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BASIC MORPHOGENETIC CHARACTERISTICS OF CAVES IN THE GRABOVAC VALLEY (SLUNJ, CROATIA)

NEVEN BOČIĆ
Faculty of Science - Zagreb, Dept. of Geography
Speleological Society Karlovac
PMF Zagreb, Geografski odsjek
Speleološko društvo Karlovac

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The explored area is about 4 km east of Slunj town at the region known as Kordun Karst. This location stipulated the specific condition for the formation of the speleological objects in the south area of Grabovac Valley. The Grabovac Stream flows from the north to the south through the Grabovac Valley connected to the canyon of the river Korana. Partially the Grabovac Stream flows underground. In this area in the period of years 2000 and 2001 a member of Speleological society Karlovac (Karlovac, Croatia) explored three caves. The biggest is Ponor pod Kremenom Cave with total length of the channels of 1019 m. The underground part of the Grabovac Stream flows through its channels. In the south of the dry part of the valley there are two caves: Gornja Barićeva (260 m long) and Donja Barićeva (26 m long). Morphological characteristics indicate the dynamics of the formation of the cave system under the influence of the allogenic water. They are the result of the corrosion and erosion caused by the water of the underground part of Grabovac Stream during several phases. These tree caves are parts of one system in sense of speleogenesis. Six basic phases of the formation of the speleological objects can be established. The aim of this paper is to give the basic theses about the morphogenesis of these caves, particularly in relation to their geomorphological position.

Key words: speleology, geomorphology, morphogenesis, caves, contact karst, allogenic water, Slunj karst plateau, Croatia

Istraživano područje nalazi se oko 4 km istočno od grada Slunja, u okviru tzv. kordunskog krša. Potok Grabovac teče od sjevera k jugu dolinom koja se spaja na kanjon rijeke Korane. Potok Grabovac je ponornica, tj. djelomično teče podzemno. Ovdje su u razdoblju od 2000. do 2001. članovi Speleološkog društva Karlovac istražili tri špilje. Najveća je Ponor pod Kremenom, dužine 1019 m. Kroz nju prolazi podzemni dio potoka Grabovac. Na jugu suhog dijela doline su još dvije špilje: Gornja Barićeva (dužine 260 m) i Donja Barićeva (dužine 26 m). Morfološke karakteristike ovih špilja upućuju na dinamiku razvoja ovoga špiljskog sustava pod utjecajem alogenoga vodenog toka. Ove tri špilje nastale su kao rezultat korozijskog i erozijskog djelovanja podzemnog dijela potoka Grabovac kroz nekoliko faza. One su dijelovi jedinstvenog sustava u speleogenetskom smislu. Može se razlikovati šest osnovnih faza u nastanku toga špiljskog sustava. Naglasak je ovog rada na morfogenezi ovih špilja, posebno u odnosu na njihov geomorfološki položaj.

Ključne riječi: speleologija, geomorfologija, morfogeneza, špilje, kontaktni krš, alogeni tok, Slunjska zaravan, Hrvatska

Introduction

The explored area is about 4 km east of Slunj at the region known as Kordun Karst (Fig. 1). This is part of inner Dinaric karst belt (HERAK ET AL, 1969), mostly shallow karst with karstic and fluviokarstic characteristics (ROGLIĆ, 1978). Northeast of Slunj is the zone (approximately SE-NW) representing the transition between Dinaric Karst (S-W) and Peripanonian non-karst region (N-E). It is the meeting belt of two megageomorphological regions (Dinaric and Panonian regions in Croatia) or more precisely the subgeomorphological regions of Slunj plateau with the dominating characteristic of the karst relief and Cetingrad hills with fluvioerosional relief characteristics (BOGNAR, 2001). Grabovac Valley stretches about 6 km from the North to the South near the above mentioned transition zone.

This location stipulated the specific condition for the formation of the speleological objects in the south area of Grabovac Valley. In this area in the period of years 2000. and 2001. the members of Speleological Society Karlovac (Karlovac, Croatia) explored three caves: a smaller one, one medium size and one big cave (BAĆURIN ET AL, 2001).

The aim of this study is to give the basic theses about the morphogenesis of these caves, particularly in relation to their geomorphological position.

