STRUCTURAL BASES FOR SHAPING OF DOLINES

STRUKTURNE OSNOVE OBLIKOVANJA VRTAČ

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Izvleček

Jože Čar: Strukturne osnove oblikovanja vrtač

Z natančno registracijo geoloških strukturnih elementov (lega plasti in stopnja pretrtosti kamnin) ter opazovanjem nekaterih morfoloških značilnosti lahko za vsako vrtačo posebej neposredno ali pa s kombinacijo podatkov iz sosednjih vrtač in bližnje okolice, določimo geološke osnove, ki dajejo osnovno njeni današnji prostorski legi, obliki in velikosti. Na podlagi tega smo izdelali opisno-genetsko klasifikacijo vrtač in definirali 8 osnovnih tipov vrtač (oznake od A do H, Sl. 1). V naravi so čisti tipi redki, običajno se pojavljajo kombinacije. Ugotovitve veljajo za vrtače na različnih karbonatih kamninah in karbonatnih klastitih. Iz tega izhaja, da genezo vrtač nikakor ne moremo poenostaviti na en splošno veljaven model pač pa »veljajo« vsi modeli (korosijski, udorni, klimatski), ki se med seboj tudi kombinirajo in prepletajo v odvisnosti od okoliščin.

Ključne besede: geološko-morfološko kartiranje vrtač, opisno-genetska klasifikacija vrtač, porušne udornice, kraško površje, geološke osnove geneze vrtač.

Abstract

Jože Čar: Structural Bases for Shaping of Dolines

By a precise registration of geological structural elements (the location of beds and to what degree the rock is fractured) and by observation of some morphological properties one may define for each individual doline, either directly or by combining the data known in nearby dolines and their vicinity, the geological bases which give the foundations for its present location, shape and size. On such a basis we prepared a descriptive-genetic classification of dolines and I defined 8 basic types of dolines (labelled from A to H, Fig. 1). In nature pure types are rare; usually combinations occur. The findings relate to dolines in different carbonate rocks and carbonate clastites. Hence it follows that the genesis of dolines cannot be simplified into one general model but all the models are »valid« (corrosion, collapse, climatic) combining among them and intertwined by interdependence of circumstances.

Key words: geologic-morphologic mapping of dolines, descriptive-genetic classification of dolines, collapse dolines, karst surface, geological bases of doline genesis.
INTRODUCTION

In the past two decades a geological mapping in the scale 1:5000 of vast areas of Notranjski and Idrijski karst and karstified Trnovsko-Banjška plateau was carried out (Čar 1982, 1986; Čar & Gospodarič 1984; Čar & Šebela 1997). These regions are mostly composed of limestone of the Lower and Upper Cretaceous and partly by Jurassic carbonate rocks. By mapping we got a detailed insight into geological circumstances of the treated areas in particular in their structure in respect to lateral lithological changes, rock texture properties, and spatial location of beds as plicate and disjunctive tectonic deformations. Specially in detail and precisely we studied the interdependence among the above-mentioned geological elements and karst morphology. Gradually we evolved a method of detailed geological mapping of karstified limestone terranes which was successfully tested on some other karst terranes and karstified rocks elsewhere in Slovenia in recent years. A special study will be dedicated to this topic (Čar, in preparation).

The results of a detailed lithologic-tectonic mapping of karstified limestones are already partly published (Čar 1982, 1986; Čar & Gospodarič 1984; Čar & Šebela 1997; Šebela & Čar 2000). The same method of mapping has been successfully introduced and used in mapping the karst underground (Šebela 1991, 1992, 1998; Šebela & Čar 1991; Čar & Šebela 1998). While mapping in detail the karstified terrain in a wider vicinity of Planinsko polje and the region between Planinsko polje, Rakov Škocjan, Strmica and Pivška kotlina we examined and geologically mapped in detail - by an estimation - about 4000 dolines. It was shown that by a precise registration of geological structural elements and by observation of some morphological properties we can define geological bases for each individual doline either directly or by combination of data from nearby dolines and their vicinity which contributed to a doline’s present location, shape and size. Some basic genetic elements of dolines are thus revealed.

