Acta geographica Slovenica, 49-2, 2009, 245–262

ACTIVE AND RELICT ALLUVIAL FANS ON CONTACT KARST OF THE VRHPOLJSKA BRDA HILLS, SLOVENIA

AKTIVNI IN RELIKTNI VRŠAJI KONTAKTNEGA KRASA VRHPOLJSKIH BRD, SLOVENIJA

Uroš Stepišnik

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Northwestern slope of the Vrhpoljska brda with summit Kokoš, 663 m.
Severozahodno pobočje Vrpoljskih brd z vrhom Kokoš, 663 m.

Active and relict alluvial fans on contact karst of the Vrhpoljska brda hills, Slovenia

DOI: 10.3986/AGS49201
UDC: 911.2:551.435.8(497.472)
COBISS: 1.01

ABSTRACT: Several types of contact karst are found within the Slovenian karst, but the most common is the ponor type, which usually develops at boundaries between flysch and limestone. One of these types is in the area of Vrhpoljska brda. In this contact karst area two types of alluvial fans appear on carbonate bedrock. Members of the first type are ordinary alluvial fans with active alluvial processes where flysch derived sediment covered limestone surface in a distinct fan shape. The other type, described as relict alluvial fans, is fan-shaped features preserved in the carbonate bedrock. These essentially bedrock landforms developed as a result of the gradual removal of pre-existing alluvial fan cover and the concurrent but non-uniform chemical denudation of the underlying carbonate bedrock. Geomorphologic and morphometric description of alluvial fans and relict alluvial are provided in the article and mechanisms of relict alluvial fans formation and transformation are discussed.

KEY WORDS: karst, contact karst, alluvial fan, relict alluvial fan, Vrhpoljska brda, Kras, Slovenia

The article was submitted for publication on January 27, 2009.

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Contents

1 Introduction

In Slovenia the most common type of contact karst is the ponor type, where waters from a non-karstic catchment flow onto the karst surface. Such type of karst has developed where the non-karstic surface is at a higher elevation and where the hydraulic gradient of water is directed into the karst and is steeper than the surface gradient (Mihevc 1991). Surface karst features typical of Slovenian ponor type contact karst are blind valleys, ponor steepheads (Mihevc 1991), trough valleys, karst plains (Gams 2001) and collapse dolines (Stepišnik 2006). Caves within contact karst areas contain allogenic rivers and have sub-horizontal passages of epiphreatic origin. Extensive segments of unroofed sub-horizontal caves have been found on the karst surface (Mihevc 2001).

Investigation of contact karst in the area of Vrhpoljska brda in western Slovenia included study of the processes active on contact karst in the specific hydrological situations where alluvial fans occur. Some of the fans on the study area are undergoing active alluvial sedimentation, with flysch-derived sediment covering the limestone bedrock to produce landforms that are a typical fan-shape in ground plan. Other fans are not composed of sediment typical of fluvial alluvial fans, but are fan-like surface features standing proud of the general carbonate bedrock surface. Those fan-like features superimposed upon carbonate bedrock were defined as relict alluvial fans (Stepišnik et al. 2007).

The morphology, morphometry and spatial distribution of alluvial fans on the study area contact karst were studied in detail. The study involved geomorphological mapping of the fans and their hydrological hinterland to establish extent and location of alluvial fans, extent of flysch derived alluvium and surface morphology of the fans. Morphometric survey included measuring of long profiles of the fans.

The main purpose of the paper is to describe alluvial fans and relict alluvial fans as contact karst features and to provide some morphological and morphometric properties of the fans. The aim of the research is to deduct on basis of fieldwork data, which are the mechanisms of alluvial fan formation and mechanisms and reasons for transformation to the relict ones. The aim is also to provide some evidence why on the contact karst alluvial fans instead of blind valleys are formed.

2 Area of Vrhpoljska brda

The Vrhpoljska brda hills are situated at the southernmost part of the Karst plateau. This area extends over a 6.5 km-long ridge, which stretches from Videž above Kozina across Veliko Gradišče towards the hill of Kokoš, covering an area of some 23 km^2. The ridge is at elevation of about 620 m, which is around 200 m higher than the surrounding area (Fig. 1).

The upper part of the Vrhpoljska brda hills comprises of Eocene flysch brachysyncline surrounded by Paleocene and Upper Cretaceous bedded limestone. Flysch is exposed across an area of about 0.7 km^2 on the highest part of the ridge around Veliko Gradišče. Many inherited fluvial features such as erosion gullies and alluvial fans indicate that the flysch cover was once more extensive, but most of it has already been removed by denudation.

The main ridge of the Vrhpoljska brda hills branches into smaller ridges that lie south and southeast of Veliko Gradišče. Two valleys flanking the ridge that branches from the top of Veliko Gradišče are infilled with alluvial sediment. The valleys, Gročansko polje to the west and Vrhpoljsko polje to the east, are morphologically similar. Their northern parts are covered by small coalescing alluvial fans overlying carbonate bedrock at the ends of numerous erosion gullies that are incised into flysch bedrock. Central parts of the valleys are flat and approximately 250 m wide. Most of the surface water from the valleys drains into number of ponors on the contact between flysch-derived alluvium and carbonate bedrock. The southern floors of the valleys extend on to the planated karst surface. Though both valleys function as border karst poljes or blind valleys, realistically their dimensions are too small to fit the usual definition of a polje, and they do not have the distinct terminal steepheads that would allow them to be defined as blind valleys.