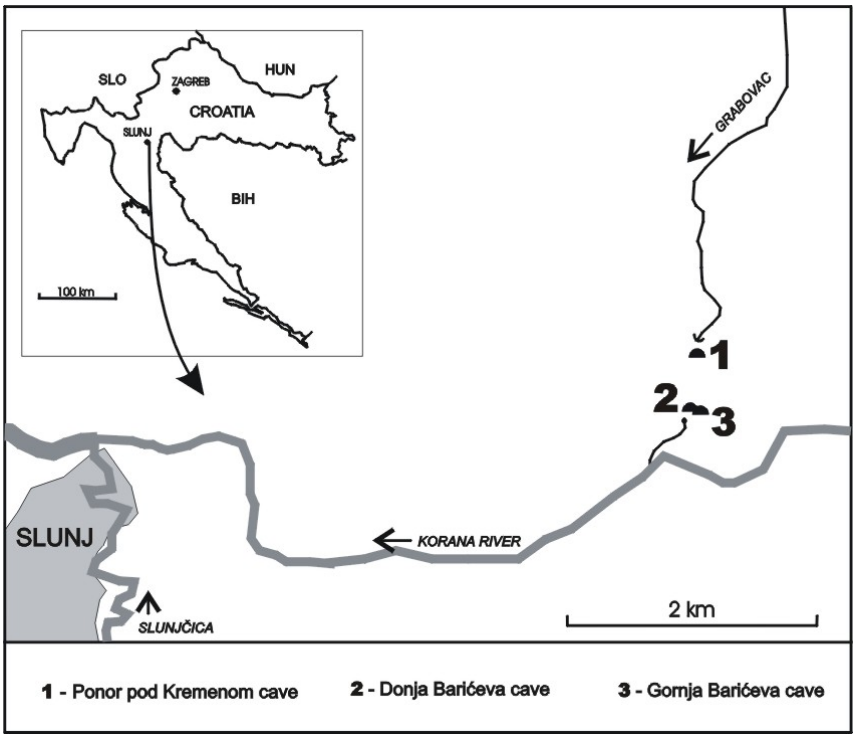

Fig. 1 Position of the explored area.
Sl. 1. Lokacija istraživanog područja.

Geological settings

According to Korolija et al. (1979, 1981) the present geological characteristics are the result of the complex evolution of the area through geological past. Especially important were the intensive processes of thrust from the north east in the Eocene period. The tectonic structure feels the consequences of the influence of the nappe of Petrova Gora in the north east. This nappe is built mainly of Permian and lower Triassic clastic sediments which are napped on the sediments of Mesozoic carbonate platform. At the same time it is a tectonic border of the structural complexes Dinaric and Supradinaric (HERAK, 1986). The Grabovac Valley area is built of following lithostratigraphical units (KOROLIJA ET AL., 1979, 1981): J_2 – Middle Jurassic dolostone with limestone lens; $J_3^{2,3}$ – Upper Jurassic limestone and dolostone; K_1^{3-5} – Lower Cretaceous limestone with dolostone lenses; K,Pc – Cretaceous and Palaeocene flysch: sandstone, marls and limestone; M_2 - Miocene marls, clay and sandstone (Fig. 2).

The Mesozoic carbonates are mutually in fault contact. Flysch sediments lie on carbonates in transgress contact. Miocene clastic sediments lie over the older sediments in transgressive contact. On the explored field they lie over carbonate and flysch in the form of the erosion remains (Fig. 2). During the field observation the youngest alluvial sediments were noticed in the Grabovac Valley and the neighbouring valley in the south-east.

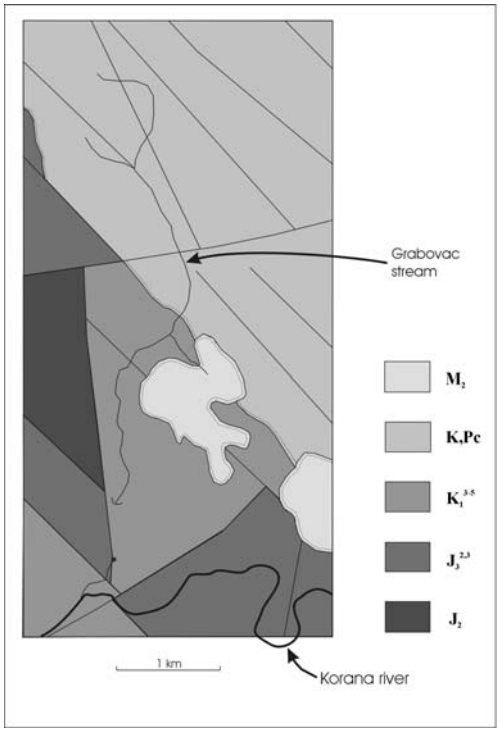

Fig. 2 Geological settings of the explored area (after KOROLIJA ET AL., 1979, 1981).
Legend:
J_2 – Middle Jurassic dolostone with limestone lens; $J_3^{2,3}$ - Upper Jurassic limestone and dolostone; K_1^{3-5} – Lower Cretaceous limestone with dolostone lens; K,Pc – Cretaceous and Palaeocene flysch: sandstone, marls and limestone; M_2 - Miocene marls, clay and sandstone.

