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KARST DEPRESSIONS WITH PRECIPICED WALLS ON THE SOUTHERN SLOPE OF SNEŽNIK MOUNTAIN, SLOVENIA

KRAŠKE DEPRESIJE S PREPADNIMI STENAMI NA JUŽNEM POBOČJU SNEŽNIKA, SLOVENIJA

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Izvleček UDK 551.4(497.4)

Nadja Zupan Hajna: Kraške depresije s prepadnimi stenami na južnem pobočju Snežnika, Slovenija

Snežnik (1796 m) je visoka kraška planota, s kopastimi vrhovi in velikimi depresijami, s številnimi vrtačami in snežnimi kotliči. Na nagnjenih apnenčevih plasteh so žlebiči. Med jamami prevladujejo brezna. Snežnik gradijo jurski in kredni apnenci ter dolomiti, veliko je ledeniškega in periglacialnega gradiva. Kraške depresije s prepadnimi stenami so tipične za področje Ždrocel, južno od vrha Snežnika, na nadm. v. 1300 - 1400 m. Oblikovane so v spodnjekrednih apnencih z dolomiti in dolomitnimi brečami. Prepadne stene so izoblikovane v razpoklinski coni v smeri N-S.
Ključne besede: speleologija, speleomorfologija, kraška depresija, Ždrocla, Snežnik, Slovenija.

Abstract UDC 551.4(497.4)

Nadja Zupan Hajna: Karst depressions with precipiced walls on the southern slope of Snežnik Mountain, Slovenia

Snežnik (1796 m) is a high dissected karst plateau with cone summits, large depressions, and snow kettles. On some limestone surfaces are grooves. The shafts prevail. The Snežnik region consists of Jurassic and Cretaceous limestones and dolomites, yet there is glacial and periglacial material. Karst depressions with steep and precipiced walls are typical of the area of Ždrocle, south of the Snežnik summit at 1300 - 1400 m a.s.l. They developed in Lower Cretaceous limestones with dolomites and dolomitic breccias. The precipiced walls are controlled by fissured zone trending N-S.
Key words: speleology, speleomorfology, karst depression, Ždrocla, Snežnik Mt., Slovenia.

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INTRODUCTION

Snežnik is a high karst plateau in the south of Slovenia, near the border with Croatia. The massif of Snežnik mountain is a prolongation of Javorniki mountain, which starts E from Postojna. Snežnik's highest peak is 1796 m. At its dissected elevations cone summits with, large depressions among them are very frequent (Habič 1981). It is generally valid that the formation of deep karst depressions depends upon how much the carbonate rocks are fissured and crushed (Habič 1986). Large depresions were influenced by glaciation during the last Ice Age (Habič 1978). On levelled areas there are numerous dolines, snow kettles and larger gently sloping dolines. There are also caves, and them shafts prevail. There are almost no superficial flows, just very short ones from small local springs. The springs are at about 600 m a.s.l., so the vadose zone may be about 1000 m deep. Almost all area is covered by forest, except the slopes of highest peak and some grassy areas (Fig. 1).

This paper will represent the interesting geomorphological feature from Snežnik mountain, the so called Ždrocle (Ždrocla, in the singular). Ždrocle are karst depressions with steep and precipiced walls. They are typical of the area of Ždrocle, in the south from the Snežnik summit at 1300 to 1400 m a.s.l.. Southwest from the small source "Andrejev Studenec", the area takes its name from the 1478 m high summit called Ždrocle, and the same name is in local use for big depressions (Šušteršič 1977). Snow that may stay all the year round is additionally reshaping their bottoms. Andrejev Studenec is located on the north part of a bigger grassy area. Traces of periodical water flows and some small sink holes are situated at the south part of it.

By aerial photography at scale 1 : 30000 the location and shape of large depressions were registered as well as the main fault directions of the Ždrocle area. During the field work in 1995 and 1996 the positions of depressions were defined and measurements of geological structural elements were done. I am grateful to colleagues from the Karst Research Institute who did the field work with me, because the area is unusually wild, covered by untouched forest and inhabited by bears.