3 Types of alluvial fans in the area

According to standard geomorphological literature, alluvial fans are river accumulation landforms that are cone-shaped in long profile and fan-shaped in ground plan. They form where feeder channels leave a narrow

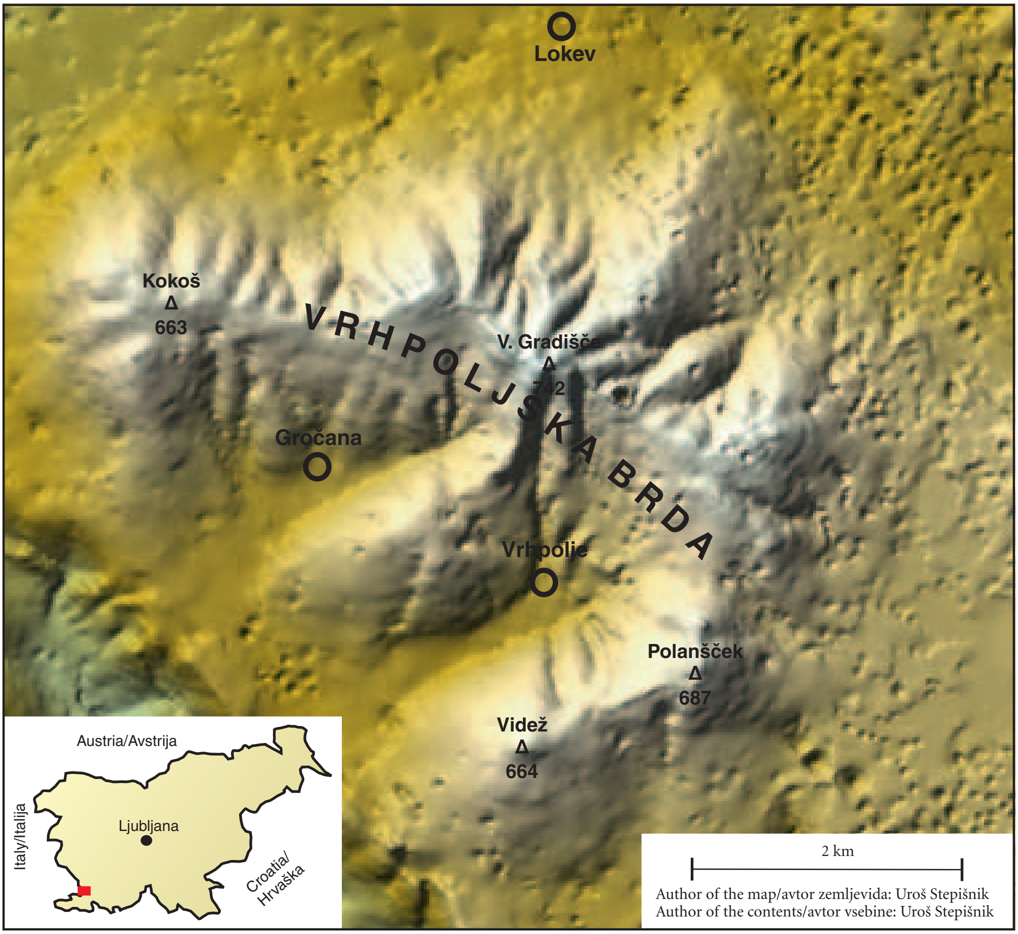

Figure 1: Annotated digital elevation model of the study area.

valley and enter a wider valley or plain. Velocity of stream and its transportation capacity are decreased, and much of the sediment load is deposited (Summerfield 1996; Goudie 2004). There are many sub-types of alluvial fans, according to their shape and age of development (Gams 1964; Gams 2001; Sauro 2001; Goudie 2004), although alluvial fan sedimentation is a specific process. The decrease in water flow velocity results in deposition of larger sediment clasts in the upper, proximal sections and finer sediment in the lower, distal sections. A typical alluvial fan has a concave long profile with a slope inclination of up to 10 degrees in its upper sections and from 1 to 5 degrees in its lower sections (Bull 1977; Summerfield 1996; Goudie 2004).

Two general types of alluvial fan occur in the study area (Figure 2). The first comprises fans undergoing active alluvial sedimentation from the flysch hinterland onto the karst area. Their thickness, internal structure and long profiles correspond to those of typical fluvial system alluvial fans. Upper parts of fans have an inclination of up to 5 degrees, with the inclinations decreasing with down slope distance. The structure of the upper part of the fan profile consists of layers of gravel, sand and loam, whereas the outer, flatter, sections comprise loamy material.

The second type of alluvial fans in the karst is relict alluvial fans (Stepišnik et al. 2007). Their ground plan shapes are fan-like, and their long profiles are also distinct in shape, with concave upper sections that become convex in the middle and lower parts. Slopes reach 11 degrees in the upper sections, whereas the middle parts are relatively flattened and the surface slopes of the outer areas reach 12 degrees. In typical active alluvial fans alluvium thickness decreases with distance from the upper sections, whereas

