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ABOUT THE FORMATION OF LIMESTONE GORGES...

ATTILA HEVESI

Abstract:

The paper describes the formation of limestone gorges and presents the basic types of limestone gorge formation. The significance of cave collapsing in gorges formation is discused.

Key Words:

Limestone gorges (canyons), epigenetic valley, gorges formed by cave collapsing, buried, mixed karst, karst-water level.

O OBLIKOVANJU GUDURA U VAPNENCIMA

Izvadak:

Ovaj rad opisuje oblikovanje gudura u vapnencima i izdvaja osnovne genetske tipove s odabranim primjerima. Razmatra se važnost procesa urušavanja špilja za oblikovanje gudura u vapnencima.

Ključne riječi:

Gudure u vapnencima (kanjoni), epigenetska dolina, gudure oblikovane urušavanjem špilja, pokriveni krš, miješani krš, razina vode u kršu.

It is well known, that the formation of limestone gorges have got two main varieties and so those can be differentiated geomorphologically as epigenetic gorges or the ones formed due to cave collapsing.

There are numerous cases, where the type of gorge formation has not yet been clarified: Hámori-szoros (Hámor-gorge, Bükk-mountains, Hungary), Tordai-hasadék (Cheile Turzii, Gyalui-havasok, Transylvania, Romania), Szádelői-völgy (Zadielska-dolina), Áji-völgy (Hajsky-dolina, Slovakia), gorges of Moravsky-kras (Czech Republic).

The origin of those gorges which still have covered sections or cave-tunnels are not questionable. Some examples of these are the Szamos-bazár, Bazerul Somesului, Galbina-kőköz, Izbucul si Cheile Galbenei, Bihar (Bihorului)-mountains

from Romania, Skocjanske Jame and Rakov Skocjan from Slovenia. These are self-explanatory examples of the cave collapsing type origin of limestone gorge formation. However, the formation of even these well known examples have not yet been proven.

In order to support the idea of cave collapsing origin of these gorges, the environmental conditions of the two for-mation types are described and compared in this paper. Both processes start on buried, mixed-karst. Due to the overall geologic uplifting of the area the surface drainage system starts deepening valleys into the covering strata till reaching the limestone base. From this point the type of the gorge formation is the function of the relative position of the karst-water level and the level of surface drainage water (Fig. 1, Fig. 2).

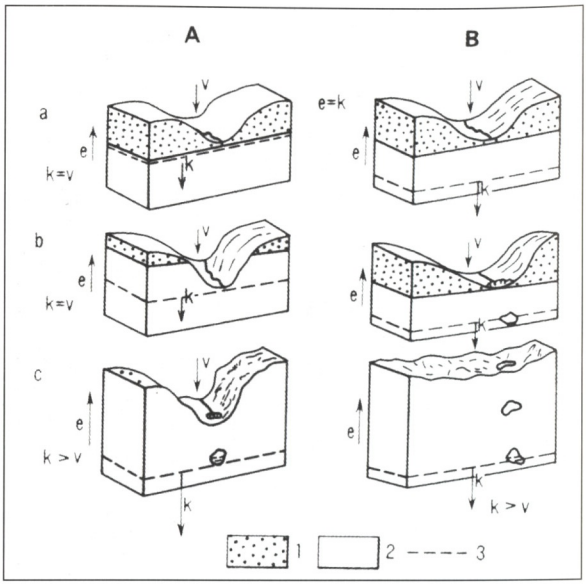

Fig. 1. The ways of inheritance of drainage on non - karstic surface over karstic rock.

1 = non - karstic rock; 2 = limestone; 3 = karst water table; e = uplift; k = sinking karst water table; d = downcutting

Sl. 1. Razvoj otjecanja na klastičnim sedimentima koji prekrivaju karbonatnu osnovu.

