable amount of older, mostly flysch alluvium. A doline in the section of Divača-Dane, at cross-section 752, consisted of flysch gravel reaching almost up to the surface. It has to be pointed out that there are many filled up dolines within the old caves, which are filled with alluvium and are already roofless. Shafts were formed beneath the channels filled with water streams which in their youngest development stages deposited also flysch loam and sand, and in dry periods flowstone was deposited. In the flysch alluvium rainwashed by the surface water, there formed funnel-shaped indentations filled with brown and red karst loam and rubble.

Near Povirje there was a sinkhole pond with permanent water at the bottom which was surrounded by walls. The pond was located on an elevation, on top of the anticline. The elevation had to be cut through, so the pond was not preserved. The digging works confirmed a supposition that surface water was held by impermeable loam which was deposited in an old channel, the floor of which was covered by a large mound of flowstone.

Shafts frequently opened up at the bottom or on the edge of the dolines in limestone and dolomite. Large dolines (Šušteršič 1985, 94) contain many shafts, which was reflected also in their shape.

Near Žirje and Dane, the construction works cut through filled up artificial dolines (Gams 1974, 177; Gams 1991, 39). The cross-section of an excavated doline gave clear evidence of filling up with rocks and stones which were collected during the removing of soil in the doline and clearing of the surrounding karstic surface. The stones and rocks had been put into the excavated doline and were covered by soil. In this way much more level cultivatable land was obtained.

During the road construction, loam and rubble were first removed from the dolines, and the bottom, particularly when cavernous, was stabilized with rocks which were fastened by concrete. The dolines were later filled up with 30 cm layers of rocky rubble which was simultaneously consolidated by means of the vibration roller (Fig. 2). Soil and loam which had been dug out from the dolines were used for filling up some dolines near the road.

CAVES

The caves investigated during the construction works for the motorway can be divided into old caves (57 newly discovered) and potholes (19). The old caves are empty (24) or filled with sediments (33). The caves Golobja jama and Mošenjska (Srnja) jama, which had to be blasted during the digging of the cuttings, had been discovered before. Altogether 76 caves were discovered on 14 km of a new road. These were mostly smaller old caves, only six of them had the passages of 5 m or more across. Parts of the same cave systems were cut several times. A lot of inaccessible fissures also opened that drained the water to the shafts. Smaller passages that developed along bedding-planes we did not consider as caves. However, the number of discovered caves is related to a sort of earth-works. The least caves were discovered in those parts where there were no important earth-works or digging.

Old caves

The caves, which are the remains of the oldest underground water courses in this part of the karst, consist of a maze of nearly gently sloping channels, which are 1 to 5 m in diameter, and small connecting chambers (Fig. 3, Fig. 7). The channels were formed by slow flowing streams, which is evidenced by the complex systems of channels, their meandering feature and in places the rocky relief. Their walls are partly covered in flowstone and dripstone formations. This type of cave (the caves are few) occurs particularly in a slightly higher part of the karst below Čebulovica. In dolomite, smaller chambers were frequently formed between nearly gently sloping beds of rock. The channels occur along the beds which were disintegraded into fine-grained sand.

More frequent are those caves filled with deposits (Fig. 4). Such caves are now roofless and meander on the surface like the water channels or filled-up

