

ACTA CARSOLOGICA	33/2	3	55-74	LJUBLJANA 2004
------------------	------	---	-------	----------------

COBISS: 1.01

**KARSTIFICATION ALONG THE THRUST CONTACT
BETWEEN THE DOLOMITE AND LIMESTONE IN IDRIJSKI
LOG AND KOŠEVNIK (IDRIJSKO, SLOVENIA)**

ZAKRASEVANJE OB NARIVNEM STIKU DOLOMITA IN
APNENCA V IDRIJSKEM LOGU IN KOŠEVNIKU
(IDRIJSKO, SLOVENIJA)

BOJANA ZAGODA¹

¹ Zadlog 48, Si-5274 Črni Vrh nad Idrijo, e-mail: bojana.zagoda@volja.net

Abstract:

UDC: 551.44:551.435.8(497.4)

Bojana Zagoda: Karstification along the thrust contact between the dolomite and limestone in Idrijski log and Koševnik (Idrijsko, Slovenia)

The paper discusses karstification along the thrust contact between dolomite and limestone at Idrijski Log and Koševnik (west-central Slovenia). Thrust contact induced the formation of a specific contact karst assemblage. Karst morphology is less strongly expressed within the dolomite, whereas the limestones are deeply karstified, with many dolines, shafts and sinkholes. Shafts in limestone and dolines in dolomite show genetic relationship with the thrust contact, whereas preserved fragments of phreatic features originated deep beneath the thrust plane.

Key words: contact karst along thrust, dolines, pothole, phreatic features, Idrijski Log, Koševnik, Slovenia.

Izvleček:

UDK: 551.44:551.435.8(497.4)

Bojana Zagoda: Zakrasevanje ob narivnem stiku dolomita in apnenca v Idrijskem logu in Koševniku (Idrijsko, Slovenija)

Članek obravnava zakrasevanje ob narivnem kontaktu dolomita in apnenca v Idrijskem Logu in Koševniku. Ob narivnem stiku se je oblikoval neke vrste kontaktni kras. V dolomitu je površinska kraška oblikovanost slabše izražena, v krednih apnencih pa so nastale številne vrtače, brezna in požiralniki. Brezna v apnencih in vrtače v dolomitu kažejo genetsko povezanost na narivni kontakt, freatične oblike pa so nastajale globoko pod narivnim pokrovom.

Ključne besede: obnarivni kontaktni kras, vrtače, brezna, freatične oblike, Idrijski Log, Koševnik, Slovenija.

INTRODUCTION

Details of karst phenomena near the thrust contact between dolomite and limestone are poorly known. To provide a better insight into the influence of the geological setting upon the location and development of karst features, detailed geological mapping at 1:5000 scale was carried out. The study area encompasses locations within an approximately 800 m-wide and 5500 m-long strip along the thrust contact, where the area mapped covers about 400-ha. Most attention was focused on dolines in dolomite and in limestone, potholes in limestone, and on fragments of unroofed caves (*sensu lato*).

During mapping, Čar's (1982) pragmatic classification of fault systems was used, and this provided excellent results when relating observed karst phenomena to the underlying geology. Dolines in the dolomite and limestone were classified according to Čar's (2001) structural-genetic classification.

GEOGRAPHICAL POSITION

The surrounding region is part of the High Karst of Western Slovenia (Janež et al., 1997), with deeply karstified plateaus and intermediate strips of lower ground. Idrijski Log and Koševnik are small settlements on the eastern border of Trnovski gozd. The northern part of the studied area along the thrust contact in Idrijski Log is a relatively flat zone at about 640m a.s.l., whereas in Koševnik (the eastern and southern part of the mapped area) the surface is more undulating, lying between about 650 and 720m. To the south and southeast the mapped area is bordered by the somewhat higher plateaus of Zadlog (717m. a.s.l.) and Črni Vrh (683m. a.s.l.). The main underground drain from this area, Divje jezero (330m. a.s.l.) lies about 4km north in the Idrijca river canyon. The elevation of the floor of the Idrijca valley is thus the local base level.

GEOLOGICAL SETTINGS

a.) Lithology

Norian to Rhaetian dolomite (T_3^{2+3}) with characteristic stromatolites is the oldest rock in the study area. Bed thickness ranges from 10cm to 1.5m, and the strata are in reversed sequence as a result of thrusting. Layers of dolomitic marl a few centimetres thick occur between the dolomite beds, providing an indication of the gradual transition from rocks belonging to the Carnian Stage (Mlakar, 1969).

Jurassic rocks are absent (Mlakar, 1969).

Dark grey bituminous limestone with prevailing fossil *Requienia* and foraminifera species *Mil-lolida* is characteristic of the Early Cretaceous succession. Interbeds of bituminous dolomite and dolomitic limestone lie between the limestone beds locally. The Early Cretaceous sequence passes gradually into pale grey radiolarian limestone of Late Cretaceous age (see geologic map in Fig.1).

In the area near Andrejček's Farm a small patch of oolitic bauxite lies within the Cretaceous limestone. X-ray diffraction analysis (Dobnikar, 2003) revealed two main minerals - boehmite [$AlOOH$] and kaolinite [$Al_2Si_2O_5(OH)_4$] - plus the iron hydroxide goethite [$FeO(OH)$].

To the naked eye, the lithological transition between the Early and Late Cretaceous limestones is difficult to detect, especially as fossils are uncommon and only poorly preserved due to effect of tectonic injury.

b.) Structure

Two periods of tectonic activity have been recognised. The older one involved early Tertiary faulting and thrusting as a result of subduction of the Adriatic microplate beneath the European plate. The nappe structure of Western Slovenia typifies the fundamental structural pattern (Mlakar, 1969; Placer, 1981). In the mapped area the Norian to Rhaetian dolomite (belonging to the Čekovnik nappe; Placer, 1981) is thrust over Early and Late Cretaceous limestones (of the Koševnik nappe, o.c.). The average thickness of rocks within the Čekovnik nappe ranges from 150 to 200m, whereas the Koševnik nappe succession is somewhat thinner (100 to 150m; Mlakar, 1969; Placer, 1973). The thrust plane is slightly tilted, with a regional dip of 15° to 45° (averaging 25° to 30°) towards the SSW. Several smaller tectonic windows and a klippe exist in the study area (see Fig.1).

A later Tertiary tectonic episode is marked by strong faulting, mainly on NW-SE (Dinaric), NE-SW and N-S trends, the latter connecting fractures within the two main fault systems. Displacements along the Dinaric faults are dextral horizontal and vertical. Faults from few to more than 300 meters apart cut and displaced the thrust front. Vertical displacement reaches more 10m and fissured or (predominantly) broken and crushed zones (Čar, 1982) occur along the faults.

PRE-EXISTING DATA ABOUT KARSTIFICATION NEAR THE THRUST ZONE

Development of karst phenomena in the area of the thrust plane juxtaposition of dolomite on limestone was first studied by Čar (1974) and later by Čar & Šebela (2001). Čar's (1974) work was relied upon when interpreting the local karst as a product of specific conditions. His statements about the origin of "covered karst" stem from extensive field experience.

The presence of an impermeable cataclastic zone within the dolomite along the thrust plane contact points to the possibility of some kind of contact karst development (Gams, 2003). Cataclastic zones will commonly become permeable if cut and displaced "en echelon" by younger fault systems. Local (synclinal or anticlinal) tilting of the thrust plane also plays an important part in karst development (Čar, 1974, Čar & Šebela, 2001).