1 = klasticni sedimenti; 2 = vapnenac; 3 = nivo podzemne vode u kršu; e = izdizanje; k = poniranje vode u kršu, d = usjecanje

If the karst water level and the level of surface drainage way were the same or close to each other, the surface drainage would continue to deepen the valley (Figure 1.A.a., Hevesi, A. 1978, 1980, 1984, 1986, 1991). In this case the seepage

Legend for pictures 2 and 3

Typical features of an uplifting mixed allogenic karst under humis-semihumid climate of the true moderate belt.
ot = solution doline; oi = solution twin doline; e = level of primary solution; ksz = karst water table; kl = karst water lentil; l = labyrinthine cave at the level of secondary solution; mk = deep karst; kf = karst spring, travertine; nk = non-karstic rock; áv = epigenetic valley; ö = karrenfield; vt = swallow hole; oiv = swallow holes twinned through solution; vb = swallow cave; áb = throuhg cave; kpv = ponor on karst margin; msz = limestone groge; ül = former labyrinthine cave, now empty; t = soil; b = sinking creek

Legenda za slike 2 i 3

Tipični reljef na izdignutom mješanom alogenom kršu u uvjetima humidne - semihumidne klime u okviru umjerenog pojasa.

ot = ponikve; oi = dvojne ponikve; e = razina prvobitnog okršavanja; ksz = razina podzemne krške vode; kl = leće podzemne vode u kršu; l = spiljski labirinti u razini sekundarnog okršavanja; mk = duboki krš; kf = krško vrelo, travertin; nk = nekarbonatna stjena; áv = epigenetska dolina; ö = polje škrapa; vt = aktivni ponor; oiv = srasli kativni ponosi; vb = spilja s vodom tekućicom; áb = manja spilja; kpv = rubni krški ponor; msz = gudura u vapnencima; ül = recentno suhi spiljski labirint; t = tlo; b = ponornica