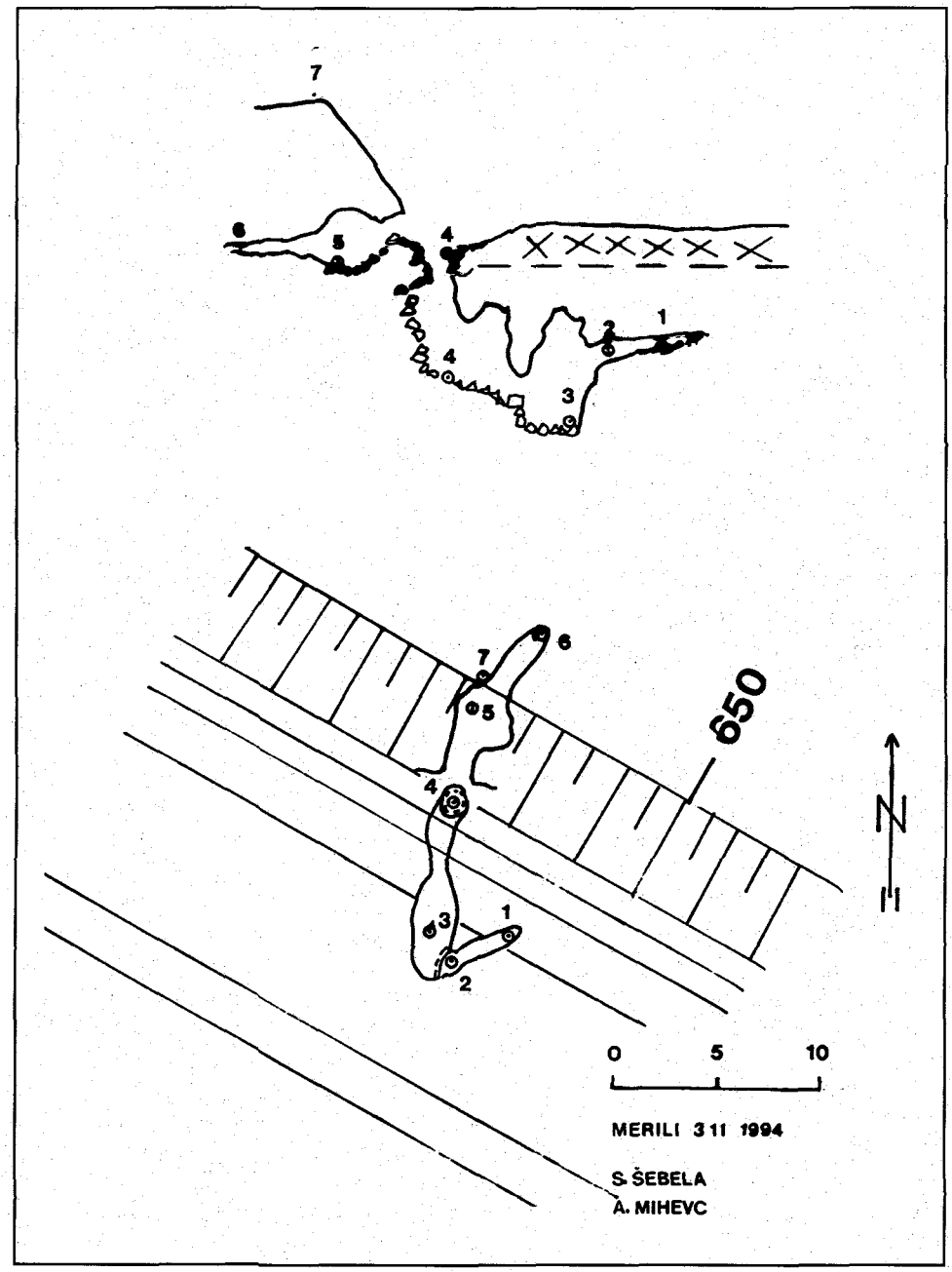

Fig. 3: Cave at the border of a roadway
Sl. 3: Jama na robu ceste

channels which can be observed in sides of the cuttings (Fig. 5). The cave channels are of different sizes and are even over 5 m in diameter. The cave walls are often flowstone encrusted and the bottoms are covered by large flowstone mounds. In the caves there are flysch and limestone gravel, flysch loam and sand. The caves filled with deposits can be followed along the whole road section Čebulovica-Divača-Dane. Several samples of deposits have been collected. The Roentgen diffraction method, mineralogical, granular-metric and pollen analyses will try to define the origin and age of the deposits. At present some characteristic periods of the cave development are evident. The meandering features and shape of the channels remind us of their primary formation in the flooded, phreatic zone. Small scallops on the walls of some channels and gravel give evidence of a relatively rapid watercourse which, as the last one and presumably for a short period, was hollowing out the channels. In dry periods of the cave development phase, flowstone was being deposited. In places it covers the scallops on the walls and also the deposits. The caves were consequently reached by flood waters which filled them with flysch loam.

In some caves below the flysch Brkini hills a fast water flow drained for shorter time and deposited a thin layer of gravel. Some caves are fissure-shaped. They were formed in the flooded zone with a relatively short period of water circulation.

The teeth and skull remains of the Pleistocene horse, which were found during the clearing of the deposit from a cave near Povirje, give evidence of life in this part of the karst. Archaeologist intend to define these finds also according to the geological period.

Shafts

In the highway section, many small entrance shafts and deeper potholes with many levels were opened up (Fig. 6). The deepest pothole reached a depth of 51 m. In this part of the karst, water streams run deeply underground (at a depth of 200 m and more). For a long period the underground streams have been reached by precipitation waters. Water worked its way along the fissures. Along less distinctive fissures with minor amounts of percolating water, caverns were formed only along the wider sections. The walls of fissured caverns are partly covered in flowstone.