PROBLEMS

A list of studies related to dolines in limestone is very long (see cited and commented literature in works of Cvijič 1893, 1895; Cramer 1941; Gams 1974; White 1988; Ford & Williams 1989; Šušteršič 1994). The authors discuss mostly the origin and development of dolines, their shape and morphometry, geomorphological installation in different karst terrains and also systematics and hydrology. There is also quite a lot of studies dealing with geological bases for origin of caves and with geology of cave systems (see references in Gospodarič 1976; Šebela 1998). But there are few studies which try to connect a complicated problems of genesis, development, distribution and shape of dolines with geological structural elements (see references in Aubert 1966; Bahun 1969; Čar 1974; Placer 1972; Cucchi et al. 1976). Till now the Slovene karstological literature does not comprise any study dedicated exclusively to geological problems of dolines. It is true that we find in studies of geological setting of some parts of the Slovene karst also data related to genetic connection of dolines in limestones with local geological structures (Čar 1974, 1982, 1986; Čar & Šebela 1998).

Numerous karstologists have studied the doline genesis from Cvijič (1893, 1895) to the present time (D’Ambrosi 1960; Williams 1985; Klimchouk 1995). In spite of several theories (collapse, corrosion, climatic) there is still quite a lot of uncertainty in relation to their genesis which was in
recent years emphasised by our researchers also (Šušteršič 1994; Gams 2000; Mihevc 1998, 2001). Mihevc (1998) specially stresses that by a superficial mapping it is very difficult if not impossible to find out their origin. Classification of dolines only by their shape and depth to dish-like, funnel-like or well-like (Cvijić 1893) is preserved till now (Gams 2000) yet in our opinion it is useless. This writes Šušteršič (1987, 1994) and Mihevc (2001) confirms. Such morphological classification of dolines is only descriptive and does not tell anything about the »essence« of dolines.

This study does not deal with doline genesis directly but it treats the connection between dolines and geological structures which can be established by a detailed geological mapping. The statements hold for dolines in variously bedded and lithologically changing limestones (for example marl limestones, calcarenites, calcrudites etc.) and dolomites as well as for dolines in carbonate clastites (for example lime sandstones, lime conglomerates etc.). Concordantly to statements we propose a doline classification which is not descriptive only but contains important genetic elements. We can call it descriptive-genetic classification as geological setting is taken into consideration defining the genesis evolution and giving morphological shape to dolines. Only for broken dolines, steep sided cliff hollows (earlier: collapse dolines, Čar 1982; Šebela & Čar 2000) we give a short description of their origin as it has not been yet presented.

COLLECTING OF FIELD DATA

The following list of data that must be obtained by mapping in the field is prepared for a suggested descriptive-genetic classification of dolines. In a morphological point of view it does not bring any changes (Šušteršič 1994). The decisive role in doline origin of how the limestone is bedded and fissured has been known since the end of the 19th century (Cvijić 1893, 1895). But new is consideration of various fractured zones (crushed, broken, fissured zones) and their influence on origin and development of dolines. We find them in the field and we follow them concordantly to the implemented method of mapping (Čar 1982, 1986; Čar & Pišljar 1993; Čar & Šebela 1997). A new view opens that spatial connection between near dolines and the form of transition between them.

The procedures of a detailed geological mapping on various carbonate rocks, clastite included are very similar. A more exacting work is a mapping of dolomite terrains. We shall discuss it in a special contribution.