Sl. 2. Geološki okvir istraživanog područja (prema KOROLIJA ET AL, 1979, 1981).
Legenda:
J_2 – (doger) dolomiti s lećama vapnenca jure; $J_3^{2,3}$ – (malm) vapnenci i dolomiti; K_1^{3-5}- (donja kreda) vapnenci s lećama dolomita; K,Pc – (kreda i paleocen) fliš: pješčenjaci, lapori i vapnenci; M_2 – (miocen) lapori, gline i pješčenjaci.

Field situation

Field situation is shown on Fig 3. The Grabovac Stream flows from the north to the south through the valley which is deeper ca. 50 m in relation to the surrounding area. The whole valley winds in the form of the letter "Z". Finally, Grabovac Valley is connected to the canyon of the river Korana. The level of the river Korana at 225 m makes the local erosion basis. Partially the Grabovac Stream flows underground. It sinks about 1000 m before it flows into the Korana and later springs again about 325 m in the south. This part of the valley is dry with the higher and rough floor. The catchment area of the ponor of the Grabovac Stream is about 5.3 km^2.

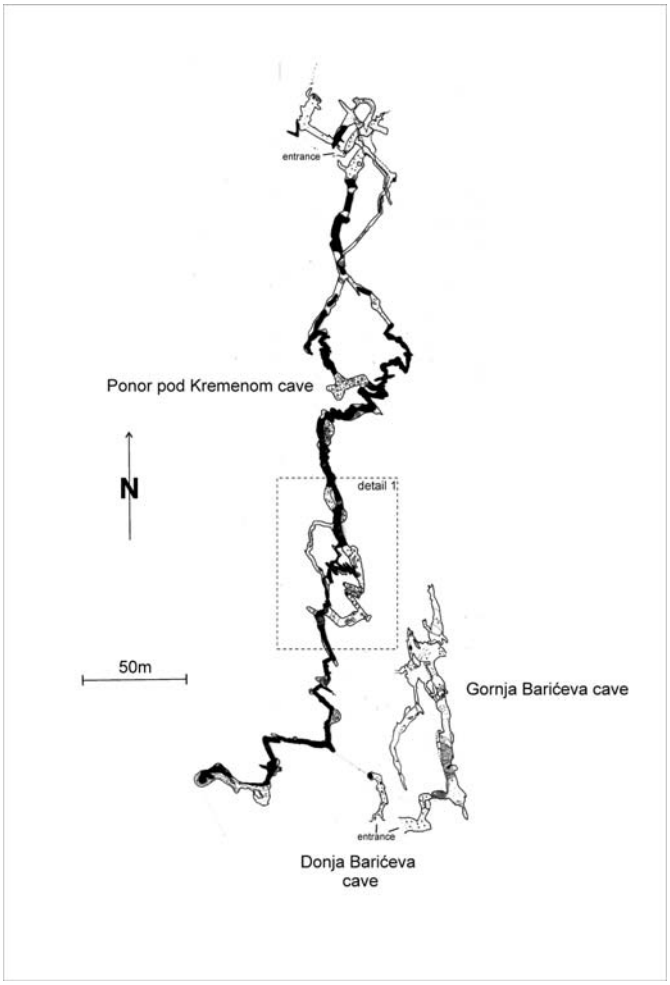

Fig. 3 Map of explored caves (cave survey BAĆURIN ET AL., 2001).
Sl. 3. Karta istraženih špilja (nacrti BAĆURIN ET AL., 2001).