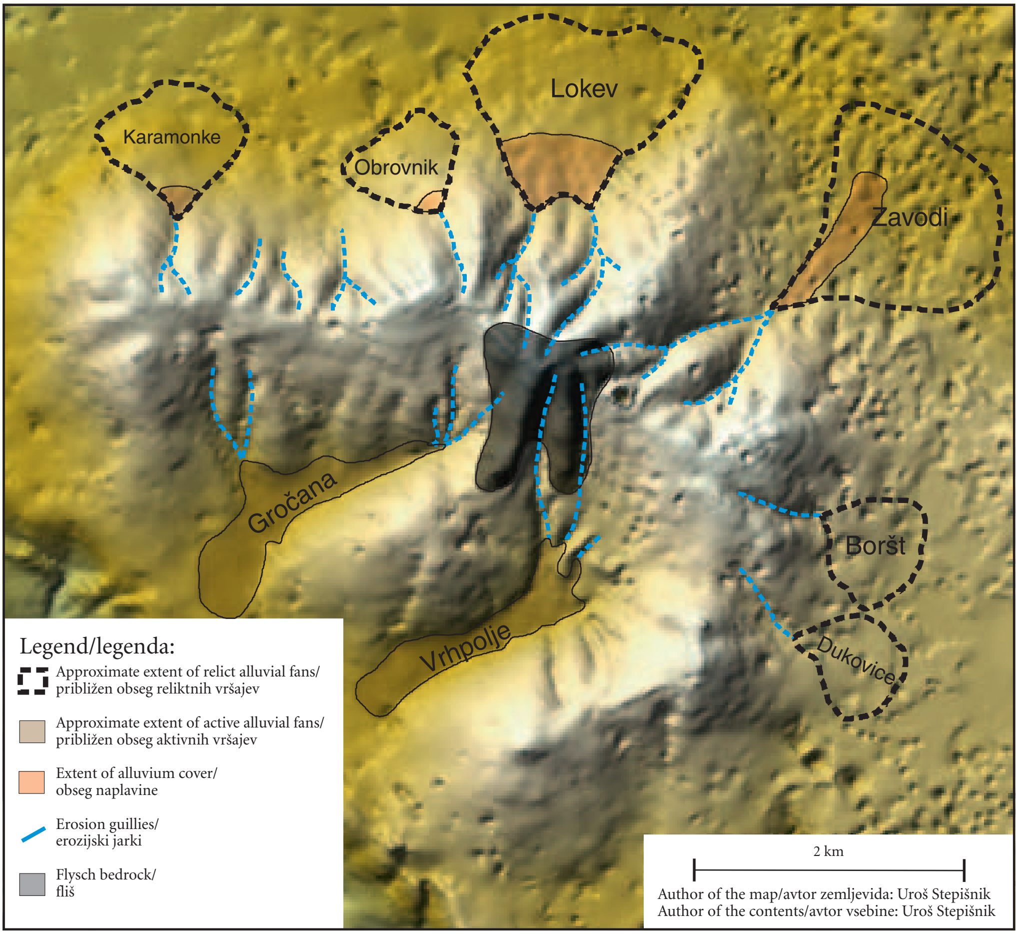

Figure 2: Active and relict alluvial fans of the study area.

alluvial deposits cover only the concave upper sections of the relict alluvial fans. Outer areas of the relict fans are convex and the limestone bedrock has no alluvial cover. Density of surface karst features increases with distance from current edge of surviving alluvial cover. However, some relict alluvial fans are completely or almost without alluvial cover even in their upper sections, and their entire long profile is convex.

3.1 Active alluvial fans

The study area includes two active fans south of the Vrhpoljska brda hills in the northern parts of Gročana and Vrhpoljsko poljes (Figure 3). The fan at Gročana covers an area of 0.2 km^2 and the fan near Vrhpolje covers 0.16 km^2 (Fig. 4 and Fig. 5). Erosion gullies with intermittent water flow have cut through flysch and carbonate bedrock at the upper ends of the fans, which are completely covered with flysch-derived alluvium. The upper parts of the fans are steepest, with inclinations of up to 4 degrees, whereas the outer fan sections merge into the flat alluvial surfaces of the Gročana and Vrhpolje poljes.

3.2 Relict alluvial fans

Relict alluvial fans are found in the northern and eastern part of Vrhpoljska Brda. Their ground plans are fan-shaped, and they have a distinctive long profile. Their upper parts are concave but in the middle and

Figure 3: Active alluvial fan in northern part of Vrhpoljsko polje.

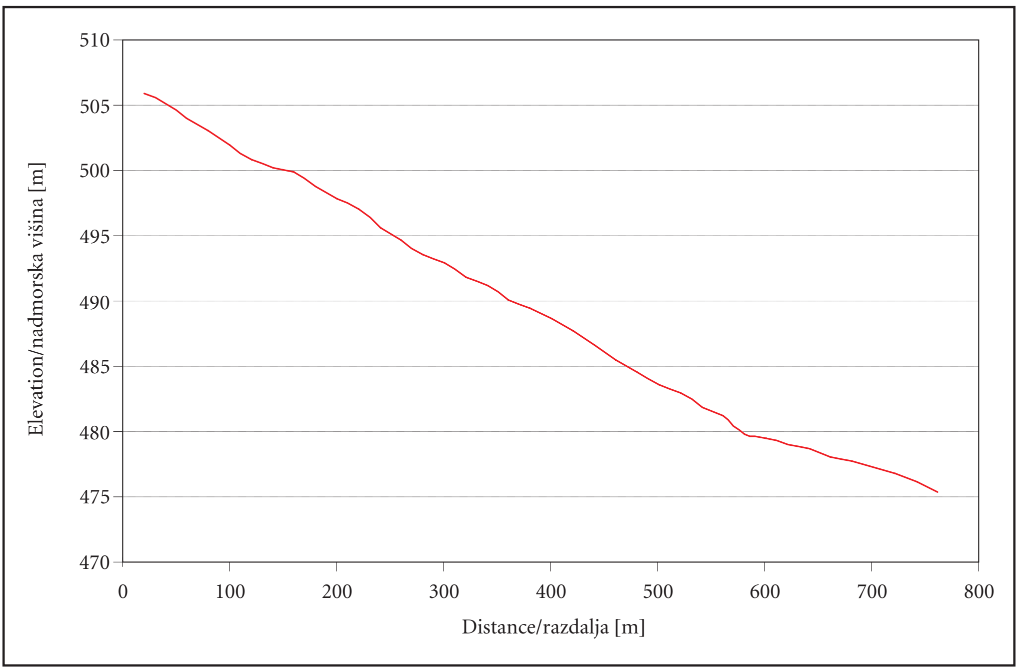

Figure 4: Long profile of the Gročana polje alluvial fan.