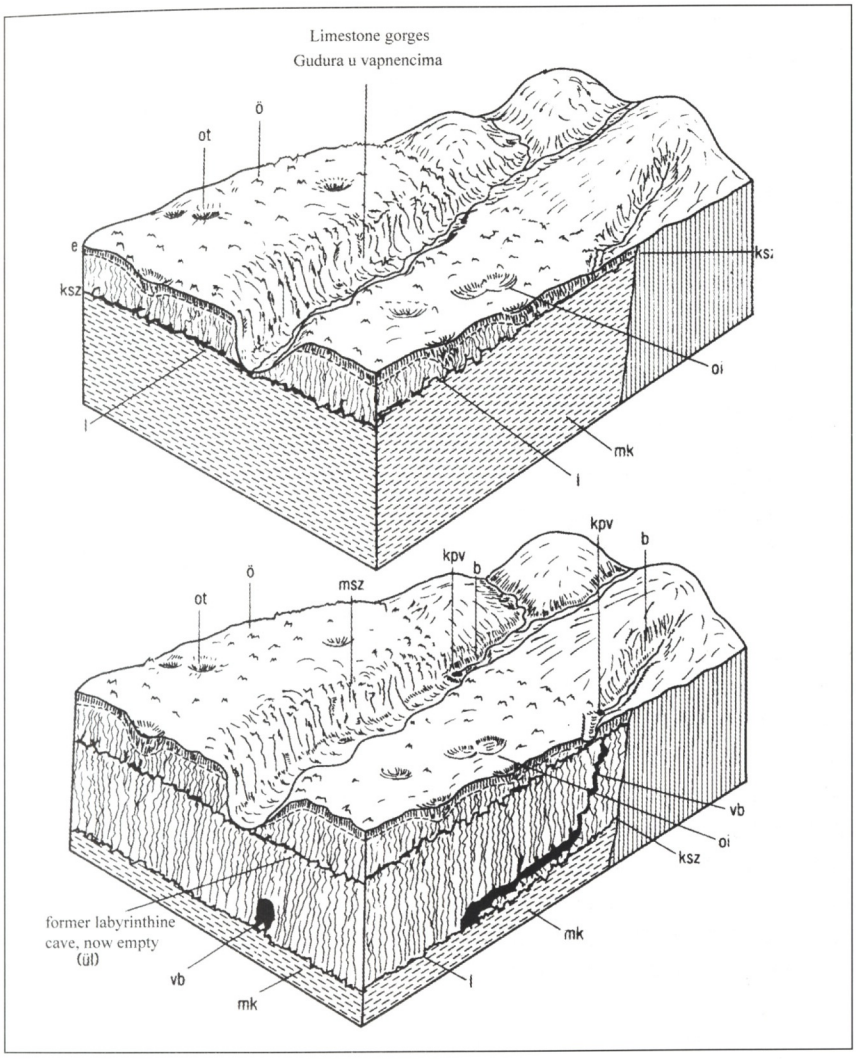

Fig. 2. Typical forms of exhumed, partly paleokarst mixed allogenic karst in the humid - semihumid provinces of the temperate belt, with the karst water table near surface (A) or lying at depth (B).
Sl. 2. Tipični oblici ekshumiuranog, djelomično paleokrša, alogenog krša u humidnim - semihumidnim područjima umjerenog pojasa s pripovršinskom podzemnom vodom (A) ili onom u većoj dubini (B).

of the surface water into the limestone would never occur, even if there is a well developed cave system underneath, because these caves are already filled up with water (Jakucs, L. 1956, 1957, 1968, 1971, 1976). If the speed of the valley deepening into the limestone is equal to the speed of geological uplifting – so that