The difference in altitude between the highest point in the catchment area and the point of ponor is 121 m. The last 250 m before the Stream sinks, it flows on its alluvium and the sinking zone is relatively long. At least three sinking points were found. The sinking holes cannot be speleologically explored because of the alluvium and accumulated wood branches. Only 25 m to the south of the last sinking hole (at the beginning of the dry part of the valley) there is the entrance to the biggest explored cave in Grabovac Valley (Fig. 3). The total length of the channels in Ponor pod Kremenom Cave is 1019 m and it extends towards the south under the dry part of the valley. The underground part of the Grabovac Stream flows through its channels. There are two caves in the south of the dry part of the valley: Gornja Barićeva (260 m long) and Donja Barićeva (126 m long) whose channels generally spread towards the north (Fig. 3). All three caves were explored by the members of Speleological Society Karlovac (BAĆURIN ET AL, 2001). They were shown the entrances by Mr. Pero Barić from Slunj. About 65 m to the south there is a permanent (collapsed) spring through which most probably the water of Grabovac Stream flows out the surface.

Basic morphological data about the speleological objects

Ponor pod Kremenom (Fig. 4)

It is the biggest cave in the explored area. The entrance is 263 m above sea-level and its dimensions are 3 x 2.5 m. The entrance channel joins the main channel after 15 m. One of the channels which is 40 m long, 0.5-1.5 m wide and high separates from the entrance channel. This channel belongs to the upper level of the cave. In the northern part the main channel is well-indented and often turns at right or acute angles. The main channel generally extends from the north to the south but it forks at several points and then connects again. It represents a typical anastomotic morphology (FORD, WILLIAMS, 1994; PALMER, 2001; BOČIĆ, 2003). The main channel forks at three major zones points. At the north point the (right) west channel is permanent active, in the middle both channels are active and at the south point two out of four (in the middle) are active. The width of the main channel is rarely over 5 m, the high is from 0.7 to 5 m. About 270 m in line distance from the entrance the channel suddenly turns towards the west. At this point there is a siphon which supposedly connects it with Donja Barićeva Cave. The main channel ends 90 m from there with the siphon which leads into the main underground stream. It is supposed that the water from this siphon springs about 90 m in the south-east.

Gornja Barićeva Cave (Fig. 4)

The entrance of the cave (dimensions 6 x 2 m) is at 252 m above the sea level. From the entrance the channel meanders in the shape of the letter S for above 25 m. There is the narrowing which was completely blocked by speleothems and the speleologists had to carve the way through in very difficult conditions. Water constantly gathers in the narrowing and has to be thrown out while passing through. The main channel is 90 m long and spreads towards the north. The average width of the channel is about 5 m, and its height varies from 1 m to 10 m (in so called Final chamber - Završna dvorana). From Završna dvorana the channel extends about 30 m towards the north at the level about 3 m higher than the main channel. Another channel extends for about 70 m to the south from Završna dvorana parallel to the main channel but 2.5-3 m higher. It is the Return channel

(Povratni kanal) where the bones of the extinct species of *Ursus spelaeus* were found (PAUNOVIĆ, 2002. – personal communication). As the entrance is not wide enough and the bones are at the place hard to reach it is not only the question of palaeontology but geomorphology as well and indicates the great dynamics in the evolution of the cave. The total length of the cave is 260 m.

Donja Barićeva Cave (Fig. 4)

Donja Barićeva is a simple object 26 m long. Its entrance is at 248 m above sea level. The dimensions of the entrance are 5 x 2 m, and the channel extends from the entrance towards the north and inclined about 10º. The average width of the channel is about 3 m while the high varies from 1,5 to 4 m. At the end of the channel there is a siphonal lake of unknown depth which is supposed to be connected with the main channel in Ponor pod Kremenom. The cave periodically functions as a spring.