Shafts with mostly circular cross-sections were formed along distinctive fissures with permanent water inflow. Their walls are dissected into large vertical grooves or solution runnels caused by the seeping water working its way underground. The walls of some large shafts are also covered in flowstone.

Most of active shafts are located in the bottom or on the edge of dolines. Some were formed beneath the old caves and dissected them, so that part of the older deposits were carried away through the potholes.

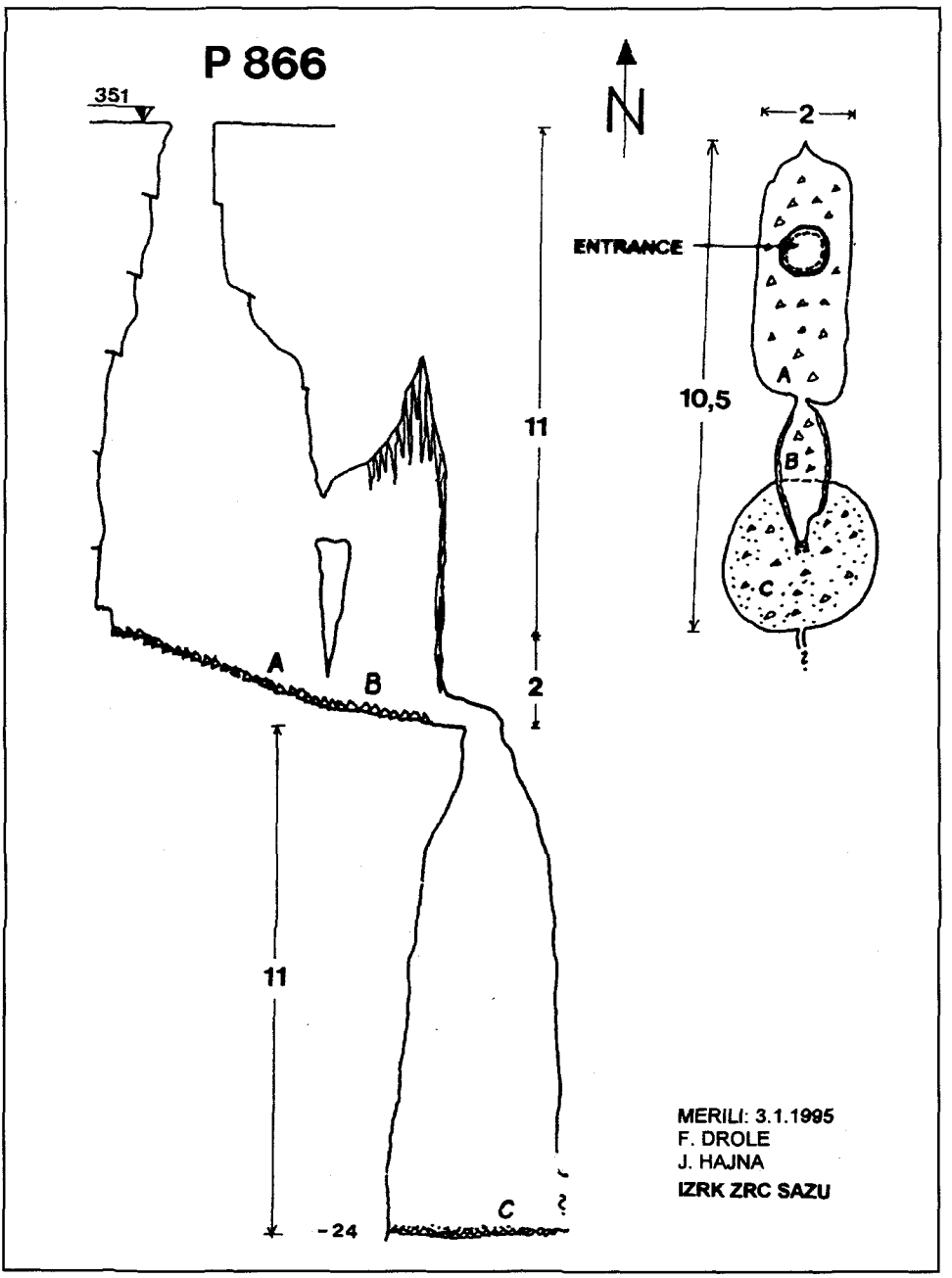

Fig. 6: A shaft below a roadway
Sl. 6: Brezno pod traso

CAVERNOSITY OF DIFFERENT ROCKS

Large old caves, empty ones or those filled with deposits, can be found in all rock types - in Palaeocene and Cretaceous limestones as well as in Lower Cretaceous bituminous dolomites near Dane. Dular (1993/a, b, 4) came to the conclusion that Palaeocene and Eocene limestones as well as Cretaceous dolomites are less karstified, but the Upper Cretaceous on the contrary are highly karstified. In the Palaeocene limestones near Čebulovica there are a few old caves but not a single pothole has been discovered. The sides of an extensive cutting section below Čebulovica with two small hollow old caves and one cave filled with deposit is example of weak cavernosity regarding big caves. In the wall of a cutting one may perceive thin beds of Paleogene limestones of varying structure. Some beds are strongly karstified with lot of channels up to one cm across (Otoničar 1994/95). In the road section Divača-Dane there is a relatively large number of caves occuring in Palaeocene limestone. In this area (segment 640-660) the old caves, empty ones (4) as well as those filled up with deposits (3), and fissured can be found.

Relatively frequent caves in dolomites are small. Their channels are usually less than a metre in diameter. Many more caves which are filled with deposits are flowstone decorated. Large caves rarely appeared, such as two 5 to 6 m deep canyon passages filled with deposits (Section D-D 872, 881).

Shafts can be found both in limestone and dolomite. The majority and the largest are in Cretaceous limestone in the vicinity of Škocjanske jame. They occur relatively rarely in Palaeocene limestone. Several shafts were in Lower Cretaceous dolomite also, but they are mostly small and inaccessible. Some 10 m east of the road section (Sector D-D 913), a 30 m deep fissured shaft opened on the edge of a doline, and at section 866 one with many levels.

The width of uncovered karst is the width of motorway and therefore it is difficult to conclude how cavernous is a single limestones. The composition of particular rock beds, how they are crushed and the ability of bedding-planes and fissures to generate caves along them prevail over general properties of rock. Also hydrological conditions that controlled the karstification of these carbonate rocks are important.

ROAD CONSTRUCTION AND CAVES

The caves were opening up during removing of vagetation and soil from the karstic surface, during the excavation of the cutting and consequently during the rubble embankement.