SPELEOLOGICAL RESEARCHES IN ŽDROCLE

The area was first researched by Italian speleologists before World War II. About 20 years ago same research was done by Karst Research Institute SAZU from Postojna. Big depressions with precipice walls were found and they named them Ždrocle (Šušteršič 1975). After that a lot of caving exploitation of the area was done by caving clubs from Rakek, Ljubljana, Postojna and others. According to data from the Cave Register there are about 20 caves, all of them vertical shafts 10 to 30 m deep on average. The deepest shaft is of U-profile and is more than 100 m deep, but has no plan in the cave register. The second is Andrejevo Brezno which is 70 m deep.

Karst depressions with precipice walls are big snow kettles or shafts and they are about 30 to 50 m deep. According to the Cave Register five of them are recorded. Only two have ground plans and cross-sections; these are Ždrocla 1 and Ždrocla 3. Ždrocla 3 is a shaft about 65 m deep. The others have only registration numbers and descriptions of their location. For the determination of positions of the depressions I have used topographical and aerial-photo maps.

From the topographic map and the co-ordinate system I have determined position of Ždrocla 1, 2, 3 and 5, but the position and even the existence of Ždrocla 4 is in doubt.

Descriptions of depressions from the cave register are as follows:

Ždrocla 1: Reg. No.: 4261; a.s.l.: 1401 m; depth: 54 m; type: 6.6 - shaft with permanent ice; lithology: $K_{1,2}$ - limestone and dolomite and breccia; genesis: obvious connection to a N-S fissure zone;

Ždrocla 2: Reg. No.: 4262; a.s.l.: 1405 m; depth: - m; type: 6,4; lithology: $K_{1,2}$ - limestone and dolomite and breccia; genesis: obvious connection to a N-S fissure zone;

Ždrocla 3: Reg. No.: 4263; a.s.l.: 1398 m; depth: 89 m; type: snow kettle with shaft 6,4; lithology: $K_{1,2}$ - limestone and dolomite and breccia; genesis: obvious connection to a N-S fissure zone;

Ždrocla 4: Reg. No.: 4297; description of its shape and location is bad; there is no such depression in the area.

Ždrocla 5: Reg. No.: 4298; a.s.l.: 1395 m; depth: - m; type: 6,4; lithology: $K_{1,2}$ - limestone and dolomite and breccia; genesis: obvious connection to a N-S fissure zone; other: without ground plan.

GEOLOGY OF THE AREA

According to Placer's (1981) the explanation of the geologic structure of south-western Slovenia, Snežnik is a thrust sheet of carbonate rocks over flysch rocks. The plateau is built of Jurassic and Cretaceous limestones and dolomites and their breccias. Also periglacial and glacial material can be found on its surface. According to the Basic geological map, sheet Ilirska Bistrica (Šikić, Pleničar and Šparica 1972), the area is built in Lower Cretaceous limestone, dolomite and breccias. On the southern slope of Snežnik on the surface are: K_1- limestones, dolomitic and limestone breccia, mostly recrystalized; $K_{1,2}$ - limestone, dolomite and dolomitic breccia; $J_3^{2,3}$ - light and dark grey limestone with clipeinas and salipingoporelas. All over the plateau a lot of glacial material could be found, first mentioned by Pleničar in 1956. The detailed research of glacial material from Snežnik was done in 1959 by Šifrer. He described the glacial material from its slopes and he defined the location of the ice and snow line and also the routes of glacier movements. From this area the glacier flowed probably towards E and SE. It is important that during