If we wish to explain descriptive-genetic bases we must define for each doline the following geological and morphological data:

1. Geological data:
   type of bedding (stratification, lithology, »bedding of regulated particles«, non-bedded rock)
   • strike and dip of strata
   • thickness of beds
   tectonic deformations
   • type of fractured zone (crushed, broken and fissured zones),
   • strike and dip of tectonic planes,
   • how much a zone is fractured (a type of cataclastic fault rocks, density of fissures, etc.)
• extent of the fractured zone
• spatial connection of different fractured zones.

2. Morphological data:
• ground plan of doline,
• the shape of slopes and walls,
• the shape of upper rim (outer border)
• depth, width and length.

3. Other:
• spatial connection with neighbouring dolines and forms of transition between them
• drawing of ground plan of each doline (or series of dolines) separately and at least two characteristic profiles of a doline (or series of dolines).

According to judgement we can draw or photograph selected details and particularities

As we see the list is rather long, time-consuming and exacting. Yet we observe and note all the listed data only when we study individual dolines. Usually we treat dolines in complex or at the same time with mapping of terrain. Numerous geological elements, in particular strike of strata and various fractured zones extend in a greater distances therefore it is not necessary to note just everything in each individual doline. Thus on the base of the terrain knowledge and experiences a geologist or a karstologist skilled in geological mapping can adequately shorten the list of above written elements.

At times it is impossible to collect all the data included in the above list due to thick vegetation. In a case of a doline where you »see nothing« one has to note it and examine the neighbouring dolines and the intermediate terrain. Experiences show that in a complex of at the most three or four dolines at least some basic elements of structural and lithological structure could be seen.

Basic types of dolines

According to previous experiences at mapping karst in limestones and checking on other karstified rocks at us all the dolines in relation to their dependence to geological structures can be divided into six basic types labelled from A to F and two special types labelled G and H and one transitional type - broken collapse dolines. The suggested sorting of dolines has a character of descriptive-genetic classification.

A. Stratification doline (Fig. 1A). Stratification dolines develop in thin bedded, gently inclined and syncline bent bedded rocks. In this case these are not a »virtual« tectonically fractured rocks but insignificant tension joint (discontinuities) which usually cross one bed and thus extend from one to the other bedding plane (interbedded joints). They occur during gentle inclination or bending of beds. Water flows by slightly inclined bedding planes to reach a sheaf of interbedded joints (discontinuities) either on normal syncline crest (channel) with small amplitudes and relatively large radius or on inclined beds where water starts to flow in generally vertical direction. Dolines of the A type are regularly shaped or oblong outer rim. They are relatively large (outer diameter more than 10 m) and relatively shallow. The deepest part is nearly in the middle of a doline. The bottom is usually not directed and if it is it trends to bedding. The rate between the diameter of the outer rim and
their depth is about 4:1 to 3:1. The conditions for an origin of the described doline type are rarely fulfilled, this is why such type is relatively rare.

Note: Dolines in a distinctive syncline or anticline bent layers are mostly B and D type.

B. *Fissure dolines (dolines in fissured zones)* (Fig. 1B). Dolines in fissured zones are the least distinctive. The limestone beds have a gentle bedding angle (up to 20°). They occur in medium to dense fissured zones. The outer rim of dolines is very irregular. In general it conforms to structural conditions in a fissured zone and indents in a form of karren. The doline slopes are prolonged in the direction of strata dip and have approximately the same angle as the layers. The slopes are irregular and covered by karren or by single rock knives peeping from the thin weathered surface. Dolines in fissured zones are shallow with one or several lowest points distributed along the strike of bedding.

C. *Bedded-fissured dolines* (Fig. 1C). Dolines belonging to group C are shaped according to bedding in fissured zones. The limestone is medium to thick layered (from 10 to 100 cm) and their dip is usually from 20° to 60°. A fissured zone is (usually) directed over the bedded limestones. In ground plan dolines display an irregular shape and they are elongated rectangularly to ridges. Upper external rim of dolines is more or less straight and directed according to bedding. In general dolines are relatively narrow and deep. Poorly distinctive lower points may be either elongated in the direction of bedding or roughly rectangular. Often there are in the bottom of dolines rock shelters of various sizes and developed according to bedding.