Karst phenomena in the dolomite on or near the thrust contact are inherited from pre-existing voids within the limestone basement (Čar, 1974). Further from the thrust contact dolines in the dolomite are less and less well expressed, as the thickness of dolomite above the contact increases. The cut-off point above which underlying limestone voids are not inherited appears to be at close to a critical dolomite thickness of Critical thickness of about 15m (Mlakar 2002, 38).

STUDY DATA

Main observations of karstification along the thrust contact

As described above the dolomite in areas away from the thrust contact is virtually impermeable and not significantly karstified, showing instead characteristically fluvio-denudational surface landforms. Closer to the contact only those karst features that were initiated and propagated from underground appear on the dolomite surface. In contrast, the limestone surface is everywhere intensely karstified, with karren, dolines, potholes and bogazes.

Dolines in limestone

The appearance and indirectly the origin of the dolines strongly reflects pre-existing tectonic

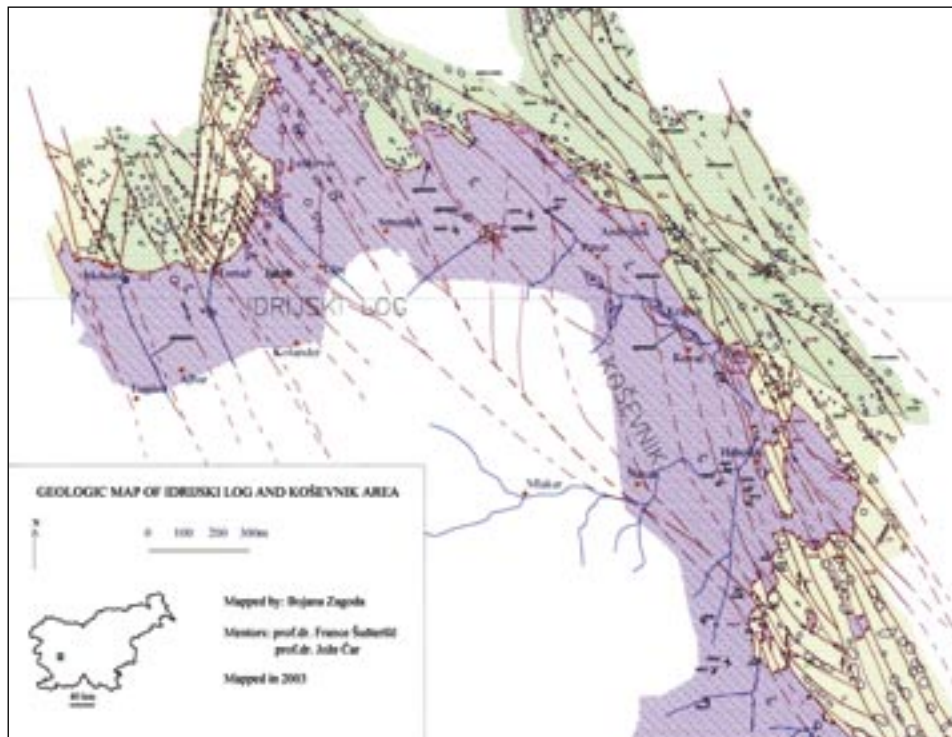
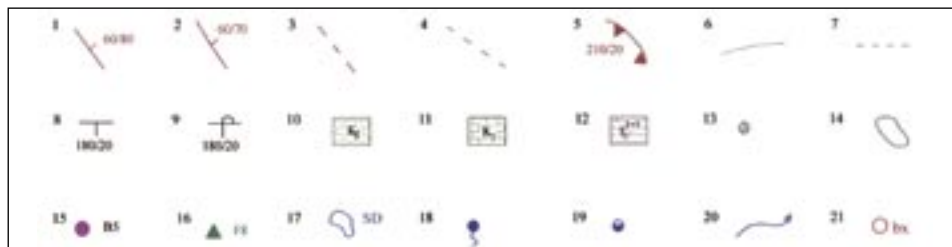


Fig.1: Geologic map of Idrijski Log and Koševnik



LEGEND TO GEOLOGICAL MAP OF IDRIJSKI LOG AND KOŠEVNIK AREA: 1- stronger fault with dip direction and dip angle, 2- less expressed fault, 3- supposed fault, stronger, 4- supposed fault, weaker, 5- thrust plane with dip direction and dip angle, 6- geologic boundary, 7- geologic boundary, strike and dip of strata, 9- strike and dip of inverse strata, 10- Late Cretaceous limestone, 11- Early Cretaceous limestone, 12- Late Triassic dolomite, 13- macrofauna, 14- doline, 15- pothole with number, 16- phreatic karst feature with number, 17- blind valley, 18- spring, 19- swallow hole, 20- direction of surface water, 21- Bauxite.

LEGENDA H GEOLOŠKI KARTI IDRIJSKEGA LOGA IN KOŠEVNIKA: 1- močnejši prelom s smerjo in vpadom prelomne ploskve, 2- slabše izražen prelom s smerjo in vpadom prelomne ploskve, 3- domneven prelom, močnejši, 4- domneven prelom, šibkejši, 5- nariv s smerjo in vpadom narivne ploskve, 6- geološka meja, 7- domnevna geološka meja, 8- smer in vpad plasti, 9- smer in vpad inverznih plasti, 10- zgornjekredni apnenici, 11- spodnjekredni apnenici, 12- zgornjetriasi dolomit, 13- makrofauna, 14- zunanji obod vrtače, 15- brežno z zaporedno številko, 16- freatična kraška oblika z zaporedno številko, 17- slepa dolina, 18- izvir, 19- požiralnik, 20- smer površinske vode, 21- pojav boksita.

Distance from thrust contact (m)	Idrijski Log	Koševnik	Both areas
0-50	30	13	43
50-100	7	2	9
100-150	15	0	15
150-200	6	2	8
200-300	1 (tectonic window)	1	2
	59	18	77

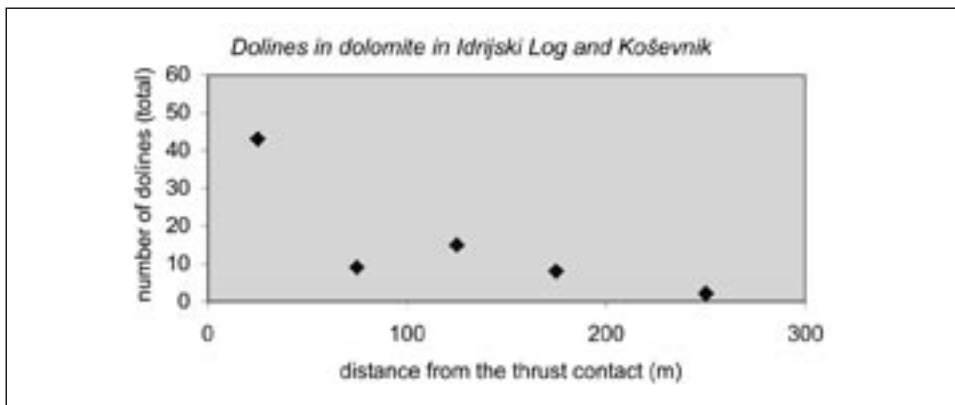


Table 1, Fig.2: Number of open dolines in dolomite in Idrijski Log and Koševnik, with respect to their distance from the thrust contact.

features. Most of them lie along fault lines or within faults zones. Most of them are ranged in strings along the fault lines or zones, though some of them are isolated.