Blasting and excavation of cuttings resulted in the fracturing of rock in the surrounding caves. The cave P 607 in the road section Čebulovica-Divača opened up after the ceiling breakdown; in this cave the rock is fractured into pieces with a volume of some cm^3 to a depth of 12 m. The fissures which

were formed by the blasting are up to 1 cm wide and reach down to the cave bottom. The majority of the dripstone decorations at the bottom of the cave remained hanging from the walls. In another cave which opened up in the side of the same road section at segment 606, the entrance part was highly fractured. For this reason the circumference of the entrance passage is partly disintegrated. In a small chamber within the cave small pieces of rock fell off the roof. The entrance part of the fissured pothole P 651, located in the road section of Divača-Dane, contains fractured rock. For this reason part of the roof was disintegrated together with a flowstone coating which fell off the roof. In the deeper section of the pothole, no consequences of blasting could be noticed.

In the southern part, the road section of Čebulovica-Divača approached the canyon passage Hanke Channel in the cave Škocjanske jame within 400 m, that is as far as the western boundary of the planned regional park of Škocjanske jame. Although it was presumed that blasting in the road section would not have any influence upon Škocjanske jame, it was decided to observe eventual consequences in the cave. The cave is relatively far away from the sites of blasting but in the terminal section of the cave there are immense underground caverns such as the 140 m high chamber Martelova dvorana with 2 million m^3 in volume. Besides, the site of the crossing of the Reka watercourse with the road section has not been precisely determined yet. Precursion has thus demanded continuous observing of eventual consequences of the blasting. Due to warnings they occured with small retarded explosions in the boreholes. The cuttings in this part of the road section are relatively small, that is the reason why the blasting was weaker and less deep. There has been no indirect influence of the highway construction on known parts of Škocjanske jame.

As far as the construction of the solid base of the road and its safe use are concerned it has been tried to preserve as many caves as possible and to investigate the ones which could not be preserved due to the technically road construction, which was an extremely difficult demanding task in the digging of the more extensive cuttings. Here the rock was blasted into relatively small rubble particles and there was not much left of the caves, in most cases only flowstone pieces and rubble. In this way a relatively large cave within the road section, Golobja jama under Čebulovica, was destroyed. The caves preserved were those located in the excavation sides. Due to the blasting, the rock is often too crushed and smaller caves are inappropriate for visiting. The entrances to some caves had to be walled up with large rocks.