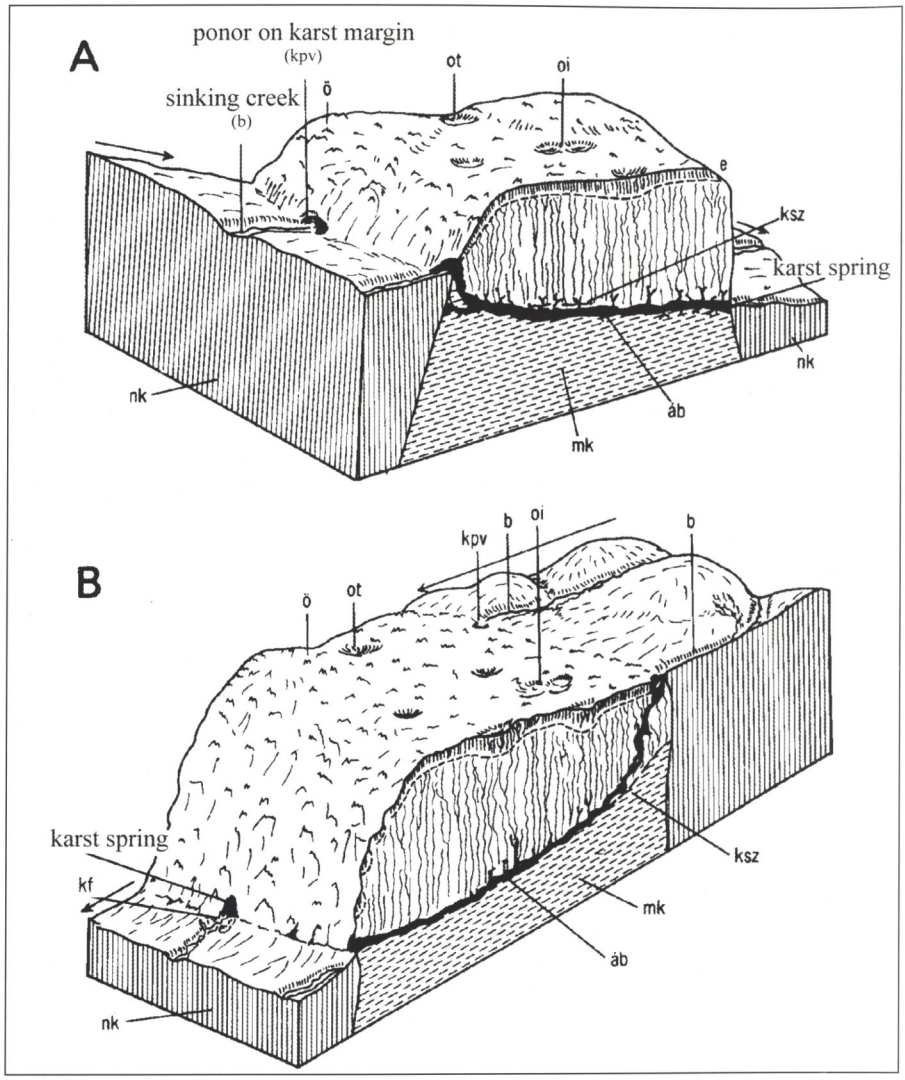

Fig. 3. Typical forms of open mixed allogenic karst in the humid - semihumid provinces of the temperature belt.

Sl. 3. Tipični oblici otvorenog mješovitog alogenog krša u himidnim - semihumidnim područjima umjerenog pojasa.

the uplifting is slow and even – the karst and the surface water stay in the same relative level. That is why surface water seepage into the limestone (batycaptured valley) can never happen in these cases and an epigenetic valley is formed (Figure 1. A.b.). If the environmental conditions stay uniform throughout the gorge

formation, a deep gorge or canyon can develop. If later on the geologic uplifting of the area speeds up, then the deepening of the epigenetic valley would not be able to catch up with the decrease of the karst water level. In this situation, a water-freed layer of the karstic limestone is formed and the water of the surface drainage flow seeps into the cave system (batycapture) (Figure 1. A.c.). The epigenetic valley formation due to surface water impact first becomes temporal and than soon would be eliminated. The batycaptured surface drainage water continues its erosional work under the surface, and instead of carving valley on the surface, it starts creating a cave system. In those cases, when the karst water level is not too deep under the surface, and the region is only slowly and evenly uplifted, the underground water flow deepens the cave bottom in the same rate as the area-uplifting and creates higher and higher cave tunnel. The ceiling of the caves formed this way is relatively close to the surface, and due to the surface erosion, the width of this limestone ceiling is continuously decreasing. If this process goes on for a long enough time, the ceiling of the cave tunnels starts collapsing and the formation of cave-collapsing type gorges begins.

If at the begining of the epigenetic valley formation the distance between the surface water level and the karst water level is higher (there is a wide enough layer of water-freed limestone throughout the years), the surface water way become batycaptured almost "immediately" and starts the cave for-mation. Its surface valley is not inherited into the limestone surface (would not form epigenetic valley) and due to the erosion of the nonkarstic covering strata the valley totally dissappeares (Figure 1. B.). If the given region start emerging slowly and evenly after the batycapture, the vertical extent of the cave becomes higher and so cave-collapsing and gorge formation can occur. However, the gorges formed this way would be clearly cave origined and even the upper sections of its walls have never been part of an epigenetic valley-wall.

Summarising the two main formation types of the gorge formation on limestone overlaid by non-karstic strata, it was concluded, that the two types are not conflicting with each other. The only difference - due to the surface water and karst water level distance – is that the stream deepens its valley on the surface or creates caves under the surface.

Further examining the Center and Southern European limestone gorge examples, it has to be stated that the covered origin of those can be proven for only a few of them (Hámori-szoros, Bükk-mountains, Hungary). The non-karstic cover is possible for many others and some of those were propably never overlaid by non-karstic strata (Moravsky-kras, Czech Republic; Bihar, Bihoroluimountains, Romania). Their common feature is that all of them have streams with high water supply flowing through them and the bottom level of the streams matches with the karst water level. These streams with high water supply refer to

opened, mixed, allogenic karst. Thus, limestone gorges can be formed not only by epigenetic streams, but by streams with relatively big non-karstic catchment area. The gorge formation in this situation has also two main types: surface formation and underground formation. The relative position of the karst water and the surface (stream) water level deteremines whether the surface or the underground process guides the gorge formation (Fig. 1).