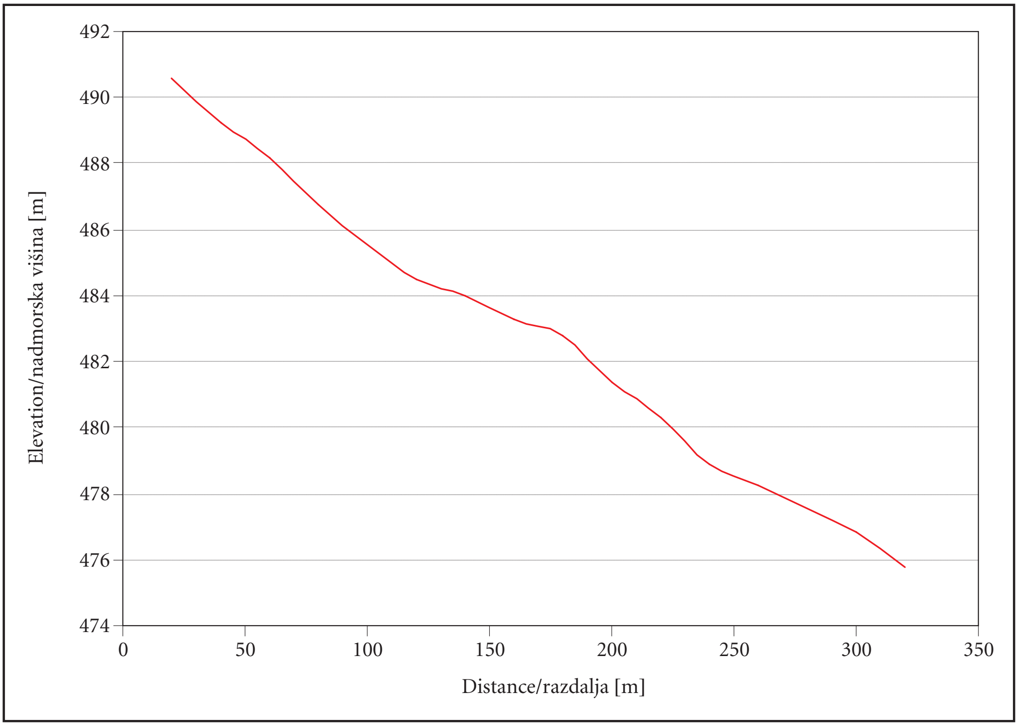

Figure 5: Long profile of the Vrhpolje polje alluvial fan.

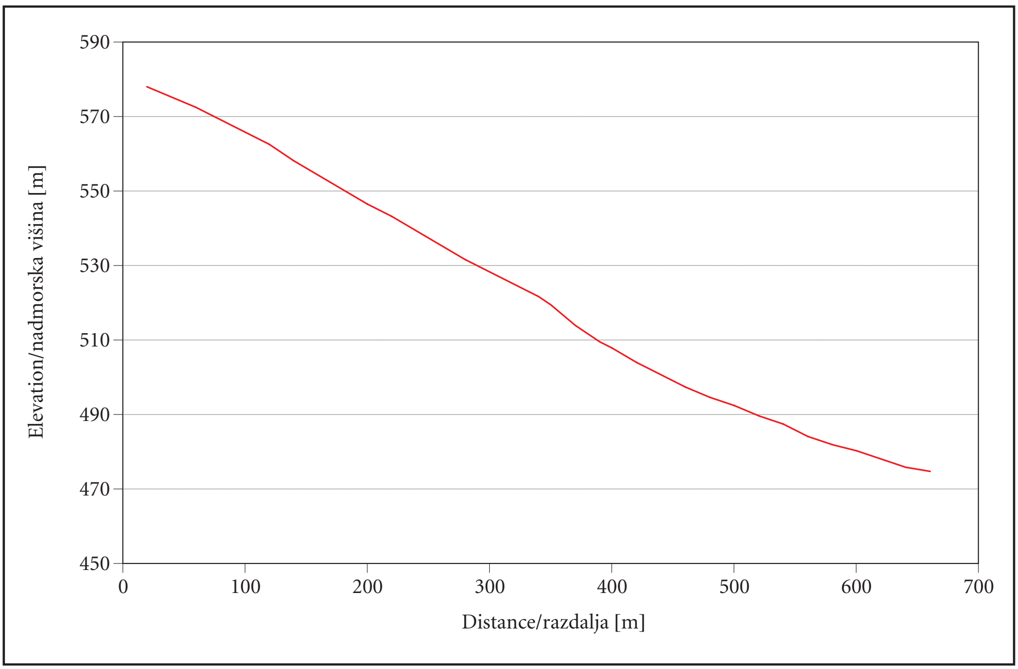

Figure 6: Long profile of the Karamonke relict alluvial fan.

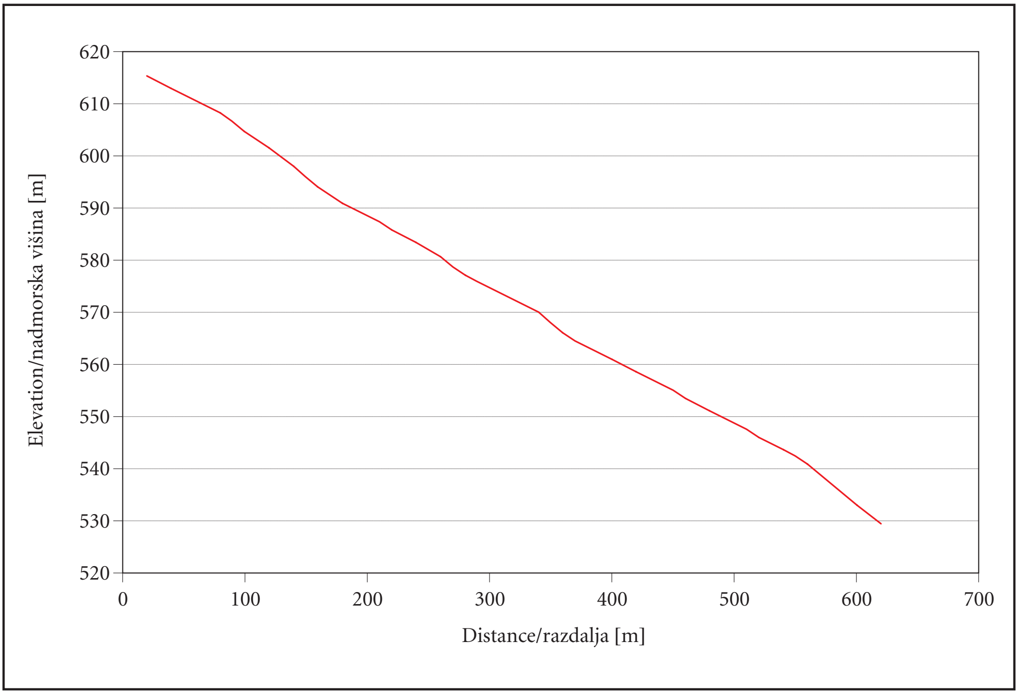

Figure 7: Long profile of the Obrovnik relict alluvial fan.

outer sections they become convex. The slopes of the upper sections reach 11 degrees, whereas the middle areas are relatively flattened. Surface slopes in the outer parts of the fans reach 12 degrees. The convex outer sections comprise limestone bedrock with no alluvial cover. The density of surface karst features increases with distance from the edge of the alluvial cover.