Dolines mapped during the study were classified according to Čar's (2001) scheme and they belong to the "broken" (type D), "near-fault" (type E) and "fault dolines" (type F) groups. Dolines with characteristics of two or even all three groups are more common than the "pure" types.

Where the lithological contact between the Early and Late Cretaceous limestone is disturbed by faults, two distinct homogeneous rock types are brought into contact. The Early Cretaceous bituminous limestone may be partly dolomitized and is obviously less stable mechanically. Compared to the Late Cretaceous limestone along the faulted contacts the Early Cretaceous limestone is less injured and its karst features better expressed. Away from the faulted contacts the differences decline due to less pronounced levels of tectonic fracturing.

Dolines in dolomite

In Table 1 statistical data for dolines in dolomite are related to their distance from the thrust contact.

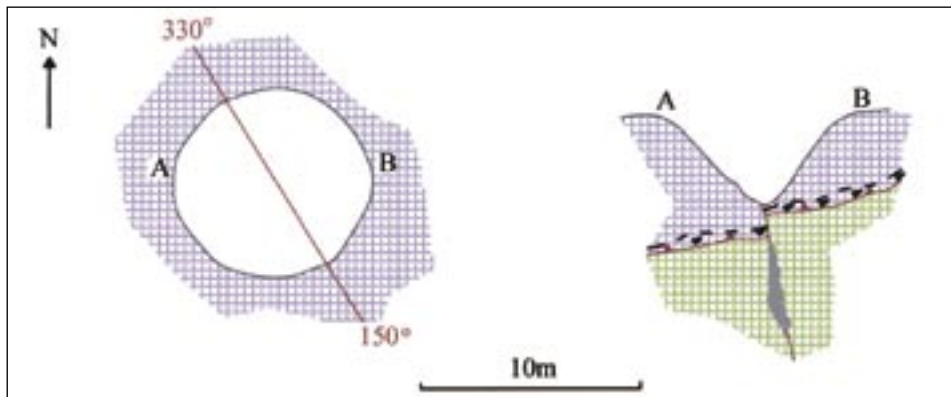


Fig.3: Doline in dolomite on a meadow in Idrijski Log, NE from Leskovec Farm (details conjectural).

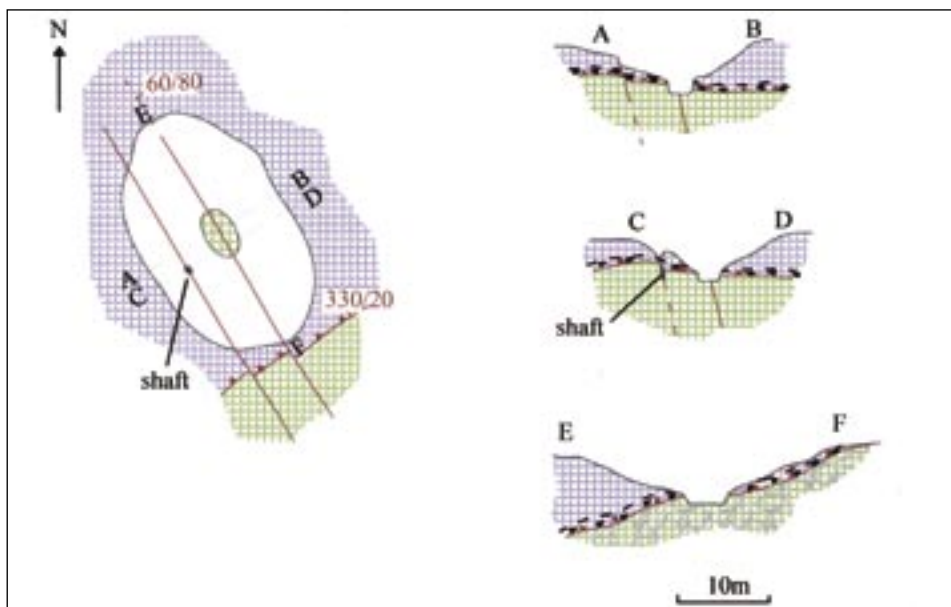
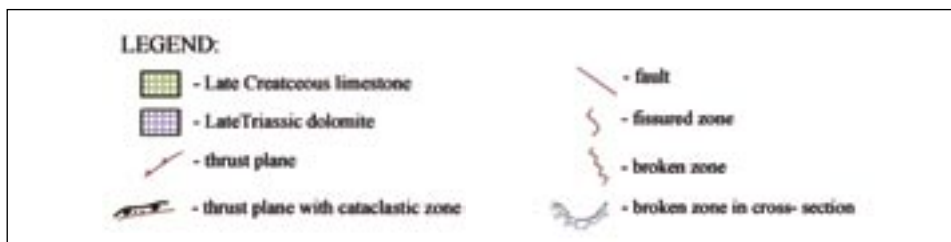


Fig.4: Doline in dolomite near the thrust contact in Koševnik (eastwards from Habe Farm).



Doline density in the dolomite is highest close to the thrust contact. Their density reduces as distance from the dolomite/limestone thrust contact increases (see Table 1, Fig. 2). There is some variation in the density of dolines at various locations due to the different tectonic settings. The number of dolines is greater between Tomaž and Leskovec farms, on the western side of the mapped area. Dolines mostly occur along the fault systems that are clearly seen in the limestones and partly inferred in the dolomite. The gentle dip of the thrust plane (about 20°) towards the SE and its local anticlinal and synclinal tilting help to provide conditions suitable for doline development farther from the dolomite/limestone contact (as compared with conditions in Koševnik). Limestone basement appears about 150m from the thrust contact (N of Tominec Farm, W of Smonček homestead). The greatest distance between dolines in dolomite and the thrust contact reaches 300m in Idrijski Log. As distance from the contact increases, dolomite thickness also increases, and the opportunity for inherited dolines (the “reproduced dolines” of Čar’s scheme, 2001) to develop declines.

On the Koševnik side, southward from Habečk’s Farm, dolines only appear close to the thrust contact. Weak vertical percolation of water through the cataclastic zone appears to relate partly to the greater thickness of the dolomite (the area is crossed by many strong faults along which the dolomite package was relatively lowered), and partly due to the local character of the Norian to Rhaetian dolomite. Between the dolomite beds are interbeds of dolomited marl a few millimetres to a few centimetres thick, which are impermeable or poorly permeable. The thickness of the dolomite package decreases northwards from here, between Kovač’s and Paver’s homesteads, where “inherited dolines” become more common. In some dolines small exposures of limestone have been noted, which implies that the overlying dolomite has been removed.

Dolines differ in their shapes and depth. They may be either regularly rounded with an average diameter of about 10m, or elongated along the fault lines. Dolines lying very close to the thrust contact usually have slopes covered with small dolomite blocks (broken zone). Farther away from the dolomite/limestone contact the slopes are mostly grassy.