Figure 2 shows two gorges of the Moravsky Kras (Suchy žleb and Pusty žleb) while figure 3 shows the canyon of the Izbucul Si Cheile Galbenei (Romania).

When deciding about which of the 4 mentioned ways of gorge formation had happened in a certain case, the existence or absence of caves in the side walls of the canyon or gorge can help. These caves are mainly in the same age as the gorge itself. This means that in the time of the gorge formation, the environmental conditions had to be favourable for cave formation. Thus, these gorges - at least in their lower part – are cave originated. Based on these findings, it is likely that the Tordai-hasadék, Cheile Turzii in Romania has been formed via collapsing caves.

REFERENCES

Cholnoky, J. (1932): A mészkőhegységek földrajzi jellemvonása. – Földgömb.

Cholnoky, J. (1939): A mészkővidék arculata. – Barlangvilág, 3.pp. 41-53.

Hevesi, A. (1978): A Bükk szerkezet- és felszínfejlődésének vázlata. Földrajzi Értesítő XXVII. 2. 169-203.

Hevesi, A. (1980): Adatok a Bükk hegység negyedidőszaki ősföldrajzi képéhez. Földtani Közlöny 110. 540-550.

Hevesi, A. (1984): On the Dating of Karst Formations and their Significance on the Late Tertiary – Pleistocene of Hungarian Limestone Mountains: the Bükk Mountains. Geographical Essays in Hungary 1984. Bp. MTA – FKI 21-35.

Hevesi, A. (1986): Rombarlangok a Bükkben. NME Közleményei, Miskolc, I. Sorozat, Bányászat, 33. (1986) kötet, 1-4. Füzet 167-169.

Hevesi A. (1986): A Déli-Bükk karsztja I-II. Karszt és Barlang, 1986 I.3-14., II. 87-94.

Hevesi, A. (1989): Development and Evolution of Karst Regions in Hungary. Karszt és Barlang, Special Iussue 3-16. Bp.

Hevesi, A. (1989): Die Systematisirung des vom Kaltwasser ausgestaltenen Karstes. Zagreb, Geographical Papers 7. 107-128.

Hevesi, A. (1990): Triedemie krasu studeny'ch vod. Slovensky' Kras VIII. 25-45. Liptovsky Mikulas

Jakucs, L. (1968): Szempontok a karsztos tájak denudációs folyamatainak és morfogenetikájának értékeléséhez. (Contributions to the evaluation of the denudation processes and morphogenetics of karst landscapes.) Földrajzi Értesítő, 17. évf. 1.f.p. 17-46.

Jakucs, L. (1971): A karsztok morfogenetikája. A karsztfejlődés varienciái. Bp. Akadémiai K. 310 p. /Földrajzi Monográfiák. 8./

Jakucs, L. (1977): Morphogenetics of karst regions. (A karsztok morfogenetikája.) Variants of karst evolution. (Transl.: by B. Balkay.) Bp. – Bristol, Akadémiai K. –Hilger. 283 p., ill.

Jakucs, L. (1977): Genetic types of the Hungarian karst.= Karszt és Barlang, Special issue. P. 3-18.

Jakucs, L. (1979): Morfogenez karsztovüh oblasztej. Variantü évoljucii karszta. Perev. Sz anglijszkogo Sz. Sz. Gorcsakovoj. (Bevezető tanulmányát írta: N.A. Gvozdetszkij.) Moszkva Bp. 1979, Progressz – Akadémiai K. 392 p.

Summary
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Two theories have been formulated about the formation of the limestone gorges. According to the first theory, the limestone gorges formation started on buried karst by surface streams with high erosion capability and the valley deepening process later inherited onto the limestone or other karstable strata (epigenetic valleys). The second theory explains their formation by the collapsing of cave-sections. However, these two theories are not exclusives!