Minor and speleologically less important caves within the road section are filled up, as well as dolines and the old caves from which thin-granular deposits were removed. Large excavations were filled in with 30 cm thick layers of rubble, which were consolidated with the vibration roller. Large caves and potholes with chimneys reaching up as far as the road section had to be

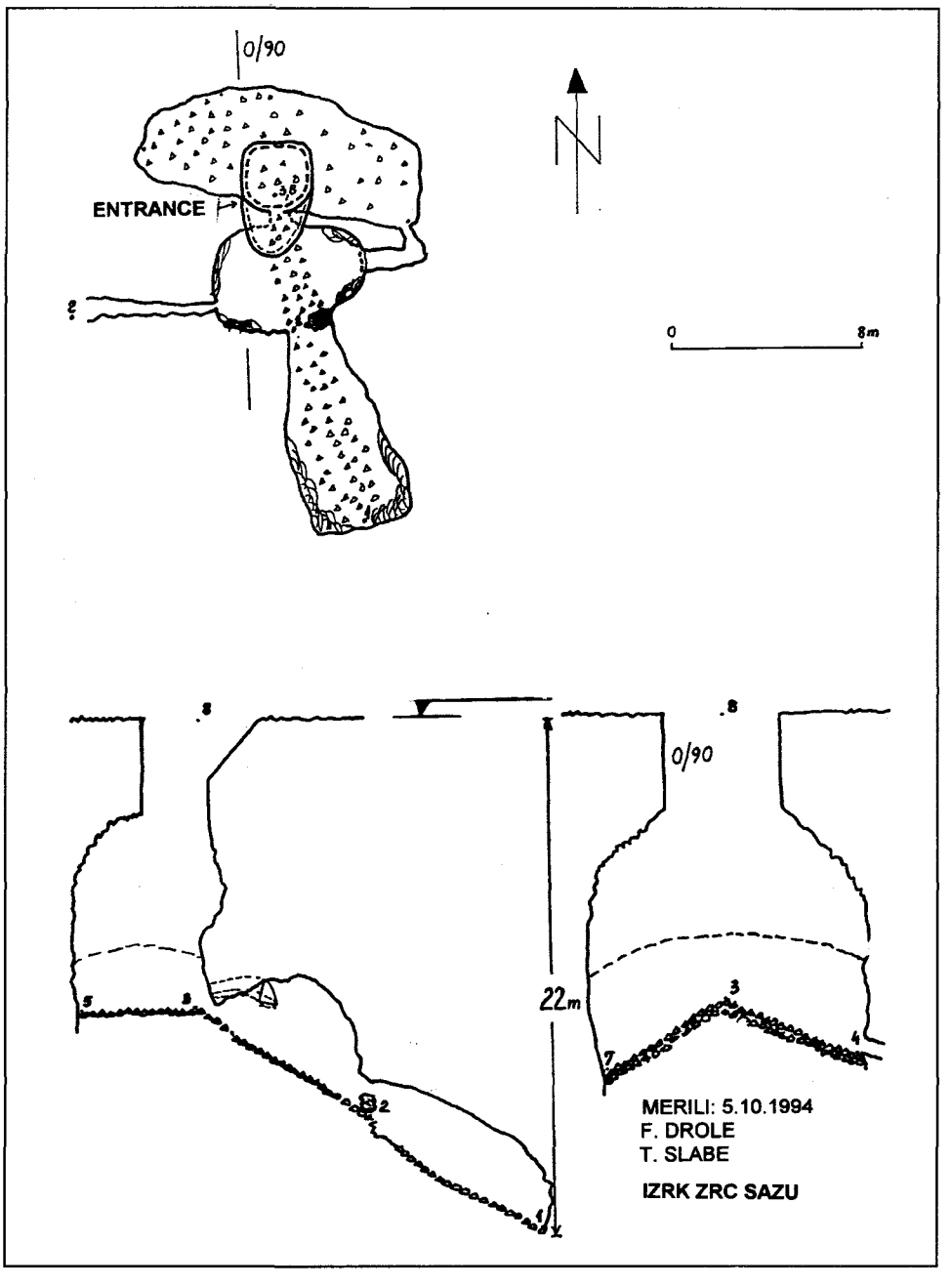

Fig. 7: A cave with collapsed roof
Sl. 7: Jama s podrtim stropom

blasted and filled up in the previously described way. Above the deeper potholes with narrow entrance parts there are concrete covers. During the investigation of the caves and the establishment of their eventual influence upon the road construction, some narrow sections were encountered. It was concluded that in the pothole within the road section of Divača-Dane, at segment 866, there is a large cavern beyond a narrow fissure which exteded up to the road section. It was tried to widen the narrow part with a vibration hammer, but the result was achieved only by blasting. In the excavation sides composed of solid rock, caves can remain untouched, but nevertheless it is necessary to consider the influence of blasting upon the permanence of their vaults and and to remove unstable and crushed rock. The rock remains solid particularly in dolomite (segment D-D 829). The caves in the excavation sides which are filled up with deposits had to be walled up because alluvium on the surface could be washed down onto the road by water.