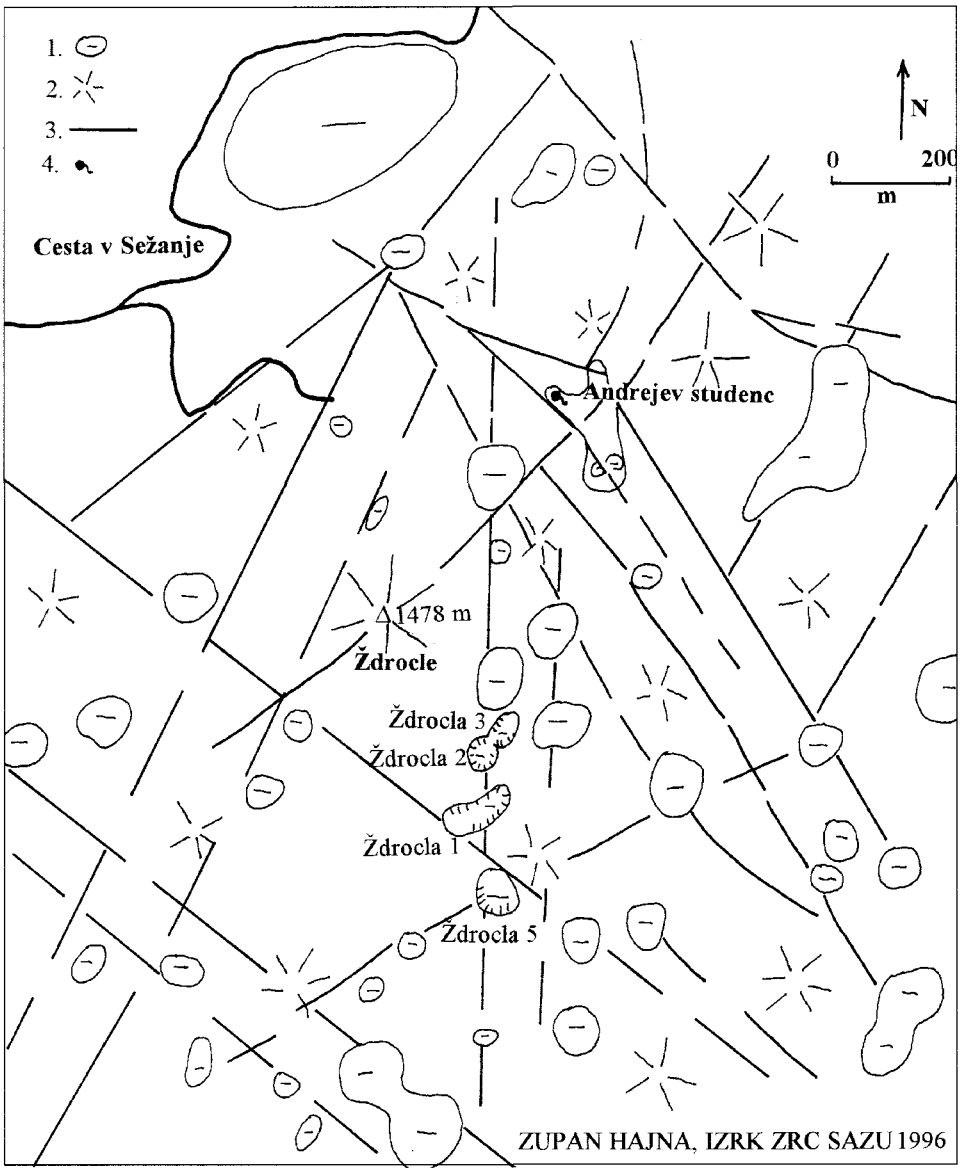

Fig. 2: Photo aerial interpretation of locations of the faults and depressions, Ždrocle, Snežnik Mt. (1. depression, 2. summit, 3. fault, 4. spring).

Sl. 2: Fotoaero interpretacija položaja prelomov in depresij, Ždrocle, Snežnik (1. depresija, 2. vrh, 3. prelom, 4. izvir).

the last glaciation the area of Ždrocle, at 1400 m a.s.l., was higher above the perpetual snow line and that it was covered by permanent ice.

By aero-photography at scale 1:30000 the location and shape of the larger depressions was registered as well as main tectonic directions (Fig. 2). The most distinctive are Dinaric trending faults yet there are also transverse faults. Less distinctive, but traced by a series of depressions, is N-S direction; the same trends were defined by mapping in the field.

RESULTS OF TECTONIC MEASUREMENTS IN THE AREA

For better explanation, why these big depressions with vertical walls are situated in this area I did some geological research during July and September 1995 and in June 1996.

In the area limestone beds generally dip toward N - NE; measured directions of dips are from 10^0 to 40^0, with dip angle from 10^0 to 30^0; at some places they are almost horizontal and at others their dips are very steep. Just at the most east part of the area I measured the dip toward NW, with dip angle 20^0. The thickness of the beds is half a meter on average. More dolomitic breccia located on west side of the area is not stratified. After Čar (1982) and Šebela (1995) I have distinguished three different types of fractured carbonate rocks: crushed zone, broken zone and fissured zone (Fig. 3).

Very well expressed are faults and crushed zones in Dinaric (NW-SE) direction. On the west side of Ždrocla 1, directly through Ždrocla 2 and 3, is situated, a strong crushed zone in cross Dinaric (NE-SW) direction. The same type of crushed zone goes through Ždrocla 5. A wide crushed zone is also situated south of Andrejev Studenec in N-S direction. But in other places the N-S direction is represented by fissures in more or less wide zones.