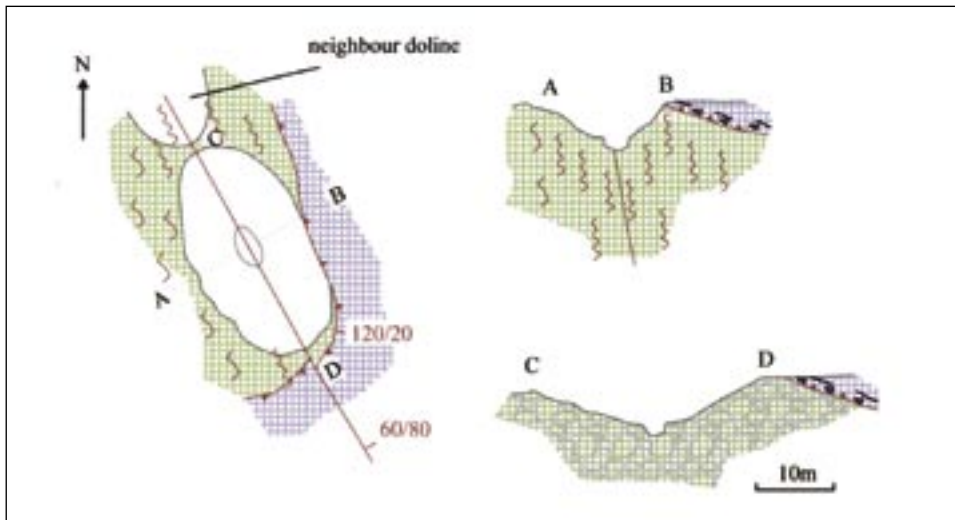


Fig.5: Doline in limestone near the thrust contact in Idrijski Log (southwest from Leskovec Farm).

Identification	Local lithology	Local tectonics	Rock properties	Geophysiography of immediate area	Depth (m)	Distance from thrust contact (m)
B1- Ajharjevo brezno, reg. num. ° 2446	dark grey bituminous limestone(K ₁)	fissure, strike 330°-150°	broken zone	slightly inclined area	18	350
B2	pale grey limestone (K ₂)	fault 60/70	broken zone	in a closed depression of modest dimensions	10	110
B3	pale grey limestone (K ₂)	fissure, strike 350°-170°	broken zone between faults 110°	in closed depression of modest dimensions	7	110
B4	pale grey limestone (K ₂)	fissures, strike 310°-130°	broken zone between faults 110°	on the slope	5	100
B5	pale grey limestone (K ₂)	faults 60/80, 190/80	broken to fissured zone	almost flat area	infilled (not deep)	3
B6	pale to mid grey limestone (K ₂)	fault, strike 320°-140°	broken zone	in a closed depression of modest dimensions	10	100
B7 (the top of vadose shaft)	pale to mid grey limestone (K ₂)	fault 240/80	broken zone	in closed depression of modest dimensions	2	100
B8	pale to mid grey limestone (K ₂)	fissures, strike 50°-230° and 350°-170°	broken zone	slightly inclined area	10	150
B9	pale to mid grey limestone (K ₂)	fault, strike 30°-210°	broken zone	in a closed depression of modest dimensions	from 20 to 40	140
B10	middle grey limestone (K ₂)	fault 110/85	broken zone	in a closed depression of modest dimensions	4	0,5
B11	mid to dark grey limestone (K ₁)	fault 110/80	broken zone	on a the flat area	6	160
B12	mid grey limestone (K ₁)	fault, strike 300°-120°	broken zone	in the floor of a doline	from 20 to 40	140
B13	dark grey bituminous limestone(K ₁)	fault, strike 340°-160°	broken zone	in a doline	5	300
B14	dark grey bituminous limestone (K ₁)	fault, strike 330°-150°	broken zone	in the slope of a doline	6	400

Table 2: Shafts in the Idrijski Log area.

Fig. 3 to 5 illustrate various examples of dolines in dolomite and in limestone close to the thrust contact between the Norian to Rhetian dolomite and the Late Cretaceous limestone.

The doline has a circular outer rim with steep doline slopes (grassy slopes). It is elongated along a Dinaric-trend fault and lies 60m from the thrust contact. According to Čar's (2001) classification this doline is regarded here as an inherited (reproduced) doline.

The thrust plane dips gently toward the NW and is disrupted by two Dinaric-trend faults. In the floor of the doline is a small shaft with dimensions of about 5x3x1.5m in Late Cretaceous limestone.

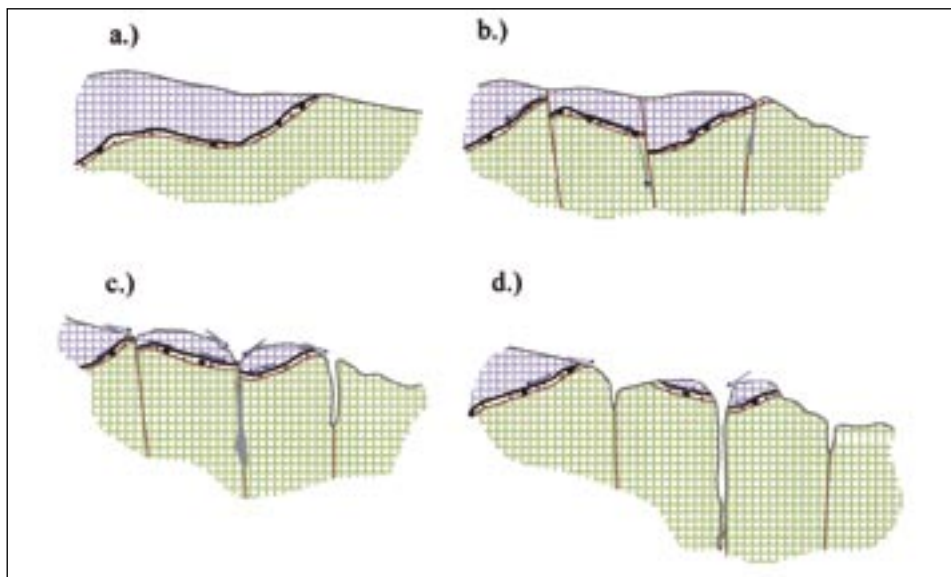


Fig. 6: Development of "covered shafts" (redrawn after Čar's interpretation, 1974).

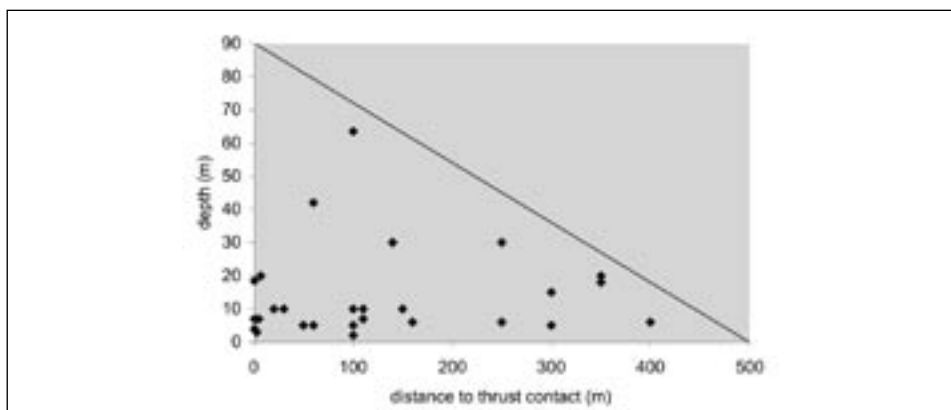


Fig. 7: Dependence of shaft depth and the distance to the thrust contact (without Habečkovo brezno, Table 3, B28).