There are four relict alluvial fans in the northern part of the Vrhpoljska brda hills, each with one or more erosion gullies in its hinterland. Most of the gullies are inactive and incised into carbonate bedrock, as the flysch bedrock has been completely denuded, but the upper sections of some of the eastern gullies are still within flysch bedrock so they still carry periodic water flow.

In the western part of the area, at the foot of Mount Kokoš, is the relict alluvial fan known as Karamonke, with an area of around 0.57 km^2 (Figure 6). Its apex lies at the end of a dry erosion gulley that is carved completely into carbonate bedrock, with the original flysch bedrock completely removed by erosion. A small patch of flysch-derived alluvium is preserved on the upper part of the fan. Inclinations of long profile are 4 degrees in the upper section, reaching 14 degrees in the outer areas. As this relict alluvial fan retains hardly any alluvial cover, it is completely convex. Surface karst features are virtually absent on its upper sections, whereas many are found on the outer areas of the fan. The margins of the fan extend into the flat Karst plateau, which is also densely covered with surface karst features.

The relict Obrovnik alluvial fan lies 1.5 km to the east of Karamonke (Figure 7). Its apex is at the foot of an erosion gulley that is incised completely in carbonate bedrock, but the upper section of the gulley lies near a remnant patch of flysch bedrock. The upper part of the fan, which is about 300 m long, is covered with flysch-derived alluvium. Carbonate bedrock is exposed in the middle of the fan and the lower section has a rocky surface with a high density of dolines and grikes. Slope inclinations reach 11 degrees in the upper part of the fan, average 6 degrees in the middle area and are up to 12 degrees in the outer convex sections. The outer sections extend gradually into the flat surface of the karst plateau.

The biggest relict alluvial fan in the study area has an area 1.8 km^2 and is situated near the village of Lokev (Figure 8). Its upper part is situated at the ends of two erosion gullies with their upper parts incised into flysch bedrock. Flysch-derived alluvium is preserved on the upper part of the fan, where slope inclinations reach 8.5 degrees. Isolated carbonate bedrock grikes are exposed in the middle section, where slope inclinations are around 2 degrees. Outer areas of the fan are inclined at up to 9 degrees, with carbonate bedrock exposed at the surface and grikes and dolines present. The fan terminates against the foothill of Taborska brda in the north, and merges into the flat karst surface towards the northwest (Fig. 9).

The Zavodi relict alluvial fan covers an area of 1.1 km^2 and is essentially polymorphic. Its apex is lies at the end of an erosion gully that is carved in flysch bedrock. It is a typical relict alluvial fan, with almost no alluvial cover in the upper section. Its long profile is completely convex with inclinations of around 2 degrees in the upper parts and around 6 degrees in the outer areas. Bedrock is exposed right across the fan, and grikes and dolines are abundant (Figure 10). A 10 m-deep and up to 120 m-wide valley that is carved into the western part of the fan extends to its outer edge, where it disappears into a series of deep dolines. Periodically the valley carries water from the erosion gulley above, and is partly filled with flysch alluvium.

Two relict alluvial fans on the eastern part of the Vrhpoljska brda are densely covered with surface karst features. They are identified as relict alluvial fans in the karst surface on the basis of their ground plans and slope inclinations.

The northernmost fan, known as Boršt, covers an area of 0.44 km^2 (Figure 11). There are many dolines on the fan's apex, which lies below a relict erosion gully, whereas many larger dolines cover the entire upper section of the fan. The entire long profile of the fan is convex with slope inclinations of around 1 degree in the upper parts and around 5 degrees in the outer areas. Carbonate bedrock covered with grikes and dolines is exposed across the entire fan surface. The fan's margins merge into the flattened karst surface of northwestern Matarsko podolje (Figure 7).

The Dukovce relict alluvial fan, which has an area of 0.19 km^2, lies 0.5 km farther south, with its doline-covered apex at the end of an erosion gulley (Figure 12). Carbonate bedrock with many dolines and grikes is exposed across the whole fan surface. The fan's long profile is convex with slope inclinations of up to 3 degrees in the upper section and up to 6 degrees in the outer areas.

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Figure 8: Relict alluvial fan near Lokev.