CONCLUSION

Caves can be found in all rock types. This is evidenced by the Palaeogene limestone at Čebulovica, which is only slightly cavernous regarding large caves but in single beds there is plenty of small channels; on the contrary a part of the same limestone at Povirje is extremely cavernous. Old caves and potholes are to be found in all types of limestone and in dolomite. The majority of bigger potholes is in Cretaceous limestone. General properties of rock lithology are outweighed, regarding the cavernosity, by composition of a particular rocky bed, how it is crushed and competence of bedding-planes and fissures that the caves develop along them.

It has been tried to preserve the largest number of caves possible, which was rather difficult in the construction of a safe road. Caves opened up also during the final clearing of the surface, that is short by before the metalling and consolidation works on the road. Examples of subsidence occured even during the time of these works (Fig. 8). It is possible that there are even other caves located not far below the road section. Is there any possibility of road subsidence? It has been suggested to check the road section with the georadar. In this way at least the largest eventual caves, hidden below, could be discovered.

Experience obtained during the study of the new discovered karst phenomena have led to explanations of the development of this part of the karst. In the old caves, which are the oldest remains of karstification here, several development phases can be recognized. Empty and filled up old caves are located in Divaško podolje as well as in the karst ridge to the nord-east. The caves were probably formed in the flooded, phreatic zone. Subsequently they were partly modified by rapid water streams which deposited gravel and sand within the caves, and in places hollowed out small scallops on the walls.

Where is the origin of the watercourses? Perhaps it is the Brkini flysch edge, which was closer to the caves. Was the alluvium carried along by the watercourses from the flysch which surrounded the Kras in the north, or by the streams from the elevations where the flysch was preserved after the folding of the anticline (Gams 1974, 197)? In the Pliocene the Kras was lower than the flysch surface of the Vipava and Triest syncline despite the anticline construction (Radinja 1972, 212). Flysch pebbles are not carried far underground due to crumbling and grinding (Kranjc 1986, 114). In the intermediate dry climatic periods and after the lowering of the underground water level, flowstone was deposited in the caves. Some caves which subsequently were reached by flood waters remained filled with flysch loam. In places loam was carried away by means of percolation water. The roofs above the old caves situated at higher levels and filled up with alluvium, was already carried away. Caves dissect the karst surface like furrows. According to the flowstone in caves it can be concluded that the roofs above were several metres thick. Cucchi, Forti and Ulcigrai (1994, 61) have made some surveys which show that the karst surface which is exposed to climatic conditions is lowered by 0.02 mm a year. Gams (1965, 886) explains that in the Quaternary the surface above Postojnska jama was lowered by about 40 m. The surface has been profoundly changed. The alluvium of watercourses is present mostly only in caves. Dolines were frequently formed by the opening of potholes below the old channels. Beside rubble and karst loam formed by weathering on the surface, it is often possible to find also old flysch alluvium.

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KRAŠKI POJAVI V TRASI AVTOCESTE MED ČEBULOVICO IN DANAMI

Povzetek

Trasa med Čebulovico in Divačo poteka prečno po vzhodnem robu kraškega hrbta, ki se razteza od Štorij proti Čebulovici do vrtačastega ravnika, zahodno od Škocjanskih jam, med Divačo in Danami pa po manj zakraselem Divaškem podolju (Melik 1960, 199).

Krasoslovci so ugotavljali, da so na Krasu ohranjene sledi prvotnega površinskega odtoka vode proti SZ. Melik (1960, 201) je o tem sklepal po strmcih na današnjem površju, Radinja (1972, 13) pa po opuščenih dolinah in ostankih naplavin na kraškem površju. Apnenci naj bi bili, ko so se začele razkrivati karbonatne kamnine, namreč zaprti in podzemeljska voda zajezena, kar je ohranjalo površinske vodne tokove. Nekdanji površinski odtok z Brkinov čez Kras je oblikoval vzdolžno podolje od Divače proti Brestovici (Habič 1974, 8). Gams (1965, 90) je pri proučevanju razvoja površja med Postojnskim in Cerkniškim poljem ugotovil, da so nekateri morfološki procesi pospešili kraško razčlenjevanje in nastanek dolinastih oblik, ki so jih vse prepogosto razlagali kot ostanke rečnih dolin. Reliefne značilnosti Divaškega podolja so tudi zgradbeno in litološko pogojene, saj so različni litostratigrafski elementi in glavni prelomi usmerjeni od JV proti SZ (Habič 1974, 8).