Identification	Local lithology	Local tectonics	Rock properties	Geophysiography of immediate area	Depth (m)	Distance from thrust contact (m)
B15-Andrejčkovo brezno, reg.num. °589	pale grey limestone (K ₂)	fault 240/85	broken to fissured zone	In the NW slope of a doline	63,6	100
B16- Brezno v Koševniku I, reg.num. 260	mid grey limestone (K ₁)	fault 60/80	broken zone	in a closed depression of modest dimensions	*42,5	60 (to fault boundary between limestone-dolomite)
B17-Leskovcovo brezno, reg.num. 148	dark grey bituminous limestone (K ₁)	fault, strike 300°-120°	broken zone	in the northern slope of a doline	*15	300
B18- Brezno pod Brinovim gričem, reg.num. 146	mid grey limestone (K ₁)	faults 40/85 and 290/85	broken zone	in the western slope of a doline	about 30	250 (to fault boundary between limestone-dolomite)
B19- Konjsko brezno, reg.num.154	mid grey limestone (K ₁)	fault, strike 310°-130°	broken zone	in the floor of a doline	about 20	350 (to fault boundary between limestone-dolomite)
B20	pale grey limestone (K ₂)	fault 70/90	broken to fissured zone	at the top of a doline	5	60
B21	pale grey limestone (K ₂)	fault 75/80	broken to fissured zone	at the top of a doline	5	50
B22	pale grey limestone (K ₂)	fault 40/90	broken to fissured zone	in the slope of a small closed depression	6	250
B23	pale grey limestone (K ₂)	fault 70/90	fissured zone	slightly inclined area	7	5
B24	pale grey limestone (K ₂)	fault 60/90	fissured zone	in a closed depression of modest dimensions	7	0,5
B25, B26- Dvojno Pircovo brezno, reg.num. 273	pale grey limestone (K ₂)	fault 60/90	fissured zone	at the foot of a hill	about 15-20	7
B27	pale grey limestone (K ₂)	fault 50/55	broken zone	on a slope	about 10	30
B28- Habečkovno brezno, reg.num. °487	pale grey limestone (K ₂)	fault 290/60	broken to fissured zone	in a poorly developed channel	#350 (to siphon lake)	5
B29	pale grey limestone (K ₂)	fissure, strike 330°-150°	fissured zone	in the western side of a channel	8-10	20
B30-Požiralnik pri Hab. Breznu, reg.num. °549, sinkhole	pale grey limestone (K ₂)	fault 90/90	broken zone	in a slightly depressed area	#18,5	0

Notes: *: data after Caving Association Idria/JDI
 ° : reg. num. after Speleological Association of Slovenia
 #: data after Habe et al. (1954)

Table 3: Shafts in Koševnik area.

On the SW side of the doline slope is a shaft about 2m deep that opens on a fault, with its entrance in dolomite. The doline slopes are covered with small dolomite blocks. The doline is classified here as an inherited (reproduced) doline (Čar, 2001).

The doline lies on a Dinaric-trend fault with a few metres vertical displacement of the thrust plane. The E and SE part of the inner rim of doline coincide with the thrust plane. A shaft (dimensions about 5x3.5x3m) open in the doline floor. This is classified here as a contact - near fault - broken doline (Čar, 2001).

POTHOLES

Čar's (1974) statements concerning the origin of the potholes were relied upon when considering the origin of "covered shafts". The conceptual drawing in Fig. 6 illustrates their mode of development in limestone under a thin dolomite cover.

- a.) the thrust contact of Norian to Rhaetian dolomite over Cretaceous limestones,
- b.) the pre-existing synclinally and anticlinally tilted thrust plane is cut and displaced by younger faults,

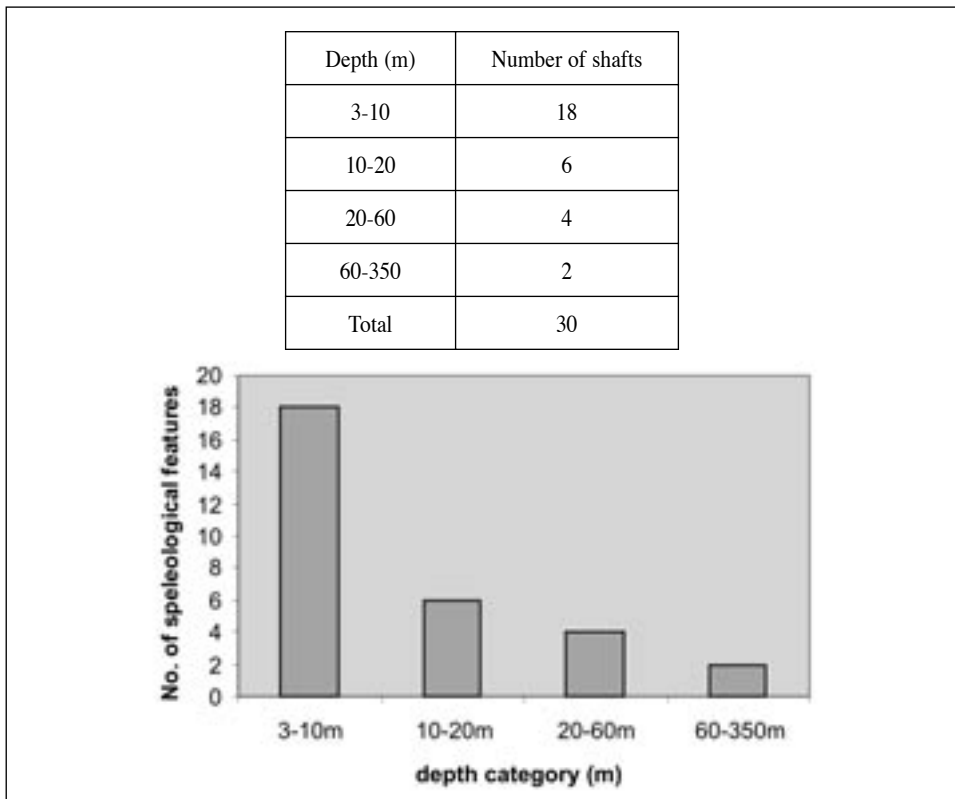


Table 4, Fig. 8: Number of shafts according to depth category.

c.-d.) development of caves at different depths due to the tectonic disposition of the thrust plane, with consideration of the effects of a denudation.

In the limestone along the thrust contact in the mapped area there are many shafts openings of various depths and perhaps at different stages of development. Most of them are of vadose origin, though indications suggest that some of them are abandoned phreatic jumps.

Tables 2 and 3 summarises the basic data of shafts with depths exceeding 5m lying in the mapped area.

Shafts depths other than those obtained from JDI or literature, are estimated.

Fig. 7 illustrates the interdependence between shafts depth and distance from the thrust contact.

If only the maximum depths of potholes are considered the depths decrease more or less proportionally to the distance from the thrust contact. Relationships between the maximum depths and distance can be represented roughly by an inequality of the form:

$$y < - 9/50 x + 90; \text{ where}$$

x is the distance to the thrust contact, and

y is the depth of the shaft.

Thus, the condition for the “existence” of the shafts is:

$$y + 9/50 x < 90 \text{ [in metres]; (see Fig. 7).}$$

The shafts can be divided into four categories according to their depth (Table 4 and Fig. 8). Most of the shaft depths range between 3m and 10m. The deepest ones are concentrated within a relatively small area. Shafts with entrances in dolomite are rare, because dolomite along faults is crushed and mechanically unstable.

RELICT PHREATIC FEATURES

Several smaller relict channels exist in limestone near to the thrust contact.