D. *Broken dolines (dolines in broken zones)* (Fig. 1D). In broken zones (Čar 1982, 1986) very large and regular dolines may develop. In most cases the outer rims of dolines approach more or less to a proper circle. The rim may reach from edge to edge of a broken zone or it lies inside it. The slopes of dolines are smooth. In the upper part they are steeper and in the lower part they reach the central doline point by a gentler angle. The slopes are in general without protuberances or channel-karren-like features, dotted with some rock blocks or almost entirely covered by detritus (weathered material). Taking into account that the depths of dolines within the same broken zone are very similar I suppose that depth mostly depends on changing of how the rock is crushed in the vertical direction and also on size of blocks (autoclasts) within the broken zone. The bottoms of dolines are usually elongated in the direction of crushed zones. The biggest dolines on till now mapped areas are found just in broken zones.

E. *Near-fault dolines (dolines near the fault zone)* (Fig. 1E). On one side a doline is bordered by a fault. In case when the fault is a simple one composed of only one distinctive fault plane with a crushed zone on one side, the walls are poorly or not at all dissected and inclined under the angle of dip (usually very steep) of a fault plane towards the bottom of doline and in places subvertical into the opposite direction. If fault has a complicated internal zone the doline’s slope displays graded structure (Fig. 1E). We see several steep fault planes with intermediate ledges, more or less wide. Thin-bedded limestones do not display such structure. In such a case the wall is steep and covered by smaller or bigger broken pieces. The remaining part of a doline developed in accompanying broken, fissured or broken-fissured zone. The doline’s rim is irregular, resembling the ground plan of Type B doline (Fig. 1). Independent dolines are usually elongated roughly rectangularly to fault or fault zone direction. The bot-
Tom is directed along the fault zone and usually covered by a thick layer of weathered material. Near-fault dolines are often set in a series. In such cases the bottom of doline is elongated in the direction of the fault. In such a case strike and dip of strata play only a subordinate role.

**F. Fault dolines (dolines in fault zones) (Fig. 1F).** In such a case dolines developed entirely in a distinctive fault zone. The fault contains more or less wide internal broken zone. Thus the rock is fractured up to blocks of different size and bedding is no more visible. Usually broken rocks of the internal zone are distinctly limited by border fault planes, which may be either single or developed as fault zones with a narrow internal crushed zone. Dolines reach from one to another fault plane and usually set series along the fault zone. It is characteristic that within one series in a totally irregular order there are shallow dolines with gentle slopes and very deep dolines with steep slopes. The intermediate passages between dolines are either very lowered or only slightly lowered in relation to the surrounding terrain. The outer rim of dolines is irregular. The bottom may be either totally irregular or covered by a thicker layer of weathered material. Morphology and depth of dolines adapt to structure and distribution degree in which the internal fault zone is fractured and to morphology and direction of fault zone.

In addition to the above described, there are quite frequent also dolines with more complicated lithological structure and supplementary structural elements. Their basic properties are united into two types and they are designated by the letters G and H. Both types of dolines intertwine (Čar 1974). Genetically and morphologically such types of dolines are very complicated this is why every single example must be studied separately.

**G. Contact dolines (dolines at geological contacts) (Fig. 1G).** Contact dolines develop at the contact of two lithologically different rocks. This is either contact of two carbonate rocks (for example limestone - dolomite) or one carbonate and one non-carbonate rocks (for example limestone - flysch). Rocks do not differ only by lithologico-sedimentological properties but also by bedding and dip angle of strata. Contacts may be either normal and erosional but also fault and thrust with all sorts of fractured zones (fissured, broken, crushed zones). The description shows that not only contact of two different rocks but also one or many structural definition conditions exist which are typical of dolines from A to F. There are no generally valid common description properties.