At a levelled surface at about 1400 m a.s.l., north from source Andrejev Studenec, really interesting rough karst terrain is situated. The closest to the road and easiest to reach is the smallest Ždrocla - Ždrocla 3. **Ždrocla 3** is snow kettle about 30 m deep connected to fissured zone in N-S direction. The fissured zone is a series of parallel fissures where no displacement is seen. Also the fault in E-W direction is well expressed and it crosses Ždrocla on the north side. Limestone beds are almost horizontal with slight dip towards NE. The north slope is not so steep and the bottom, which is covered by snow, is easily reached by it. In the east wall the entrance to a shaft about 60 m deep. In the middle of south wall a big fissure is located. The wall is opened by it from the top to the bottom. The fissure is a few cm wide and it is prolonged to the Ždrocla 2 which is located close towards the south.

Ždrocla 2 is a depression about 40 m deep, all walls are vertical. At a depth of 30 m is a small almost horizontal step and after this there is precipiced wall down to the bottom, where snow lies during whole year (Fig. 4). The N-S fissured zone is well expressed in the south and north walls and

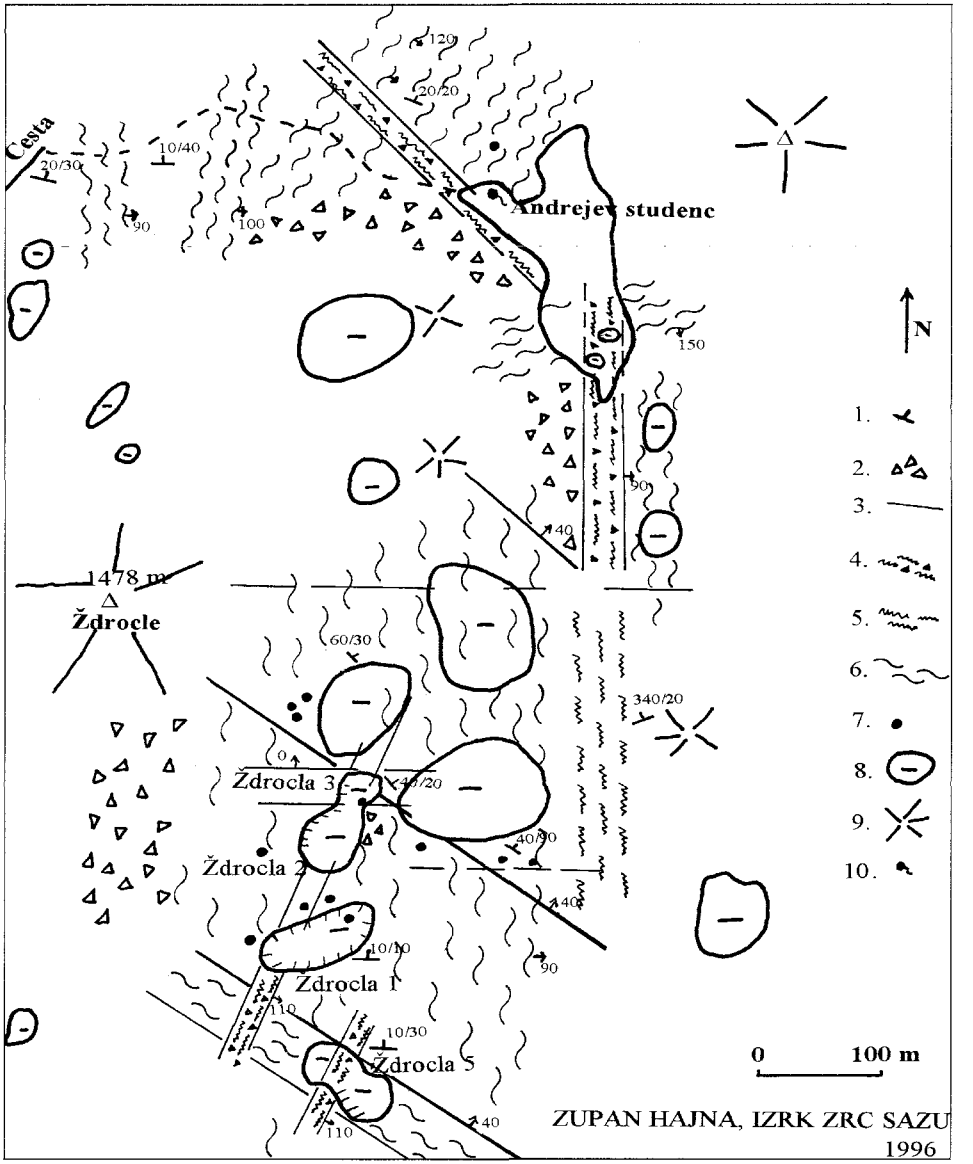

Fig. 3: Geological structural elements of the Ždrocle area.
1. dip and strike of the strata, 2. dolomitic breccia, 3. fault, 4. crushed zone, 5. broken zone, 6. fissured zone, 7. cave, 8. depression, 9. summit, 10. spring.

Sl. 3: Geološki strukturni elementi na področju Ždrocel.
1. vpad in smer plasti, 2. dolomitna breča, 3. prelom, 4. zdrobljena cona, 5. porušena cona, 6. razpoklinska cona, 7. jama, 8. depresija, 9. vrh, 10. izvir.

along the east and west walls. At the surface above the east wall of Ždrocla 2 big grikes from 0,5 m to about 2 m high are well expressed. They are also developed in a N-S direction.

South of Ždrocla 2 is located **Ždrocla 1.** With its 54 m depth and about 80 m width, it is the largest Ždrocla. All its walls are vertical; just at the SW slope the bottom can be reached without ropes. This slope is cut by a zone some meters wide of very crushed rocks. From this slope also a lot of gravel is sliding towards the bottom and the slope is covered by it. The bottom of Ždrocla 1 is covered by snow long into the summer.

The most southern depression with precipiced walls is **Ždrocla 5**. This one is not so deep; just one wall is really vertical but its bottom also was still covered by snow in June.