Depending on the relative levels of the stream and the karst-water, the surface streams, which reach the limestone from the covering strata of the buried karst can create either gorges or caves. The rapid increase in the distance between the stream and the karst-water level results in the disappearance of surface water and the beginning of cave formation underneath. In case of an oncoming rapid uplifting, the cave stream can be batycaptured, which can be followed by the formation of gorges via cave collapsing. On mixed-karst, the streams arriving from the non-karstic surface often go underground through the karst-edge sinkholes and continue their way underground till reaching the next non-karstic strata. If the region is only slowly uplifted for a relatively long time, than the distance between the bottom and ceiling of the cave also increase. If the cave-ceiling is close to the surface and thus relatively thin, the cave can collapse due to the physical and/or chemical weathering, even if there is still a stream at the bottom of the cave channel.

Sažetak

O OBLIKOVANJU GUDURA U VAPNENCIMA

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Dobro je poznato da postoje dvije glavne vrste oblikovanja gudura u vapnencima, pa geomorfološki možemo razlikovati epigenetske gudure i one oblikovane urušavanjem špilja.

Postoje brojni slučajevi gdje tip oblikovanja gudura još nije pojašnjen: Hámori-sutjeska (Bükk-gorje, Mađarska), Tordai-hasadék (Cheile Turzii, Gyalui-havasok, Transylvania, Rumunjska), Szádelöi-völgy (Zadielska-dolina), dolini Áji (Hajsky-dolina, Slovačka), gudure Moravskog krša (Češka Republika).

Nije upitno porijeklo onih gudura kod kojih još uvijek postoje ostaci svodova (prerast) špilja. Neki primjeri su Szamos-bazar, Bazerul Somesului, Galbina-köhöz, Izbucul si Cheile Galbenei, Bihar (Bihorului) gorje u Rumunjskoj, Skocjanske Jame i Rakov Skocjan u Sloveniji. Ovo su sami po sebi jasni primjeri oblikovanja gudura u vapnencima urušavanjem svodova špilja. Međutim, čak niti oblikovanje ovih dobro poznatih primjera još nije dokazano.

Da bismo podržali ideju o postanku ovih gudura urušavanjem špilja, u ovom radu će se opisati i usporediti uvjeti u okolišu kod dva tipa oblikovanja gudura u vapnencima. Oba procesa počinju na pokrivenom, miješanom kršu. Uslijed općeg tektonskog izdizanja površinski sustav otjecanja počinje produbljavati doline u pokrovnim slojevima dok ne dođu do vapnenačke osnove. Od te točke tip oblikovanja gudure je u funkciji relativnog položaja razine vode u kršu i razine površinske vode koja otječe (sl 1).

Ako su razina vode u kršu i razina površinskog otjecanja iste ili blizu jedna drugoj, površinka voda koja otječe produbljivat će dolinu (slika 1.A.a., Hevesi, A. 1978., 1980., 1984., 1986., 1991.). U ovom slučaju neće doći do procijeđivanja površinske vode kroz vapnenac čak ni ako ispod postoji dobro razvijen sustav špilja, jer ove su špilje već ispunjene vodom (Jakucs, L.1956., 1957., 1968., 1971., 1976.). Ako je brzina produbljivanja doline u vapnencima jednaka brzini tektonskog izdizanja - tako da je izdizanje sporo ili jednako - krška i površinska voda zadržavaju istu relativnu razinu. U takvim slučajevima nikada ne dolazi do procijeđivanja površinske vode kroz vapnenac pa se oblikuje epigenetska dolina (slika 1.A.b.). Ako uvjeti u okolišu ostanu isti duže vrijeme, može se razviti duboka gudura. Ako se kasnije tektonsko izdizanje područja ubrza, produbljivanje epigenetske doline neće moći dostići opadanje razine krške vode. U ovoj situaciji oblikuje se sloj vapnenca bez vode, a vode površinskog toka procijeđuju se u sustav špilja (slika 1.A.c.). Zbog utjecaja površinske vode oblikovanje epigenetske doline postaje povremeno, da bi nakon toga ubrzo bilo prekinuto. Površinski vodeni tok nastavlja svoje erozijsko djelovanje u podzemlju i, umjesto da oblikuje dolinu na površini, počinje oblikovati špiljski sustav. U tim slučajevima, kada razina vode u kršu nije suviše duboko ispod površine, a područje se polako i ujednačeno uzdiže, podzemni vodeni tok se usijeca kompenzirajući