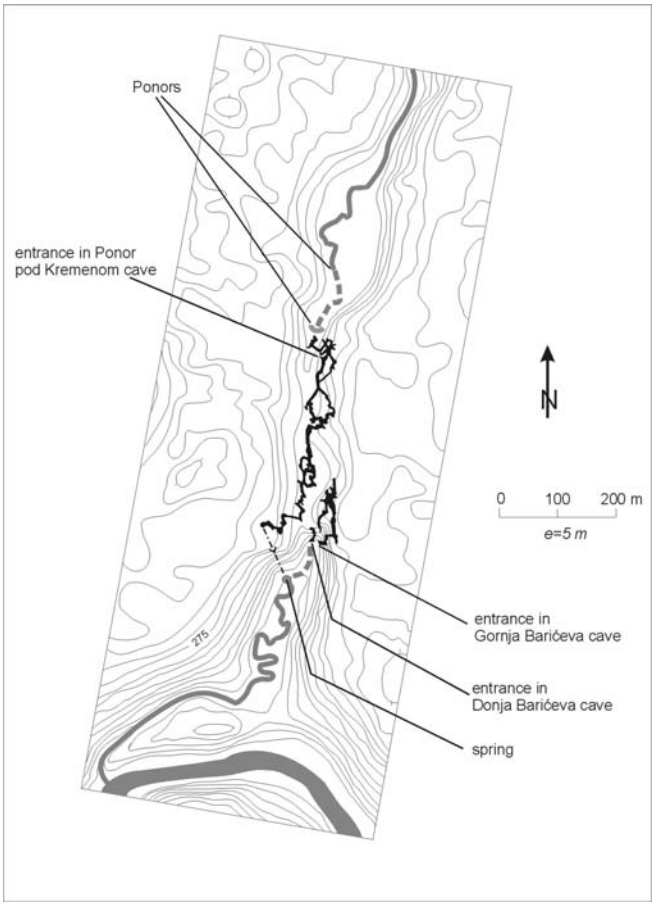

Fig. 4 Relation between caves and surface relief.
Sl. 4. Odnos špiljskih kanala i površinskog reljefa.

Morphogenesis of the speleological objects

These three caves (Figs. 3 and 4) are not parts of the unique system in the speleomorphological (GARAŠIĆ, 1991) sense as it would mean their physical connection which hasn't been done yet. There is a great possibility of finding connection between Ponor pod Kremenom with Donja Barićeva Cave by diving ,as well as the connection Ponor pod Kremenom and Gornja Barićeva Cave by breaking rocks. However the tree caves are parts of one system in sense of speleogenesis (BOČIĆ, 2001). They are the result of the corrosion and erosion (FORD, WILLIAMS, 1992; GARAŠIĆ, 1995) caused by the water of the Grabovac Stream during several phases. The Ponor pod Kremenom is a percolating, recently active speleological object through which the underground stream of Grabovac flows. The entrance to Ponor pod Kremenom is probably an old sinkhole or is caused and formed by denudation of the cave channel of the older generation. Donja Barićeva Cave is a part of branch of Ponor pod Kremenom, and at present periodically functions as a spring. The spring in Donja Barićeva Cave activates at high waters when the unexplored part of the channel in Ponor pod Kremenom from the final siphon to the spring cannot let the increased amount of water. The water level rises and flows through Donja Barićeva Cave. Gornja Barićeva Cave is probably the oldest part of this system, without any function today, but in the past it was a spring. Two levels can be seen in it – older and younger. When the younger level was formed the collapsing caused the formation of the final chamber (Fig. 5). Nowadays Gornja Barićeva Cave, in distinction from the other two is intensely covered and filled with speleothems on the walls and the floor of the channel which indicates a longer period without any active hidrogeological function.

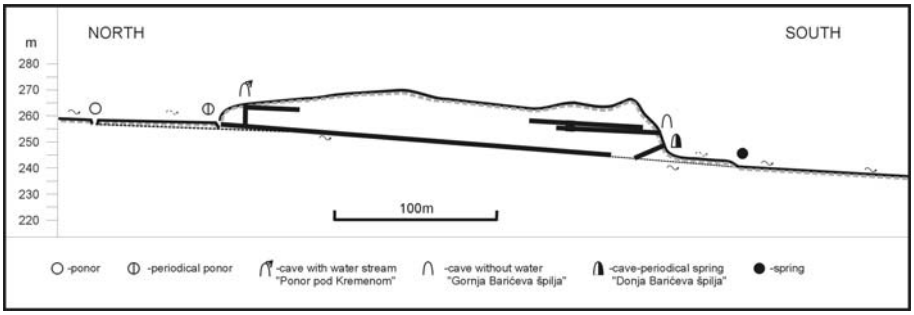

Fig. 5 Generalized longitudinal morpho-hidrographic profile of the dry part of Grabovac Valley with position of hidrogeological objects and cave channels.
Sl. 5. Generalizirani uzdužni morfo-hidrografski profil "suhog" dijela doline potoka Grabovac s pozicijama hidrogeoloških objekata i špiljskih kanala.