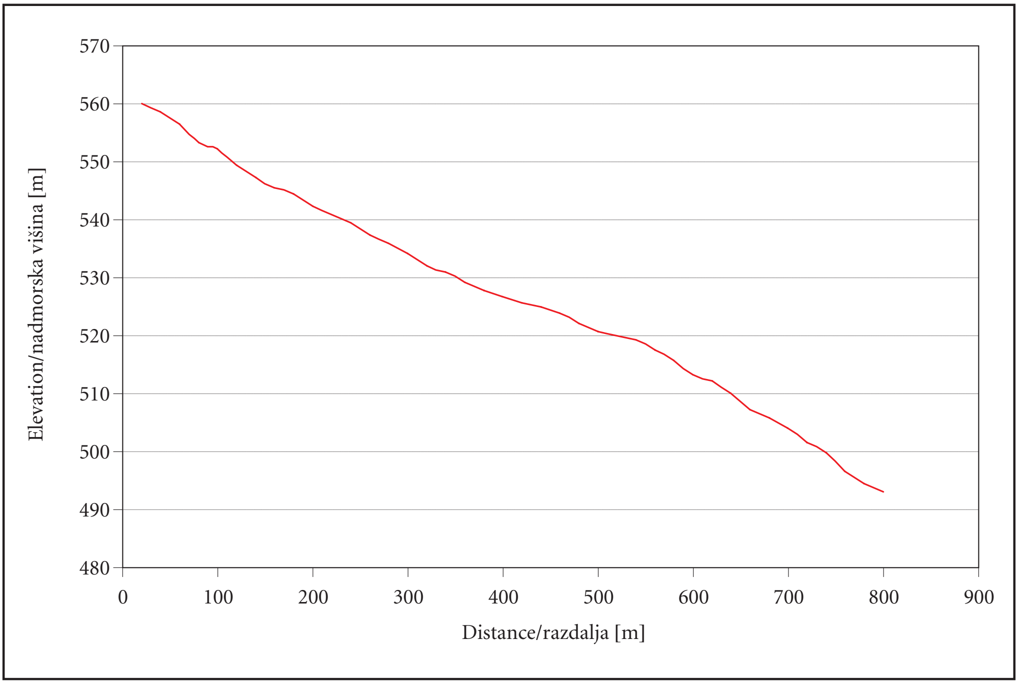

Figure 9: Long profile of the Lokev relict alluvial fan.

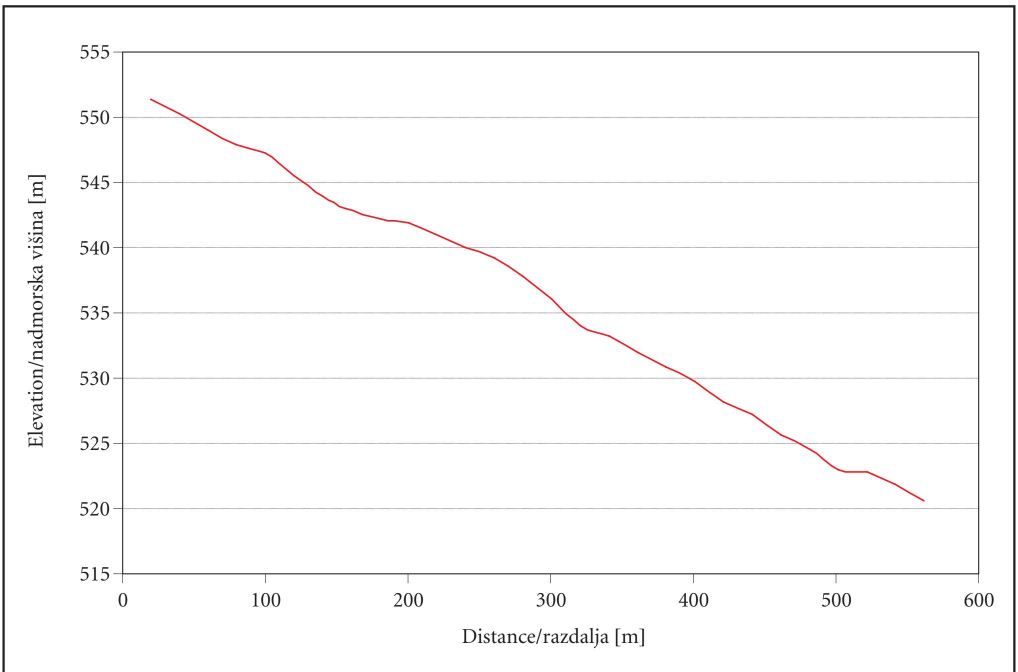

Figure 10: Long profile of the Zavodi relict alluvial fan.

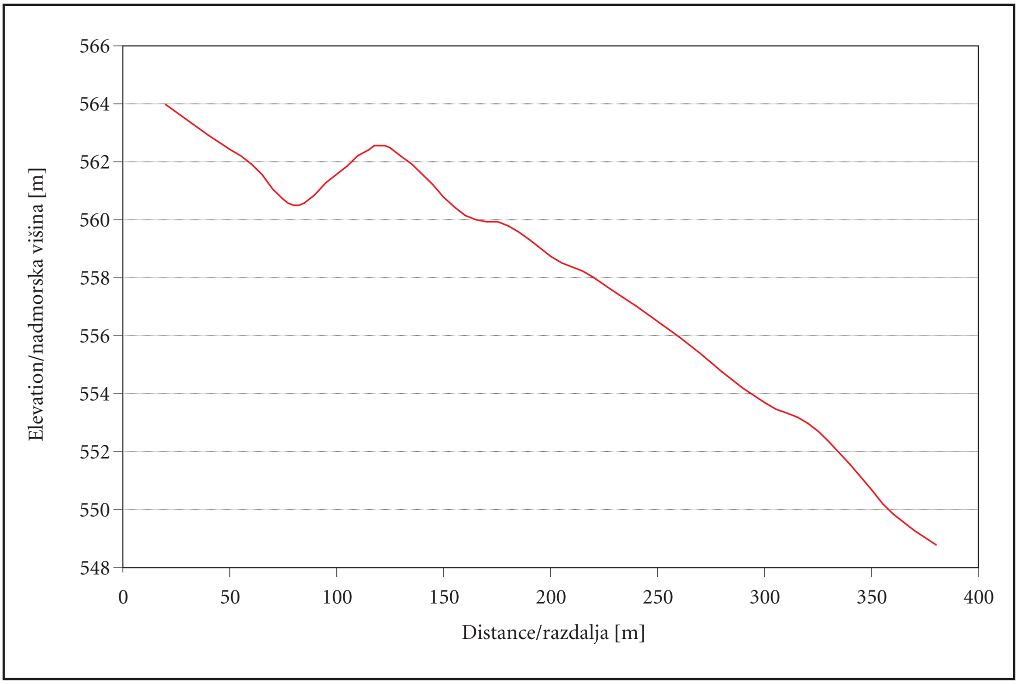

Figure 11: Long profile of the Boršt relict alluvial fan with a large doline in the upper section.