The most distinctive phreatic feature is a small unroofed cave (Šušteršič, 1998; Knez, Slabe, 1999) with flowstone and loam formed in broken zones within the Early Cretaceous bituminous limestone. Phreatic channel openings of smaller dimensions along bedding planes are more common.

Phreatic jumps or lifts are perhaps rare or simply difficult to recognize. The main factor that differentiates them from vadose shafts, though it is not always observable, is that the latter are sub-vertical, whereas the phreatic features are not. The distance of relict phreatic features from today's thrust contact position ranges from 50 to 250m.

Phreatic channels inaccessible to humans	7
Phreatic caves	2
Total	9

Table 3: Number of open phreatic features in the mapped area.

GENERAL CONCLUSIONS AND DISCUSSION

About dolines

Formation of dolines in dolomite is generally a reflection of karstification at the limestone base. Dolines opened along fault systems are mostly concentrated close to the thrust contact. The doline density relative to the distance from the dolomite/limestone contact provides a clear reflection of the tectonic situation. Provided that the thrust plane dips at a generally constant angle of about 30°, the dolomite thickness is about 60m at a distance of 100m from the thrust contact (with local variations due to tilting of the thrust plane and the effect of common stronger faults). According to Mlakar (2002) such a thickness does not allow formation of dolines, but as they appear up to 300m from the thrust contact, the “transmission” value must be higher. However, dolines do not exist once a certain thickness of dolomite cover over the limestone is reached. This could be because voids at great depth are not “inherited” at the surface or it could indicate that water sinking through dolomite becomes over saturated and cannot dissolve the limestone basement (so no initial voids develop). The virtual non-existence of dolines in dolomite farther from the thrust contact is probably also a consequence of dolomite’s mechanical properties. Crushed zones resulting from thrusting and faulting within the dolomite locally reach more than 10m in thickness. Meteoric water runs through this mass of small dolomite blocks in dispersed fashion and cannot gather together to form viable initial voids or channels in the dolomite.

The morphological characteristics of individual doline change due to progressive denudation. If chemical denudation predominates over mechanical, a doline that first opened in dolomite, such that the inherited (reproduced) doline, shown in Fig.3 will become like the doline shown in Fig.4. The open shaft in the doline floor is just below the cataclastic zone, which is cut and displaced by the fault. With progressive chemical denudation the doline will remain completely in limestone and hardly be recognisable as a former inherited (reproduced) doline (a possible example is the doline in Fig.5).

The land surface in dolomite that overlies karstified limestone is mechanically less stable very close to the thrust contact. The sandy nature of the doline slopes indicates that such dolines change shape relatively quickly due the intensity of processes in the basement.

Underground karst features

Most of the shafts in the mapped area formed when dolomite still overlay Cretaceous limestone and water was gathered together to sink at points where the cataclastic zone was disturbed by local faults. Deep shafts were formed in cases where greater amounts of subsurface water were gathered (such as where there was synclinal tilting of the thrust plane, Čar, 1974). In the mapped area several shafts were formed under such conditions (Table 2,3, B9, B12, B15, B28). Where the tectonic situation (position of thrust plane) was less favourable, the amounts of collected water were smaller, but still sufficient to form smaller shafts under the dolomite cover. As is seen in Table 4 and Fig.8 such potholes predominate. From Fig.7 it is also clear that the greatest density of shafts with depth from 5 to 10m is close to the thrust contact. With increasing distance from the contact the pothole’s depths decrease, possibly because mechanical denudation predominates over deepening (most of the observed shafts are in broken zones where mechanical crushing is most intensive).

When interpreting the genesis and development of potholes (and all karst phenomena), knowledge of geological, especially tectonic conditions is very important. As well as the vertical

displacement of individual blocks along the faults, one must also consider the local tilting of the thrust plane.

Limestone areas with higher relative elevations (»hills«, such as Smrekovec-730m, Jasni Vrh-715m, etc) appear to be the ones where overthrust dolomite was most recently removed. Some small klippes still exist there. The biggest one is preserved in the Pevec area (Mlakar, 1969, outside of the mapped territory), but small patches can still be found on higher elevations in the wider area of Habečkovo brezno (Table 3, No. B28). It appears that potholes B18 and B19 (Table 3), which presently lie in the slope of Jasni Vrh 250 to 350m from the current dolomite/limestone contact are related to remnants of former klippes that extended onto Jasni Vrh.

Potholes within the study area are of invasion vadose cave type (Ford and Williams, 1989, 268). The most important zone for vadose shaft formation is the epikarst zone (Klimchouk, 1995; Klimchouk et al., 1996), where water can gather together and move vertically through the rock mass. In the study area the boundary between the epikarst zone and the zone of vertical water movement is a cataclastic zone in the dolomite along the thrust plane.

Several proofs of phreatic karstification exist. Fragments of abandoned phreatic passages testify that karstification of the limestone began when it was still deeply buried beneath the overthrust dolomite. Their origin is related to dissolution by horizontally flowing water and is therefore not connected directly with the thrust contact.

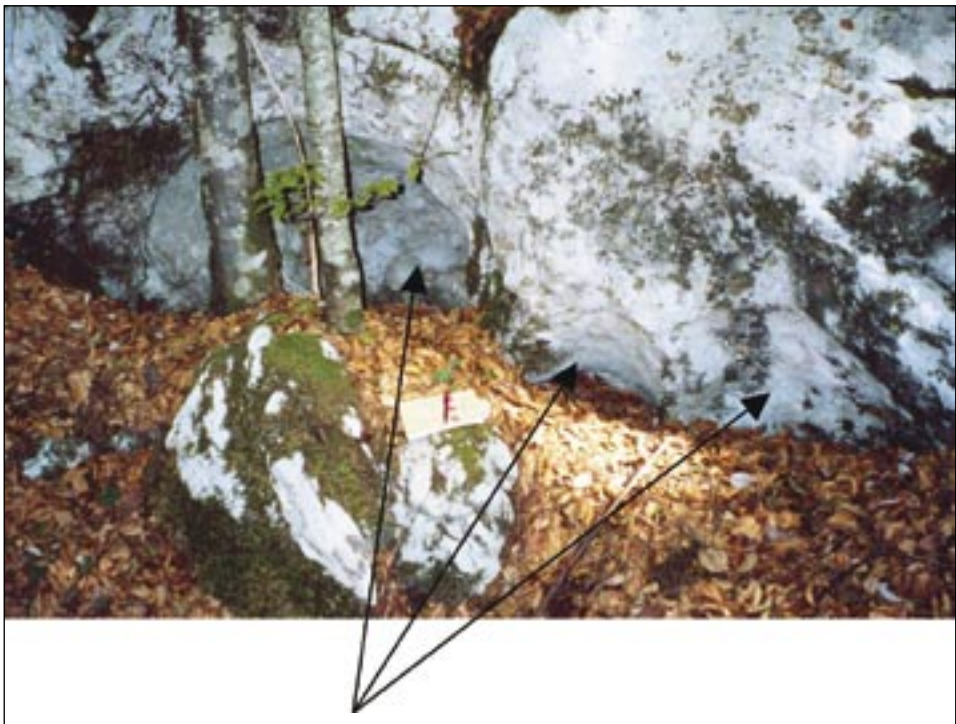


Fig.9: A sequence of three phreatic channels (arrowed), NE of Smonček homestead, Idrijski Log).