The Grabovac Stream flows mainly through the area made of impermeable and slightly permeable rocks. The lower part of the stream flows over permeable rocks (about 2 km before the sinkholes). It is an allogenic water flow in the condition of contact karst (GAMS, 1986.). We can wonder why the Grabovac Stream flew on the surface and formed the valley at the beginning and why today it doesn't sink before but only after more than two kilometres of flowing on the carbonate (limestone with dolostone lenses; KOROLIJA

ET AL, 1979, 1981). It is due to several factors but to determine which of them is more dominating is not the subject of this paper. It should be taken into consideration that at the time of the formation of Grabovac Valley the extension of flysch and Miocen clastic sediment was much bigger than nowadays. As there sediments are mainly impermeable the water couldn't sink underground. Uncovering of the carbonates in the area of Grabovac Valley was probably increased by erosional retreatment of impermeable sediments. The current extension of M_2 sediment is characterized as the erosion remnants. The second reason is relatively big amount of alluvium in the valley (whose original material is in erodated clastites), and its thickness is estimated at more than 3 m in the sinking zone. The third reason is a relatively high level of a local erosion basis (the Korana River) which in that case was not much lower than the floor of Grabovac Valley. The condition for the sinking of the stream could be created by lowering of the local erosion basis (by increasing erosion power of the river Korana) and uplifting of the block which is the current dry part of the valley. It is not known which of the processes were more intensive. Due to these facts the following basic phases of the formation of the speleological objects can be established:

1. formation of the Grabovac Stream valley; erosion of clastic sediments in the background area.
2. lowering of the erosion basis, uplifting of the block – the current dry part of the valley, sinking of the stream
3. formation of the higher, now eroded cave channels (?)
4. the development of the system consisting of the parts of the upper level channel in Ponor pod Kremenom and Gornja Barićeva Cave (formation in several subphases), Gornja Barićeva Cave as a spring
5. further lowering of the erosion basis and/or uplifting of the block between the sinkhole and the spring, formation of the parts of Ponor pod Kremenom and Donja Barićeva Cave which functions as a spring, formations of speleothems in Gornja Barićeva Cave, the backward change of sinkhole's position
6. formation of the new channels in Ponor pod Kremenom (the final 100 m and unexplored part behind the siphon), formation of the current spring, Donja Barićeva Cave loses the function of a permanent spring and becomes a periodical one

Extreme dynamics in the formation of these caves can be seen from a few facts. More levels of the cave channels have been noticed near the spring than in the north closer to the sinkholes (Fig. 5). It can suggest that the uplifting of the current dry part of the valley was more intensive in the south, or that the older cave channels in the north had already been destroyed by erosional lowering of surface relief.

In Ponor pod Kremenom stalactites and flowstones dipped into water (during the whole year) can be found as well as corroded stalactites which are not dipped into water. The former indicate once lower water level than today while the latter indicates the higher water level. Underground karrens, which are the positive signs of vadoze conditions, have smooth lower parts caused by corrosion which means that they were subsequently flooded. This proves frequent changes of water level in the cave channels. It means that the process of speleogenesis went through the above mentioned phases with the constant tendency of lowering the underground water level. It wasn't constant but it varied i.e. shorter periods' processes of the opposite signs took place. The causes can be various: from changes of the climate to changes in the intensity and signs of tectonic movements. Probably at least a part of positive changes of the underground water level was caused by

changing conditions inside the caves i.e. inside the drainage system. Morphological characteristics indicate the dynamics of the formation of the cave system under the influence of the allogenic flow (PALMER, 2001). The diminished flow rate of a certain part of the channel results in flooding the upstream part of the channel. So the effects of corrosion are increased. Due to higher hydrostatic pressure water frees to find new possible ways to flow through underground. The separate detail (Fig. 3, detail 1) shows how water made a new route of flow (most probably because of collapsing of blocks in the eastern channel). The important role in this process had the fracture system with the extension of about 320º-140º which helped the water to find the new way. It is visible that water often changed its route in this part, and even today it flows through two channels.

Along the channel in Ponor pod Kremenom Cave there are frequent scallops and ceiling pockets (SLABE, 1995.), the shapes which are formed in epiphreatic conditions i.e. under the influence of allogenic flow.

Along the Ponor pod Kremenom Cave there are sediments consisting of particles of different size, from mud to stone blocks. Along the permanent stream, sediments partly consist of send particles. In blind branches and channels which are flooded periodically thicker layers of mud appear. Rocks dominate in extremely fractured zones inside the objects as well as in the areas near the entrance which are more influenced by the outside weather conditions.