CONCLUSIONS

Four depressions with precipiced walls to the South of the spring Andrejev Studenec display the most prominent features. All of them are developed in Lower Cretaceous limestones with dolomites and dolomitic breccias. The precipiced walls are controlled specially by fissures trending from N to S. By aero-photography the most distinctive are Dinaric-trending faults, yet there are also transverse faults, less distinctive, but traced by a series of depressions in N-S direction. In conclusion I can say that big depressions with vertical walls are developed in Lower Cretaceous well-bedded limestones with dolomites and limestone breccias and that precipiced walls are controlled specially by a fissured zone trending from N to S. But in more dolomitic breccias north of Andrejev Studenec, where karst terrain is not so rough, the surface is more gentle, and the depressions and grikes are not developed. Their connection with lithology and tectonic structure is obvious. Genesis of depressions is linked with corrosion along N-S fissure zone, where limenstone is more crushed and with this more prepared for solution. Corrosion is forced also by snow which may stay in the bottoms of depressions all the year and it can strongly reshape their bottoms. And we also have to take into account that during last glaciation this area was covered by ice (Šifrer 1959). Arguing against the possibility that they are collapse dolinas is fact that the origin of collapse dolines is attributed to collapse of large horizontal passages above underground water flows (Mihevc 1995), and in this area no horizontal galleries were found. But the question of they are shafts or snow kettles is still open.

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Povzetek

Snežnik je visoka kraška planota, ki ima razčlenjene povprečne višine, z najvišjim vrhom 1796 m. Velika večina površja je porasla z gozdom (Sl. 1). Področje Snežnika gradijo jurski in kredni apnenci ter dolomiti, veliko je pa tudi ledeniškega in periglacialnega materiala. Poledenitve na področju Snežnika je opazil že Pleničar (1956), podrobneje jih je pa opisal Šifrer (1959). O preoblikovanju kraških depresij z ledom, je na področju visokih kraški planot v Sloveniji pisal tudi Habič (1978).

Kraške depresije s prepadnimi stenami so tipične za področje Ždrocel, južno od vrha Snežnika, na nadmorski višini med 1300 in 1400 m. Globoke depresije so oblikovane v spodnje krednih apnencih z dolomiti in dolomitnimi brečami.