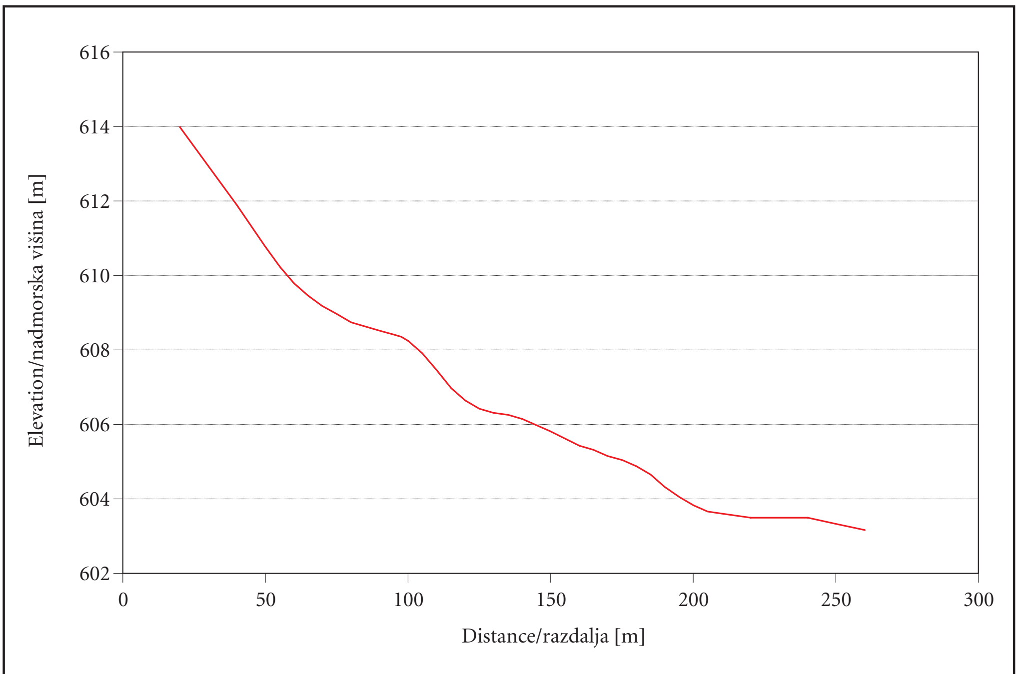

Figure 12: Long profile of the Dukovce relict alluvial fan.

4 Conclusion

Detailed investigation of the contact karst in the Vrhpoljska brda hills area revealed that the process of alluvial fan formation is in general the same on karstic as in non-karstic fluvial geomorphological systems. Active alluvial fans are related to the present process regime. They are being formed because the flysch outcrops of the Vrhpoljska brda hills stand high above the flat karst surface. Intensive erosional processes on the higher ground resulted in generation of flysch debris and subsequent input of alluvial material to the karst flat. Due to the concentrated material input the sediment-laden waters deposit alluvial fans rather than forming blind valleys.

The characteristic long profile of the relict alluvial fans is the result of significant reduction or total cessation of deposition of flysch-derived residual sediment and water inflow in the fan area. In the study area it is a result of a partial or complete denudation of flysch bedrock in which feeder channels were formed. Subsequent denudation effects on the residual alluvial cover on the fans appear to be less intense than those affecting the neighboring karst surface where limestone bedrock is exposed. Thus, denudation lowering appears to be less rapid on alluvial fan surfaces that remain covered with flysch-derived deposits than on the non alluvium covered karst surface. This difference in denudation rates results in the distinctive shape of the fan long profiles. Such fans exhibit typical long profiles only in their upper sections, where relatively thick alluvial cover is preserved. Where the alluvial cover is denuded the dynamics of limestone bedrock corrosion are intense and, thus, surface lowering is more rapid. Alluvial cover thickness diminishes with distance from the uppermost section of the fan, so the alluvial cover on the margins of the fan will be the first to be denuded, exposing the bedrock to corrosion. Subsequently, sediment will gradually be removed back towards the core of the fan and more and more carbonate bedrock will be exposed, resulting in the development of the typical convex long profile. The final outcome, if all alluvial cover is removed, is a bedrock geomorphic feature that is fan shaped in ground plan and convex in long profile; in this article, we term it relict alluvial fan. The bedrock feature that has been developed as a final outcome is a kind of pseudomorph that has inherited the form of the original alluvial fan.

Relict alluvial fans embossed upon the karst surface have not previously been interpreted as landforms typical of contact karst, even though the process of their formation is exclusively related to contact karst. The fans in the study area can be used as type examples to aid the interpretation of alluvial fan formation mechanisms on other dynamic karst surfaces.

The author would like to thank the reviewers of this paper and dr. Karel Natek for helpful suggestions and comments. Especially I am grateful to Bruno Tomšič for help with fieldwork.

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Aktivni in reliktni vršaji kontaktnega krasa Vrhpoljskih brd, Slovenija

DOI: 10.3986/AGS49201
UDK: 911.2:551.435.8(497.472)
COBISS: 1.01

IZVLEČEK: Na slovenskem krasu se pojavljajo različni tipi kontaktnega krasa, najbolj razširjen je ponorni tip, ki je najpogostejši na stiku med flišem in apnenci. Kontaktni kras tega tipa je prisoten tudi na Vrhpoljskih brdih. Na tem območju se pojavljata dva tipa vršajev na karbonatni matični podlagi. Prvi tip predstavljajo vršaji z aktivnimi procesi fluvialne akumulacije, kjer se flišni sediment odlaga preko apnenčaste matične podlage v značilni pahljačasti obliki. Drug tip vršajev, za katere se uporablja termin reliktni vršaji, predstavljajo vršajem podobne oblike ohranjene v karbonatni matični podlagi. Te pretežno živoskalne oblike so se razvile s postopno denudacijo aluvialnih vršajev in sočasno neenakomerno kemično denudacijo karbonatne matične podlage. V članku so predstavljene geomorfološke in morfometrične značilnosti vršajev in reliktnih vršajev ter možni mehanizmi oblikovanja in preoblikovanja reliktnih vršajev.