Z zgradbenimi značilnostmi tega dela krasa se ujemajo tudi sedanje hidrološke razmere. Današnji podzemeljski tokovi se pretakajo 200 m globoko pod površjem. Reka teče od Škocjanskih jam, južno od Divače, vzporedno s traso, jo pri Divači preči in nato pod Divaškim podljem proti SZ k izvirom

Timava. Padavinske vode jih dosegajo z navpičnim prenikanjem. Vseskozi opozarjamo na nevarnost onesnaženja podzemeljskih voda, ki so spričo kraške prepustnosti, ogrožene. To nam dokazujejo tudi proučevanja kakovosti voda, ki se stekajo z avtocest (Kogovšek 1993) in izkušnje ob nesrečnih izlitjih škodljivih snovi (Knez et al. 1994).

Vrtače na teh odsekih avtoceste je Habič (1974, 6,7) po obliki razdelil na lijakaste, iz katerih je ilovica večinoma sprana, v skledatih vrtačah je na dnu večja ilovnata površina, zasute vrtače so plitve, ilovica v njih pa je malo prepustna. V zasutih vrtačah se pogosto zadržuje voda. Pri Divači je 11 vrtač ma km^2 trase, med Divačo in Sežano pa 5. Na južnem delu odseka avtoceste Čebulovica-Divača so na krednem apnencu velike lijakaste vrtače. V njih je bilo le malo ilovice. Na apnencu Divaškega podolja prevladujejo skledaste in zasute vrtače. Slednje so manjše, s 30 do 50 m premera in 5 do 15 m so globoke. V vrtačah prevladuje rdeča in rjava kraška ilovica, sprana s pobočij vrtače na gruščnato podlago. Nastala je s preperevanjem skalne podlage. V nekaterih vrtačah je tudi flišni pesek in prod ter rumenkasta ter pasovita glina. V grbinasto dolomitno površje, prekrito s tanjšo plastjo zemlje, se zajedajo manjše in redko posejane zasute vrtače. Zgornja plast zapolnitve vrtač je rjava zemlja, 1,5 m pod površjem pa je rdeča ilovica.

Različna kamnina je resda različno gosto prevotljena, a jame so v vseh njenih tipih. To potrjuje tudi primer paleogenskega apnenca, ki je pri Čebulovici le malo prevotljen, nasprotno pa je zelo prevotljen pri Povirju. V vseh tipih apnenca in v dolomitu so stare jame in brezna. Velikih brezen je največ v krednem apnencu. Po prerezu krasa v širini avtoceste je težko sklepati o prevotljenosti različnih apnencev. Sestava posameznih skladov kamnine, njihova pretrtost in lastnost lezik in razpok, da se ob njih razvijejo votline, prevladajo nad splošnimi lastnostmi kamninskih paketov.

Ohraniti smo skušali čimveč jam, kar pa je bilo zaradi izdelave varne ceste dokaj težavno. Tudi ob zadnjem čiščenju površja, tik pred nasipanjem in utrjevanjem grušča so se odpirale jame. Grezi pa so lahko nastajali celo med tem delom. Možno je, da je plitvo pod traso še kakšna jama. Lahko pride do ugreza na cesti. Predlagali smo, da se traso pregleda z georadarjem. Na ta način bi lahko razkrili vsaj morebitne največje jame, ki so skrite očem.

Iz spoznanj, pridobljenih pri proučevanju novo odkritih kraških pojavov, so se porodile razlage razvoja tega dela krasa. V starih jamah, ki so najstarejša sled zakrasevanja, lahko razberemo več obdobij razvoja. Votle in z naplavinami zapolnjene stare jame so tako v Divaškem podolju kot v kraškem hrbtu, ki ga obdaja na SV. Jame so po vsej verjetnosti nastajale v zaliti coni. Kasneje so bile deloma preoblikovane s hitrejšimi vodnimi tokovi, ki so v jamah odlagali tudi prod in pesek ter ponekod na stenah izdolbli manjše fasete. Od kod so pritekali vodni tokovi? S flišnega brkinskega roba, ki je bil bližje jamam? So naplavino prinašali vodni tokovi s fliša, ki je kras obrobljal na severu ali pa potoki z vzpetin, kjer se ohranil fliš po bočenju antiklinale (Gams 1974, 197)?