**H. Reproduced dolines (repeated dolines; dolines reproduced from the base foot-wall) (Fig. 1H).** Special structural conditions must exist (Čar 1974) to get a reproduced doline. In the base there must be rocks favourable for karstification, in particular different types of limestone which must be covered by impermeable rocks or such that are less favourable for karstification non-compact rocks (tectonically fractured or mechanically non-resistant - various lithology) or weathered material. The karstification process goes on in the base while dolines are formed in upper layers by reproduction. Almost as a rule in the lower layers there must exist smaller or larger karst caves to “swallow” the material from upper layers. The upper layer must not be too thick as this prevent collapsing and transport of material. Which is the crucial thickness depends on size and intensity of karstification in the base and on degree how the rock is fractured or solid and on lithological character of the upper layers. The contact between the karstified base and upper layers can be either normal, erosional or thrust.
In nature the dolines of “pure” type, such that completely correspond to the above descriptions are rare. The problem may be solved by writing down the assessed combination. For example the combination EB means that the central part of doline developed along the fault zone (near-fault doline) and border parts are characteristically shaped and elongated at fissured zones (fissure doline). Less distinctive properties can be written in brackets, for example EF(B) (Fig. 2a). If a doline lies on limestone entirely this is not specially stressed; if it lies on dolomite or conglomerate this fact is written at the right side, for example EF do and Dko. The first case means a doline of EF type on dolomite and in the second broken doline in conglomerate.

**Broken collapse dolines** (Fig. 2)

Broken collapse dolines are transitional features between “real” collapse dolines and broken dolines (dolines of type D; dolines in broken zones). They develop in cases when in a certain depth water flow crosses vertical or subvertical broken zone. If the rocks are tectonically less fractured, growing cave passages develop and this can cause a sudden roof collapse and origin of

![Diagram of dolines](image)

Text to legend in Fig. 2:
1. flysch rocks (in general: any poorly permeable rock - carbonate or non-carbonate), 2. bedded dolomite (in general: upper impermeable or poorly karstifiable layers non-solid - tectonically fractured and mechanically weak - rocks or weathered material), 3. thin-bedded limestone, 4. medium to thick-bedded limestone, 5. strike and dip of strata, 6. crushed zone, 7. broken zone in cross-section, 8. broken zone in longitudinal section, 9. fissured zone, 10. fissures in inner layers (discontinuities), 11. visible and covered fault plane with strike, 12. thrust line, 13. outer doline rim, 14. bottom of doline and its elongation, 15. lowered parts in broken zone, 16. ground-plan and cross-section of rock shelters, 17. cross-section of sinkhole filled by weathered material in near-fault zone, 18. ground-plan of sinkhole in near-fault zone, 19. direction of cross-section, 20. profile of cave passage, 21. underground water flow and direction of flow.
typical collapse dolines (Michler 1954; Gams 1974; Šušteršič 1973, 1974, 1987). In broken zones the rocks are broken to a degree of blocks of various size, from fine rubble to blocks. Due to mechanical instability of blocks, cave spaces (at least larger ones) cannot exist (Čar 1982).

Depending on the power of water flow and hydrological gradient rinsing and transporting of debris from broken zone can be extremely intensive. Also, due to limestone breaking into rubble and blocks the reaction surface essentially increases and consecutively also corrosion dissolution and transport of weathered particles of rock in the broken zone above the water flow (vadose zone). The lack of material is replaced by simultaneous subsiding of higher-lying rubbles and blocks. Breaking processes advance to the surface where so-called broken collapse dolines are formed (Čar 1982).