CONCLUSIONS

- Both the formation of dolines in dolomite and the occurrence of potholes in limestone are connected genetically with the dolomite/limestone thrust contact.
- This may be explained by the vertical displacement of individual blocks of the dolomite cover bringing about effective shortening of the paths of downward-percolating water. Consequently, vadose water could reach the underlying limestone while still undersaturated.
- The organization thus observed can be viewed as a type of contact karst effect.
- Morphological characteristics of individual karst features related to the thrust contact are evolving due to the effects of progressive denudation.
- These observations generally confirm the indications presented by earlier authors.
- The present “working conclusions” are based only on field observations and must be tested by ongoing monitoring of the operative processes.
- Fragments of phreatic tubes and unroofed caves testify to the formation of system drains at least 350m above the present water table.

ACKNOWLEDGEMENT

I would like to thank prof. France Šušteršič and prof. Jože Čar for their guidance of this work, advises and many useful suggestions. I also wish to thank dr. David J. Lowe for smoothing the English translation and his critical review of the text. All others who were of whatever assistance in the elaboration of this paper are also warmly thanked.

REFERENCES

- ČAR, J., 1974: Zakriti kras v bližnji okolici Idrije (The covered Karst in the near Idrija Vicinity). *Naše jame*, 16, 51-61, Ljubljana.
- ČAR, J., 1982: Geološka zgradba požiralnega obrobja Planinskega polja. *Acta Carsologica* (Geological setting of the Planina polje ponor area). *Acta Carsologica*, 78-104, Ljubljana.
- ČAR, J., 2001: Structural bases for shaping of dolines. *Acta Carsologica*, 30/2, 239-256, Ljubljana.
- ČAR, J., ŠEBELA, S., 2001: Kraške značilnosti naravnega stika apnenec-dolomit pri Predjami (Karst characteristics of thrust contact limestone-dolomite near Predjama). *Acta Carsologica*, 30/2, 141-156, Ljubljana.
- DOBNIKAR, M., 2003: Personal communication.
- FORD, D.C. & WILLIAMS, P.W., 1989: *Karst geomorfology and hidrology*. 1-601, London.
- GAMS, I., 2003: *Kras v Sloveniji v prostoru in času*. Založba ZRC, Ljubljana.
- JANEŽ, J., ČAR, J., HABIČ, P., PODOBNIK, R., 1997: *Vodno bogstvo Visokega krasa*. Geologija d.o.o. Idrija, Idrija.
- KLIMCHOUK, A., 1995: Karst morphogenesis in the epikarstic zone. *Cave and Karst Science*, 21/2, 45-50.
- KLIMCHOUK, A., SAURO, U. & LAZZAROTTO, M., 1996: “Hidden” shafts at the base of the epikarstic zone: a case study from the Sette Comuni plateau, Venetian Pre-Alps, Italy. *Cave and Karst Science*, 23/ 3, 101-107.

- KNEZ, M., SLABE, T., 1999: Unroofed caves and recognising them in karst relief (Discovered during motorway Construction at Kozina, South Slovenia). *Acta carsologica*, 28/2, 103-112, Ljubljana.
- MLAKAR, I., 1969: Krovna zgradba idrijsko žirovskega ozemlja (Nappe structure of the Idrija-Žiri region). *Geologija*, 12, 6-70, Ljubljana.
- MLAKAR, I., 2002: O nastanku hidrografske mreže in o nekaterih kraških pojavih na Idrijskem (On the origin of the hydrographic net and on some karst phenomena in the Idrija regions). *Acta Carsologica*, 31/2, 10-60, Ljubljana.
- PLACER, L., 1973: Rekonstrukcija krovne zgradbe idrijsko žirovskega ozemlja (Reconstruction of the Nappe Structure of the Idrija-Žiri Region). *Geologija*, 16, 317-334, Ljubljana.
- PLACER, L., 1981: Geološka zgradba jugozahodne Slovenije (Geological structure of Southwestern Slovenia). *Geologija*, 24/1, 27-60, Ljubljana.
- ŠUŠTERŠIČ, F., 1998: Interaction between cave systems and the lowering surface; case study: Laški Ravnik. *Acta Carsologica*, 27/2, 115-138, Ljubljana.
- ZAGODA B., 2004: Zakrasevanje ob narivnem stiku dolomita in apnenca v Idrijskem Logu in Koševniku: Diplomaska naloga. p.67, Ljubljana.

ZAKRASEVANJE OB NARIVNEM STIKU DOLOMITA IN APNENCA V IDRIJSKEM LOGU IN KOŠEVNIKU (IDRIJSKO, SLOVENIJA)

Povzetek

Da bi dobili podrobnejši vpogled v problematiko zakrasevanja v odvisnosti od geoloških parametrov, smo v merilu 1:5000 kartirali območje ob narivnem stiku norijskoretijskega dolomita na spodnje in zgornjekredne apnence v Idrijskem Logu in Koševniku. Pozornost smo namenili pojavljanju vrtač v apnencih in dolomitu, pojavljanju brezen v apnencih in fosilnim freatičnim oblikam. Pri tem nas je zanimalo, kako se spreminja gostota vrtač na dolomitu z oddaljevanjem od narivnega kontakta in globina brezen v apnencih z oddaljevanjem od narivnega stika dolomit-apnenec.

Pri kartiranju sem uporabila Čarjevo klasifikacijo prelomnih con (1982), ki je pri številnih kartiranjih dala odlične rezultate za razlago kraških terenov.

GEOLOGIJA KARTIRANEGA OBMOČJA

Litostratigrafski podatki

Najstarejša kamnina je norijskoretijski dolomit. Dolomit je svetlo do temno siv, ponekod porozen ali znat. V njem so pogosti stromatoliti s številnimi izsušitvenimi porami. Plasti so debele od 10 centimetrov do 1,5 metra in povsod ležijo v inverzni stratigrafski legi (Mlakar, 1969). Tako dobimo nad zgornjetriasnim dolomitom značilne medplastne vložke rumeno rjavega ali sivega dolomitnega laporovca, debelega od nekaj mm do več decimetrov, ki že nakazuje postopen prehod v karnijsko dobo (Mlakar, 1969).

Jurskih kamnin na obravnavanem ozemlju ni zaradi narivne tektonike.

V spodnji kredi je nastajal temno siv srednje plastnat apnenec z močnim vonjem po bitumnu, za katerega so značilni preseki školjk rekvienij in foraminifer rodu *Miliolide*. Med plastmi apnenca so posamezni nepravilni vložki bituminoznega dolomita in dolomitiziranega apnenca (Mlakar, 1969). Spodnjekredne kamnine postopno prehajajo v zgornjekredne svetlo sive srednje plastnate apnenca s preseki rudistnih školjk.

Tektonika

Najpomembnejša strukturna enota je narivni stik norijskoretijskega dolomita čekovniške vmesne luske na spodnje in zgornjekredne apnenca koševniške vmesne luske. Narivni kontakt ima smer od JZ proti JV in vpada pod položnim kotom od 20-40°, v povprečju okoli 20-25°. Narivna ploskev je značilno sinklinalno in antiklinalno povita tako v prečni kot v vzdolžni smeri.

Starejšo narivno ploskev sekajo in premikajo številni mladoterciarni prelomi s prevladujočo smerjo SZ-JV, delno tudi SV-JZ. Prelomi so po značaju poševni in imajo poleg prevladujoče zmične komponente tudi premik po vpadu. Močnejše prelome (navidezni premik do 350 m) spremljajo šibkejši, ki so bolj ali manj vzporedni glavnemu ali pa se od njega odcepljajo in vezni prelomi v smeri S-J. Prelomi tvorijo razpoklinske, predvsem pa porušene in ponekod tudi zdobljene cone. Prelomne cone lahko tako v vzdolžni kot v prečni smeri prehajajo druga v drugo (Čar, 2001).