V pliocenu je bil kras kljub antiklinalni zgradbi nižji od flišnega površja vipavske in tržaške sinklinale (Radinja 1972, 212). Flišni prodniki se zaradi drobljenja in mletja ne prenašajo daleč v podzemlje (Kranjc 1986, 114). V vmesnih sušnejših klimatskih obdobjih in po znižanju gladine podzemeljske vode, se je v jamah odlagala siga. Veliko jam, ki so jih kasneje dosegle poplavne vode, so ostale zapolnjene s flišno ilovico. Strop nad višje ležečimi starimi jamami, ki so zapolnjene z naplavino, je že odnešen. Jame kot korita členijo kraško površje. Po sigi, ki je v jamah, lahko sklepamo, da je bil strop nad njimi debel več metrov. Cucchi, Forti in Ulcigrai (1994, 61) so namerili, da se kraško površje, ki je izpostavljeno vremenskim vplivom, znižuje 0,02 mm na leto. Gams (1956, 86) ugotavlja, da se je v kvartarju znižalo površje nad Postojnsko jamo za okoli 40 m. Površje se je že temeljito spremenilo. Naplavine vodnih tokov so se kot prvotne večinoma ohranile le v jamah. Vrtače so namreč pogosto nastale z odpiranjem brezen pod starimi rovi. Ob grušču in kraški ilovici, ki sta nastala s preperevanjem na površju, je zato moč v njih pogosto najti tudi starejše flišne naplavine.

Fig. 2: Filling up a doline
Sl. 2: Zasipanje vrtače

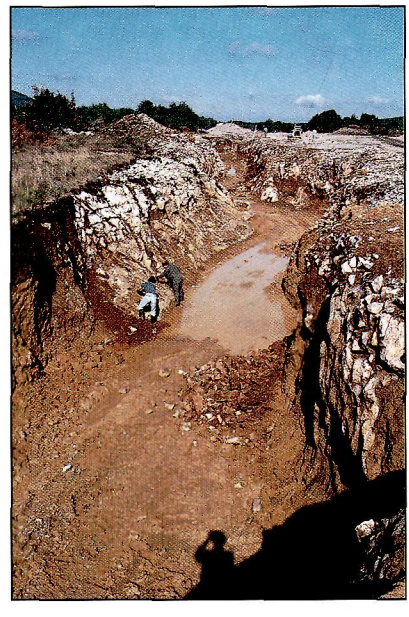

Fig. 4: Cave that was filled with sediments
Sl. 4: Jama, ki je bila zapolnjena z naplavino

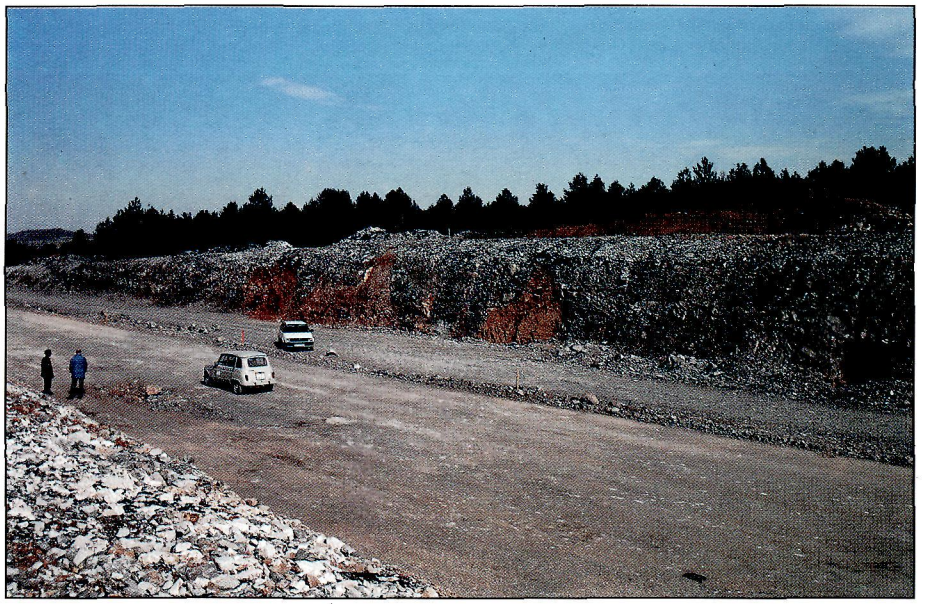

Fig. 5: Caves, filled with sediments on a slope of a cutting
Sl. 5: Jame, zapolnjene z naplavino, na brežini useka

Fig. 8: Collapse above a cave
Sl. 8: Udor nad jamo