Due to extreme permeability in broken zones there are no preferential directions for water flow (Čar & Pišlar 1993). Depending on general geomorphological circumstances and regional hydrological conditions the underground water flow can cross broken zone even rectangularly, under various smaller angles or it flows in certain distance through a broken zone. The outer features of doline rims adapt to this fact. Dolines may be either regularly round or very elongated including all the transitional forms. The diameter of broken collapse dolines depends upon the size of broken zones. They reach several tens of meters in width and up to 200 m in length. The slopes of collapse dolines are steep, in any case steeper than slopes of broken collapse dolines, uniform and morphologically poorly developed. Usually the slopes reach the outer rim, very rarely the uppermost part is steeper. Only in case when the outer rim indents into the less fractured border of a broken zone it may be subvertical. The bottom of active broken collapse dolines (for example Globoščak) is usually thinly covered by weathered material or even without it and funnel shaped. The bottom of older, non-active (for example Jeršanova Dolina) is flat viewed from a wider side, thickly covered by weathered material and often dotted by more or less distinctive dolines.

**EXAMPLES FROM POSTOJNSKA GMAJNA**

For illustration and better understanding of the proposed classification and its use there are in Figure 3 some dolines from the Postojnska gmajna area. I have chosen the examples of dolines bound to fault zones which are in some places difficult to be defined unambiguity.
The first example (Fig. 3a) shows a double doline of EF(B) type. The main fault zone crosses in the middle of fractured zone which looks like long channel and a series of dolines. The crushed zone did not develop. To the left and right of the fault plane there is broken zone with lateral passages into the fissured zone. Less important particularity is lengthening of the northern part of the southern doline in karren field (sign B). The ridge between the two dolines is much lowered regarding the field in a wider vicinity of the series.

The doline shown in Fig. 3b can be marked as EB type. In this case doline is not included in a series but it lies independently. Along weak fault plane only a narrow broken zone developed...
while rock is fissured in a rather wide belt (fissured zone). Doline is distinctly elongated in a
direction of broken zone, the outer rim is irregular. On the border there are karren features in the
fissures.

The doline c in Fig. 3 is a typical example of E type doline. Related to sample example in Fig.
1 (E type) the fault zone is weak with simple structure. Beside single fault plane which does not
dip towards doline only a weak fissured zone is seen.

Also doline d in Fig. 3 makes part of doline series in a morphological channel formed in
unilaterally developed fault zone related to fault plane (doline of E type). Fault plane is accompa-
nied by a broken zone which sideboard passes into the fissured zone. At first sight a
single doline has two less distinctive lowering developed at the passage between broken and
fissured zone. Due to favourable bedding on the eastern, non-fractured side of the main fault
plane smaller rock shelters developed. Such an example is denoted as ED type of doline.

DISCUSSION

First I would like to remind of generally known fact that for the origin of dolines a subvertical
drainage of atmospheric water through the rock is required. This is fulfilled when, in a large
enough area of rocks (rock block) based on appropriate lithological and tectonic-structural cir-
cumstances, is established effective porosity (Čar & Šebela 1998). Such conditions due to struc-
tural and textural particularities of tectonically undamaged rocks and changing permeability in
horizontal and vertical direction inside fractured zones (Čar 1986) exist at certain places only and
by a progress of denudation lowering of the terrain they move over the »spatial structural grid«
. Based on slightly different presumptions similar ideas of »moving« swallow-holes (dolines) in
the space due to lowering of the surface and in connection with previous development of »caverns
and fissures« in the interior were spread by d’Ambrosi (1960) and Bahun (1969).

As a karst surface is a very dynamic system it is logical that the above described and classi-
fied dolines represent only »pure« examples. As already stated we must expect on a karst terrain
different types of dolines and connections among them depending on concrete geological facts
(Fig. 3). Also, it must be considered that single dolines, broken collapse dolines and other super-
ficial karst objects are to be found in different development phases. This one depends on location
in geological »structural grid« and actual erosional situation and also climatic conditions. Some
are thus »completely« developed, others are almost gone and represent just a »remnant« of a
former doline. What we observe today is only the actual state in a continuous process of perma-
nent lowering, shaping and changing of karst surface (Čar 1986).