Conclusion

Three caves were explored in Grabovac Valley. They are Ponor pod Kremenom 1019 m long, Donja Barićeva Cave 26 m long, and Gornja Barićeva Cave 260 m long. The formation of these caves is connected to the underground flow of the Grabovac Stream (Figs. 3 and 5) where the two caves have hydrogeological function while the remaining one lost its function. The underground flow of the Grabovac Stream goes mostly through Ponor pod Kremenom and with its smaller part (before the spring) through at present unknown underground area. In seasons with more water (spring and autumn) a part of water spring through Donja Barićeva Cave. Gornja Barićeva Cave used to function as a paleospring. Morphological characteristics of these caves are the result of the influence of allogenic water flow (the Grabovac Stream) where the cave channels conduct water which sinks at the end of the active part of the valley. Morphological characteristics of outside relief indicate that the Grabovac Stream flew on the surface to the stream mouth into the Korana River (Fig. 3). Subsequently due to combined influences of the lowering of the erosion basis and uplifting of the part of Grabovac Valley the stream started to sink and a part of the valley became dry. By further development of these processes several cave channel levels were formed (Fig. 5). Six basic phases of the function of the speleological objects and the surrounding area were established. For further exploration of speleogenesis of these objects we should investigate the influence of structural elements and differences in lithological composition on the development of the cave channels. The age of the speleothems at particular places should be determined so that the processes and phases of development could be more precisely placed on the time scale.

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SAŽETAK

Neven Bočić: Temeljna morfogenetska obilježja špilja u dolini Grabovac (Slunj, Hrvatska)

Istraživani teren nalazi se oko 4 km istočno od grada Slunja na području poznatom kao kordunski krš. Tu je dodir dviju megageomorfoloških regija (dinarskog i panonskog prostora Hrvatske) ili točnije subgeomorfoloških regija Slunjske zaravni s pretežitim obilježjima krškog reljefa i Cetingradskog pobrđa s pretežitim fluviodenudacijskim reljefnim obilježjima. Upravo takav položaj uvjetovao je specifične uvjete za nastanak speleoloških objekata. Cilj je ovog rada dati osnovne postavke o morfogenezi špilja u dolini potoka Grabovac, posebno u odnosu na njihov geomorfološki položaj.

Današnje geološke karakteristike ovog terena odraz su kompleksne evolucije terena kroz geološku prošlost. Područje doline Grabovca građeno je od sljedećih litostratigrafskih jedinica mezozojskih vapnenca i dolomita, paleocenskog fliša te klastita miocena. Mezozojski karbonati su međusobno u rasjednom kontaktu. Naslage fliša leže u transgresivnom kontaktu preko karbonata. Klastične naslage miocena leže transgresivno preko starijih naslaga. Na istraživanom dijelu terenu leže preko karbonata i fliša u obliku denudacijskih ostataka. Pri terenskom istraživanju uočene su i najmlađe aluvijalne naslage u dolini potoka Grabovac i susjednoj dolini na jugoistoku.

Potok Grabovac teče od sjevera k jugu dolinom koja je u odnosu na okolni teren usječena oko 50 na svom središnjem dijelu. Konačno, dolina Grabovac spaja se na kanjon rijeke Korane. Razina rijeke Korane na 225 m n.m. čini lokalnu erozijsku bazu. Potok Grabovac djelomično teče podzemno. U tom dijelu dolina je suha, s izdignutim i neravnim dnom. Južnije od ponora (na početku suhog dijela doline) nalazi se ulaz u najveću špilju istraženu u dolini Grabovac. To je špilja Ponor pod Kremenom, koja ima ukupnu dužinu svih kanala 1019 m. Kroz njezine kanale prolazi podzemni dio toka potoka Grabovac. Glavni se kanal pruža generalno u pravcu sjever – jug, ispod suhog dijela doline, ali se na nekoliko mjesta račva i onda ponovno spaja u jedan.

Na južnom (nizvodnom) kraju suhog dijela doline nalaze se dvije špilje: Gornja Barićeva dužine 260 m i Donja Barićeva dužine 26 m, čiji se kanali generalno pružaju prema sjeveru. Oko 65 m južnije nalazi se stalni (neprolazan) izvor kroz koji najvjerojatnije na površinu izlazi voda potoka Grabovac. Donja Barićeva špilja ima funkciju povremenog izvora. Funkcija izvora Donje Barićeve špilje aktivira se u vrijeme visokih voda kada neistraženi dio kanala u Ponoru pod Kremenom od završnog sifona do izvora ne može propustiti povećanu količinu vode. Razina vode raste i prelijeva se kroz Donju Barićevu špilju. Gornja Barićeva špilja vjerojatno je najstariji dio tog sustava, danas bez funkcije, a u prošlosti u funkciji izvora. Danas je Gornja Barićeva špilja, za razliku od ostale dvije, intenzivno zasigana, što upućuje na duže razdoblje bez aktivne hidrogeološke funkcije. Sve tri špilje istražili su članovi Speleološkog društva Karlovac, a ulaze im je pokazao gosp. Pero Barić iz Slunja.