izdizanje pa se špilja sve više vertikalno razvija. Svod špilja oblikovanih na ovaj način je relativno blizu površine i zbog površinske erozije debljina vapnenačkog svoda se neprekidno smanjuje. Ako se ovaj proces nastavi dovoljno dugo, strop tunela špilje počinje se urušavati i tako počinje oblikovanje tipa gudure urušavanjem špilje.

Ako je na početku oblikovanja epigenetske doline razlika između razine vodotoka i razine podzemne krške vode veća (postoji dovoljno debeo sloj vapnenca bez vode), vode površinskog vodenog toka gotovo se "odmah" procijeđuju i započinje oblikovanje špilja. Njegova dolina na površini nije oblikovana u vapnencima (neće oblikovati epigenetsku dolinu) i zbog erozije nevapnenačkih pokrovnih slojeva dolina potpuno nestaje (sl. 1.B). Ako se dato područje počne polagano i ujednačeno uzdizati, vertikalna dimenzija špilje raste, tako postoje sve pretpostavke njezinog urušavanja, a time i oblikovanja gudura. Međutim, gudure oblikovane na ovaj način nesumnjivo su nastale urušavanjem stropova špilja bez obzira na to što gornji dijelovi dolinskih strana nikada nisu bili dio epigenetske doline.

Ako sumiramo ova dva glavna tipa oblikovanja gudura u vapnencima koji su pokriveni nekarbonatnim naslagama, možemo zaključiti da se oni međusobno ne isključuju. Jedina razlika - zbog razlike u razini površinske i krške podzemne vode - je da vodeni tok produbljuje svoju dolinu na površini ili stvara špilje ispod površine.

Daljnje ispitivanje primjera gudura u vapnencima u Srednjoj i Južnoj Europi pokazalo je da se gudure oblikovane u vapnencima prekrivenim nekarbonatnim naslagama mogu dokazati za samo nekoliko njih (Hámori-szoros, Bükk-gorje, Mađarska). Nekarbonatni pokrov je moguć za mnoge druge, a neke gudure vjerovatno nikad nisu oblikovane u pokrivenim vapnencima (Moravski krš, Češka Republika, Bihar, Bihorolui-gorje, Rumunjska). Njihovo zajedničko obilježje je da sve imaju snažne stalne tokove, a dna im odgovaraju razini krške vode. Ovi tokovi vodom vežu se za otvoren, miješani, alogeni krš. Gudure u vapnencima mogu oblikovati ne samo epigenetski tokovi, već i vodotoci sa relativno velikim nekarbonatnim područjem. U oblikovanju gudura u ovom slučaju također se mogu razlikovati dva tipa: površinski i podzemni. Relativan položaj razine podzemne krške vode i razina površinske vode tako određuje da li površinski ili podzemni proces ima odlučujući utjecaj na oblikovanje gudure.

Slika 2. pokazuje dvije gudure Moravskog krša (Suchy žleb i Pusty žleb) dok slika 3.pokazuju kanjon Izbucul Si Cheile Galbenei (Rumunjska).

Pri odluci koji od 4 spomenuta tipa oblikovanja gudura se može primijeniti u određenom slučaju, od pomoći je postojanje ili odsustvo špilja na stranama kanjona. Naime, špilje su, uglavnom, iste starosti kao i sama gudura. To znači da je u vrijeme oblikovanja gudure okoliš pogodovao razvoju špilja. To istodobno znači da su one, nesumnjivo, špiljskog porijekla. Na temelju tih otkrića možemo zaključiti da je gudura Tordai-hasadék, Cheile Turzii u Rumunjskoj sasvim sigurno oblikovana putem urušavanja špilja.

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