To understand geological morphological and consecutively genetical properties of single dolines
or series of dolines one must take into account spatial changing of lithological properties of
karstified rocks and eventual alternating of bedding and one must precisely follow the sequence
of changing of fractured zone in the horizontal direction and assume from geological properties
eventual changes in rock fractures in vertical direction (Čar 1986; Čar in preparation).

Dolines cannot be unlimitedly large or deep. According to experience there exist an upper
limit. The largest single dolines are about 60 to 80 m in diameter of the outer rim; rare are 100 or
more; and they are from 20 to 50 m deep. Only some dolines of D and F type may be deeper.
Assuming that direct genetic circumstances were approximately the same then experience shows
that the width of a doline mostly depends on the width of fractured zones and the way how the rock is fractured, while depth is connected with vertical changing of permeability of fractured zones and filling of footwall by weathered materials which may interrupt effective porosity.

According to geology, considering in particular mechanical properties and changing of permeability in fractured zones and also speleological development of an area, there may exist a connection between dolines and cave spaces, filled up shafts, open shafts deeper inside, cave chimneys and corrosionally widened fractures but it is not indispensable. This implies that the doline genesis cannot be simplified into one, generally sound model but all the models are »valid« (corrosion, collapse, climatic) and they combine and interact depending on circumstances. In all models an essential process is corrosion. To similar conclusion came Gams in 1974 already (p. 153).

According to previous experiences and on the basis of quoted geological-morphological properties 70 to 75% of all superficial features on the mapped terrain belong to dolines and broken collapse dolines. If we take from them morphologically undisputed collapse dolines and some other karst depressions (Habič 1985) that represent spatial connections of already described features and structural phenomena (Čar 1986) other, morphologically less clear and distinctive superficial features can be attributed to corrosionally reduced dolines or series of dolines, broken collapse dolines and collapse dolines (Šebela & Čar 2000) or to different roofless speleological objects (shafts and caves) (Mihevc 1998, 2001; Šušteršič 1987, 1994) which are formed as a consequence of gradual corrosion lowering of terrain.

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STRUKTURNE OSNOVE OBLIKOVANJA VRTAČ

Povzetek

Uvod in problematika


Zbiranje terenskih podatkov

Da bi lahko razporedili vrtače sogласno s predlagano klasiﬁkacijo, moramo za vsako vrtačo določiti sledeče geološke in morfološke podatke:
Geološki podatki:
Plastnatost - slemenitev in upad plasti ter debelino plasti.
Tektonske deformacije - tip pretre cone (zdrobljene, purušene in razpoklinske cone), vpad in slemenitev tektonskih ploskev, stopnja pretrosti v coni (vrsta kataklastičnih prelomnih kamnin, bloki, gostota razpok, itd), širina pretre cone ter prostorska povezava različnih prettih con.

Morfološki podatki:
Tloris dna vrtče, oblika pobočij ali sten, oblika zgornjega oboda vrtče ter globina, širina in dolžina vrtče

Ostalo:
Prostorska povezava s sosednjimi vrtčami in oblike prehoda med njimi, izris tlorisa za vsako vrtčo (ali niz vrtč) posebej in izdelava najmanj dveh karakterističnih profilov čez vrtčo (ali niz vrtč).

Zbiranje vseh podatkov, ki jih vsebuje zgornji seznam, je dostikrat tudi onemogočeno zaradi pokritosti terena. V takem primeru je potrebno pri vrtči, kjer se “nič ne vidi”, to zabeležiti in podrobno pregledati sosednje vrtče in vmesni teren. Izkušnje kažejo, da se v sklopu največ treh do štirih vrtč še pokažejo vsaj nekateri osnovni elementi strukturne in litološke zgradbe terena.

**Osnovni tipi vrtč**

Soglasno z dosedanjimi izkušnjami pri kartiranju krasa na apnencih in preverjanju na drugih zakraselih kamninah pri nas, lahko vse vrtče glede na njihovo odvisnost od geološke strukture razdelimo na šest osnovnih, ki smo jih označili z velikimi žrkami od A do F, dve posebni vrsti z oznakami G in H (sl. 1) ter eno prehodno vrsto - porušne udornice (sl. 2).