Ove tri špilje nisu dio jedinstvenog sustava u speleološkom smislu jer bi to podrazumijevalo njihovo fizičko spajanje, što zasad nije učinjeno. Međutim, sve su tri špilje dijelovi jednog sustava u smislu speleogeneze. Nastale su radom (korozijom i erozijom) vode potoka Grabovac.

Potok Grabovac ima veći dio slijevnog područja na terenu izgrađenom od nepropusnih i slabo propusnih stijena. To je alogeni vodeni tok u uvjetima kontaktnog krša. Treba uzeti u obzir da je u vrijeme usijecanja doline Grabovca rasprostiranje naslaga fliša i miocenskih klastičnih naslaga bilo veće od današnjeg. S obzirom na to da su te naslage uglavnom nepropusne, nije moglo doći do poniranja. Ekshumacija karbonatnih naslaga u području doline Grabovac vjerojatno se povećavala s denudacijskim povlačenjem nepropusnih naslaga. Današnje rasprostiranje klastičnih naslaga miocena karakterizira se kao "denudacijski ostatak". Uvjeti za poniranje potoka Grabovca mogli su se stvoriti zbog snižavanja lokalne erozijske baze (pojačanog usijecanja rijeke Korane?) te izdizanja bloka koji danas predstavlja suhi dio doline. Iz navedenog možemo izdvojiti osnovne faze razvoja speleoloških objekata:

1. usijecanje doline potoka Grabovca, denudacija klastičnih naslaga;
2. spuštanje erozijske baze, izdizanje bloka - današnjega suhog dijela doline, poniranje potoka;
3. nastanak viših, sada denudiranih špiljskih kanala (?),
4. razvoj sustava čiji su dijelovi kanal gornje etaže u Ponoru pod Kremenom i današnja Gornja Baićeva špilja, koja je u funkciji izvora;
5. daljnje spuštanje erozijske baze i/ili izdizanje bloka između ponora i izvora , nastanak dijelova Ponora pod Kremenom i Donje Baićeve špilje, koja preuzima ulogu izvora, zasigavanje Gornje Baićeve špilje, unazadno pomicanje ponora;
6. nastanak novih kanala u Ponoru pod Kremenom (zadnjih 100 m i nepoznati dio iza sifona), nastanak današnjeg izvora, Donja Baićeva špilja gubi ulogu stalnog te postaje povremeni izvor.

Potopljene sige u Ponoru pod Kremenom upućuju na nižu razinu vode od sadašnje, dok korodirane nepotopljene sige upućuju na višu razinu vode od sadašnje. Podzemne škrape koje su sigurni pokazatelji vadoznih uvjeta, na više mjesta imaju korozijom zaravnjene donje dijelove, što znači da su naknadno potopljene. Ovo dokazuje česte promjene u razini vode u špiljskim kanalima. To znači da se proces speleogeneze odvijao kroz navedene faze uz stalnu tendenciju snižavanja razine podzemne vode. No ona nije bila konstantna, već je varirala, tj. javljale su se kraće faze kada su se odvijali procesi suprotnog predznaka. Uzroci toga mogu biti mnogobrojni, od klimatskih promjena do promjena u intenzitetu i predznaku tektonskih pokreta. Međutim, vjerojatno je barem dio pozitivnih promjena razine podzemne vode u špiljama uzrokovan promjenom uvjeta unutar samih špilja, tj. unutar sustava odvodnje. Morfološke karakteristike upućuju na dinamiku razvoja špiljskog sustava pod utjecajem alogenog toka. Smanjena protočna moć nekog dijela kanala uzrokuje poplavljivanje uzvodnog dijela kanala. Time se pojačava korozijski rad vode. Zbog povećanoga hidrostatskog tlaka voda traži nove mogućnosti kretanja kroz podzemlje. Pritom je važnu ulogu odigrao pukotinski sustav s pružanjem oko 320°-140° koji je olakšao probijanje novog puta. Za daljnja istraživanja speleogeneze ovih objekata bilo bi potrebno detaljnije ispitati utjecaj strukturnih elemenata i razlika u litološkom sastavu stijena na razvoj špiljskih kanala. Također bi trebalo odrediti starost speleothema na pojedinim odabranim mjestima jer bismo tako navedene procese i faze razvoja mogli točnije smjestiti u vremenu.