OBSTOJEČI PODATKI O ZAKRASEVANJU OB NARIVNEM KONTAKTU

O nastanku kraških pojavov v odvisnosti od geoloških pogojev ob narivnih conah dolomita in apnenca, sta pisala predvsem Čar (1974) in Čar & Šebela (2001).

Ker je kataklastična cona ob narivni ploskvi v dolomitu neprepustna, nam tak stik predstavlja neke vrste kontaktni kras (Gams, 2003). V primeru, da kataklastično cono sekajo in dovolj premikajo prelomi, se pod narivno ploskvijo v apnencih prične zakrasevanje, prazen prostor pa se preslika na površje v obliki reproduciranih vrtač (Čar, 1974). Med pogoje, ki so nujni za zakrasevanje pod narivno ploskvijo, pripisuje Čar (1974) poleg prelomov še položaju narivne ploskve. Če je ta sinklinalno upognjena, je podpovršinski in površinski dotok vode večji, kar se odraža v bolj izraženih kraških oblikah.

TERENSKA OPAZOVANJA

Vrtače v apnencih

Oblikovane so ob prelomih in prelomnih conah in lahko ležijo samostojno, vendar si največkrat sledijo v nizih, ki jih narekujejo prelomi s spremljajočimi, predvsem porušeni in razpoklinskimi conami.

Vrtače, ki sem jih klasificirala po Čarjevi opisno-genetski klasifikaciji (2001), uvrščam med porušne (tip D), obprelomne (tip E) in prelomne (tip F). Pogostejše, kot »čisti«¹ tipi vrtač, so vrtače, kjer se prepletajo lastnosti, ki pripadajo eni in drugi ali vsem trem skupinam.

Vrtače v dolomitu

Največja gostota vrtač je v bližini narivnega kontakta, z oddaljevanjem od kontakta pa njihova gostota upada (Tabela 1, Slika 2). Število vrtač je večje med kmetijama Tomaž in Leskovec na zahodni strani kartiranega ozemlja. Odpirajo se ob prelomih, ki so lepo vidni v apnencih in delno tudi v dolomitu. Položen vpad narivne ploskve (okoli 20°) proti JV in lokalno povijanje narivne

ploskve ustvarjajo pogoje za razvoj vrtač tudi dlje od kontakta. Manjši tektonski okni ležita 150m od naravnega kontakta (S od kmetije Tominec, Z od domačije Smonček). Največja razdalja vrtače v dolomitu do naravnega kontakta je v Idrijskem Logu do 300m.

V Koševniku je gostota vrtač manjša (Tabela 1). Vzrok za manjše število vrtač in njihovo hitro upadanje z oddaljevanjem od kontakta dolomit-apnenec, je verjetno v preveliki debelini dolomitnega pokrova (tod potekajo številni zmični prelomi s poudarjeno vertikalno komponento) in delno tudi v značaju norijskoretjskem dolomitu. Ta v tem območju vsebuje tanjše medplastne vložke dolomitnega laporovca, ki je delno prepusten ali neprepusten.

Brezna

Glavni podatki brezen na kartiranem območju so zbrani v Tabeli 2, njihov nastanek in razvoj pa je prikazan na sliki 6. Ob upoštevanju največjih globin brezen, je razvidno da njihova globina z oddaljevanjem od naravnega kontakta upada bolj ali manj sorazmerno (slika 7). Območje pojavljanja brezen je pod premico, neenačbo pa lahko zapišemo kot: $y + 9/50 x < 90$ (v metrih).

V tabeli 4 in sliki 8 je prikazano število brezen glede na globinsko kategorijo. Prevladujejo brezna z globinami od 3m do 10m. Najgloblja brezna se odpirajo znotraj relativno majhnega območja.

Freatične oblike

Najpogostejše freatične oblike v apnencih so freatični kanali, ki so manjših dimenzij (tabela 3, slika 9).

DISKUSIJA

Vrtače v dolomitu so preslikava zakrasevanja v apnencu na dolomitno površje. Njihovo število z oddaljevanjem od naravnega kontakta upada. Ob predvidevanju, da vpada narivni stik pod kotom 30°, se dolomit na razdalji 100m odebeli za 60m (izračun je nenatančen, saj ne zajema lokalnih odklonov zaradi povijanja narivne ploskve in prelomov). Po Mlakarjevi oceni (kritična debelina je 15m, 2002, 38) je ta debelina dolomita že prevelika za preslikavo zakrasevanja iz apnenca na površino. Ker se vrtače pojavljajo do 300m od naravnega kontakta, ocenjujemo da je kritična debelina večja. Vzrokov, da na določeni debelini dolomita nad apnencem vrtač ni več, je lahko več. Zaradi prevelike debeline dolomita reprodukcija ne doseže površja ali voda pa se voda v dolomitu že zasiči preden doseže apnenčevo podlago in je ne more več raztapljati.

Večina brezen na obravnavanem območju je nastajala v času, ko je norijskoretjski dolomit še prekrival kredne apnence, voda pa se je precejala skozi tanko in ob prelomih odprto kataklastično cono. Globoka brezna so nastajala v primeru, da so bili maksimalno izpolnjeni vsi pogoji (poleg preloma, ki seka in premika kataklastično cono še sinklinalno upognjena narivnica in večji točkovni dotok površinske in podpovršinske vode, Čar, 1974). Izvzamemo lahko kar nekaj brezen, ki so nastajali pod takimi pogoji (B9, B12, B15, B28; Tabela 2,3). V primeru, da je bila tektonska zasnova manj ugodna (položaj narivne ploskve), je bila količina vode manjša, a še vedno v mejah, da se je lahko pod narivnico oblikovalo brezno manjših dimenzij. Taka brezna so tu prevladujoča (tabela 4 in slika 8). Iz slike 7 je razvidno, da se brezna z globinami od 5-10m odpirajo v bližini naravnega kontakta. Z oddaljevanjem od kontakta se njihova globina zmanjšuje, ker je mehanska denudacija učinkovitejša od kemične (večina brezen se odpira v porušeni conah, zato je mehansko kršenje še intenzivnejše).

Računati moramo tudi z zakrasevanjem apnenca, ko je bil še globoko pod dolomitnim pokrovom in se je voda pretakala lateralno. Take oblike tukaj niso pogoste. Dokaj številni so le freatični rovčki, ki ponujajo ključ do odgovora na vprašanje, kam je odtekala podzemna voda.

ZAKLJUČKI

- Nastanek vrtač v dolomitu in brezen v apnencih je vezan na narivni kontakt dolomita in apnenca.
- Kraške oblike v dolomitu nastajajo tam, kjer se še nenasičena voda pretaka skozi ob prelomih odprto kataklastično cono v apnenčevo podlago.
- Ob narivnem kontaktu je razvit neke vrste kontaktni kras.
- Morfološke lastnosti posameznih kraških oblik so posledica napredujoče denudacije.
- Terenska opazovanja potrjujejo ugotovitve, ki jih navajajo ostali avtorji.
- Freatične oblike so nastajale globoko pod dolomitnim pokrovom in niso genetsko vezane na narivni kontakt.