A - *Stratifikacijske vrtče* (vrtče v tanko plastnatih, blago nagnjenih ali sinklinalno upognjenih plastnatih kamninah), (sl. 1A),
B - *Razpoklinske vrtče* (vrtče v razpoklinskih conah), (sl. 1B),
C - *Plastno-razpockinske vrtče* (vrtče oblikovane po plastnotosti in rozpoklinskih conah), (sl. 1C)
D - *Porušne vrtče* (vrtče v porušenih conah), (sl. 1D),
E - *Obprelomne vrtče* (vrtče ob prelomni coni), (sl. 1E),
F - *Prelomne vrtče* (vrtče v prelomnih cona), (sl. 1F),
G - *Kontaktna vrtače* (stišne vrtče; vrtče na geoloških stikih), (sl. 1G),
H - *Reproducirane vrtče* (ponovljene vrtče; iz podlage ponovljene vrtče), (sl. 1H).

V naravi najdemo le redko vrtče “čistega tipa”, torej take, ki se povsem skladajo z zgornjimi opisi. Problem rešimo tako, da zapišemo ugotovljeno kombinacijo. Naprav kombinacijo zapisa EB pomeni, da je osrednji del vrtče nastal ob prelomni coni (obprelomna vrtča), obrobni deli pa so značilno oblikovani in podaljšani po razpoklinskih conah (razpoklinska vrtča). Manj izražene tipičnosti zapišemo v oklepaju npr. EF(B), (sl. 2a). Če leži vrtča v celoti na apnencu tega ne poudarjamo posebej; če pa leži naprimer na dolomitu ali konglomeratu, pa podatek zapišemo na desnem strani in sicer EF, D. V prvem primeru pomeni torej vrtča tipa EF na dolomitu, v drugem pa porušno vrtčo na konglomeratu.
Na sliki 2 smo izrisali nekaj konkretnih vrtač iz območja Postojanske gmajne. Prvi primer a) predstavlja vrtačo EF(B). Objekt pod oznako b) je značilna vrtača tipa EB, medtem ko predstavlja c) in d) vrtači tipa E.

Porušne udornice


 Diskusija

Znano je, da je za nastanek vrtač potrebno subvertikalno pretakanje atmosferske vode skozi kamnino. To je izpolnjeno takrat, ko se v nekem dovolj velikem območju kamnin (bloku kamnin), na podlagi primernih litoloških in tektonsko-strukturnih razmer, vzpostavi prejemajoča efektivna poroznost (Čar & Šebela 1998). Taki pogoji so, zaradi strukturnih in teksturnih posebnosti tektonsko nepoškodovanih kamnin ter spreminjanje se prepustnosti v horizontalni in vertikalni smeri znotraj pretrehtih con (Čar 1986), dani le na določenih mestih in se z napredujočim erozijskim zniževanjem terena selijo po “geološki prostorski strukturi rešetki” (Čar, v pripravi).


Soglasno z geološkimi danostmi, predvsem upoštevanjem mehanskih lastnosti in spreminjanja prepustnosti pretrehtih con ter speleološkim razvojem terena, lahko obstaja povezava med vrtačami in jamskimi prostori, zasutimi brezni, odprtimi brezni globlje v notranjosti, jamskimi kamniki ali korozioni razširjenimi razpokami, ni pa nujna. Iz tega izhaja, da genezo vrtač nikakor ne moremo poenostaviti na en enostavno veljaven model pač pa “veljajo” vsi modeli (korozinski, udorni, klimatski), ki se med seboj tudi kombinirajo in prepletajo v odvisnosti od okoliščin. Pri vseh pa je bistven proces korozija. Podoben zaključek je zapisal že Gams leta 1974 (str. 153).