Italijani raziskovali tu pred II. svetovno vojno. Velike snežne kotle so našli člani Inštituta za raziskovanje krasa ZRC SAZU pri pripravi Speleološke karte, ko so iskali udornico že s prej obstoječe italijanske specialke, in so jih poimenovali Ždrocle (Šušteršič 1975). Na tem področju je raziskanih tudi veliko brezen, nekatera od njih imajo vhode v samih Ždroclah, na njihovem robu ali pa v neposredni bližini. Po Jamskem katastru je tu registriranih 20 jam, načrte pa jih ima 13. Vse so brezna globoka med 10 m in 30 m, najgloblje pa je brezno U-profil z več kot 100 m, vendar njegovega načrta ni v katastru.

Ker je sama orientacija na terenu otežena zaradi prekritosti z gozdom in slabih kart, sem si pomagala s fotoaero posnetki v merilu 1 : 30000. Tako sem lahko določila lego večjih globeli in njihovo število ter glavne smeri prelomov (Sl. 2). Najlepše so izraženi prelomi v dinarski smeri in prečno nanje. Slabše opazna, vendar sledena z nizom globeli, je smer N - S. Vse smeri prelomov opazne na aero posnetkih so bile določene tudi na terenu. Po Čaru (1982) in Šebeli (1992) sem na terenu ločila tri različne tipe tektonsko pretrtih karbonatnih kamnin: zdrobljeno cono, porušeno cono in razpoklinsko cono (Sl. 3).

Po podatkih iz Jamskega katastra, foto-aero posnetkih in terenskem kartiranju sem določila lego Ždrocle 1, Ždrocle 2, Ždrocle 3 in Ždrocle 5. V obstoj Ždrocle 4 pa glede na podatke dvomim, možno je, da obstaja, vendar precej drugje kot je opisano. Največja je Ždrocla 1, Ždrocla 2 in 3 pa sta povezani skozi nekaj centimetrov široko razpoko. V vzhodni steni Ždrocle 3 se odpira vhod v okrog 60 m globoko brezno. Ždrocle so globoke med 30 in 50 metri, različno široke, za vse pa so značilne prepadne stene vsaj s treh strani. Prepadne stene so kontrolirane z razpoklinsko cono v smeri N-S, vzhodna in zahodna stena, in s prelomi v dinarski smeri (NE-SW), južna in severna stena. V dnu Ždrocl se zadržuje sneg, včasih tudi čez vse leto in tako preoblikuje njihovo dno. Proti možnosti, da so te depresije po svojem nastanku udornice, govori dejstvo, da je nastanek udornic povezan z velikimi vodoravnimi jamami nad vodnimi tokovi (Mihevc 1995), na tem področju pa ni znanih večjih vodoravnih jam. Vprašanje ali so te depresije s prepadnimi stenami po svojem nastanku brezna ali snežni kotliči pa še vedno ostaja odprto.

Fig. 1: Snežnik is a high karst plateau; it has a dissected average elevation; the highest peak is 1796 m; almost all area is covered by forest.

Sl. 1: Snežnik je visoka kraška planota; ima razčlenjene povprečne višine, z najvišjim vrhom 1796 m, skoraj vsa površina je pokrita z gozdom.

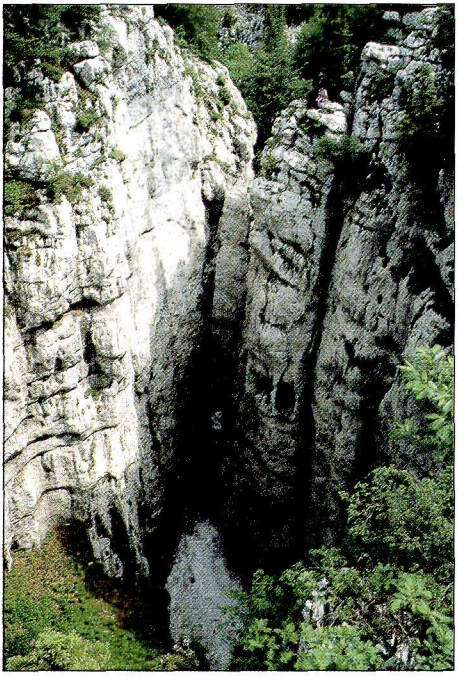

Fig. 4: Ždrocla 2, about 40 m deep depresion, with snow at the bottom and with fissures in N-S direction.

Sl. 4: Ždrocla 2, okrog 40 m globoka depresija s snegom v dnu in razpokami v smeri N-S.