KLJUČNE BESEDE: kras, kontaktni kras, vršaj, reliktni vršaj, Vrhpoljska brda, Kras, Slovenija

Uredništvo je prispevek prejelo 27. januarja 2009.

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Kazalo

1 Uvod

V Sloveniji je najpogostejši tip kontaktnega krasa ponorni kontaktni kras, kjer vode iz nekraškega porečja tečejo na kraško površje. Ta tip kontaktnega krasa je razvit, kjer ima nekraško površje višje nadmorske višine. Hidravlični gradient mora biti usmerjen v smeri krasa, hkrati mora biti bolj strm od gradienta površja (Mihevc 1991). Tipične kraške oblike ponornega krasa v Sloveniji so slepe doline, ponorni zatrepi (Mihevc 1991), suhe doline, kraške uravnave (Gams 2001) in udornice (Stepišnik 2006). Skozi jame kontaktnega krasa se pretakajo alogeni vodni tokovi. Zanje so značilni horizontalni jamski rovi epifreatičnega nastanka. V bližini kontaktov se pojavljajo daljši odseki denudiranih epifreatičnih jamskih rovov (Mihevc 2001).

Raziskava kontaktnega krasa Vrhpoljskih brd, ki se nahajajo v zahodni Sloveniji, je obsegala proučevaje aktivnih procesov na kontaktnem krasu v specifičnih hidroloških razmerah, kjer se pojavljajo vršaji. Na nekaterih vršajih proučevanega območja so aktivni procesi fluvialane akumulacije materiala flišnega izvora na karbonatno matično podlago. To so tipični fluvialni vršaji s pahljačasto tlorisno obliko. Drug tip vršajev ne gradi fluvialni sediment, ampak so vršajem podobne oblike izoblikovane predvsem v karbonatni matični podlagi. Te vršajem podobne oblike, ki jih gradi karbonatna matična podlaga, so bile opredeljene kot reliktni vršaji (Stepišnik et al. 2007).

Na območju raziskave so bile podrobneje proučene morfološke in morfometrične značilnosti vršajev in njihova prostorska razporeditev. Raziskava je obsegala geomorfološko kartiranje vršajev in njihovega hidrološkega zaledja z namenom, ugotoviti obseg in razporeditev flišne naplavine ter površinske oblikovanosti vršajev. Morfometrična analiza je vključevala meritve podolžnih profilov vršajev.

Glavni namen članka je opis fluvialnih in reliktnih vršajev kot površinskih geomorfoloških oblik kontaktnega krasa ter podati osnovne geomorfološke in morfometrične značilnosti njihovih oblik. Cilj članka je, na podlagi podatkov pridobljenih s terenskim delom, ugotoviti, kateri so mehanizmi oblikovanja vršajev na kontaktnem krasu in kateri so mehanizmi in razlogi njihovega preoblikovanja v reliktne vršaje. Cilj članka je tudi nakazati razloge, zakaj se ponekod na kontaktnem krasu oblikujejo vršaji in ne slepe doline.

2 Vrhpoljska brda

Vrhpoljska brda ležijo na skrajnem jugovzhodnem delu planote Kras. Glavni greben Vrhpoljskih brd je dolg 6,5 km in sega od Videža nad Kozino, preko Velikega Gradišča do Kokoši. Razteza se na nadmorski višini okoli 620 m, kar je okoli 200 m nad okoliškim površjem. Vrhpoljska brda obsegajo območje veliko 23 km^2.

V geološkem smislu gradi vrhnji del Vrhpoljskih brd brahisinklinala eocenskega fliša, ki prekriva paleocenske in zgornje kredne plastovite apnence. 0,7 km^2 velika površina flišne matične podlage prekriva najvišji del grebena v okolici Velikega Gradišča. Na grebenu in pod njim je cela vrsta podedovanih fluvialnih oblik na karbonatni matični podlagi, kot so erozijski jarki in aluvialni vršaji, kar nakazuje, da je bil obseg flišnega pokrova v preteklosti večji, a je bil kasneje denudacijsko odstranjen.

Glavni greben Vrhpoljski brd se razcepi v bližini Velikega Gradišča v dva manjša grebena v smeri juga in jugozahoda. Vzporedni dolini, Gročansko polje in Vrhpoljsko polje, ki ležita med grebeni, sta si morfološko podobni. Njune severne dele prekrivajo vršaji, ki se nahajajo pod številnimi erozijskimi jarki, zarezanimi v flišno matično podlago. Osrednji del dolin je širok okoli 250 m. Vode odtekajo v številne ponore na kontaktu fluvialnih flišnih nanosov in karbonatne matične podlage. Južna dela dolin preideta v pretežno uravnano kraško površje na jugu. Obe dolini imata hidrološko funkcijo robnih kraških polj oziroma slepih dolin, a so njune dimenzije premajhne za kraška polja, hkrati pa jih zaradi odsotnosti strmega zatrepa, ki je značilen za zaključke slepih dolin, ne moremo opredeliti kot slepe doline.

Slika 1: Digitalni model višin preučevanega območja s toponimi.
Glej angleški del prispevka.

3 Tipi vršajev na proučevanem območju

Geomorfološka literatura navaja vršaje kot rečne akumulacijske oblike, ki so v tlorisu pahljačaste oblike v podolžnem profilu pa konkavne oblike. Nastanejo na mestih, kjer ožje doline preidejo v širše dele ali uravnavo. Hitrost in transportna moč vodnega toka se zmanjšata, kar povzroči sedimentacijo večine transportiranega materiala (Summerfield 1996; Goudie 2004). Obstaja cela vrsta podtipov vršajev, ki se delijo glede na oblikovanost in čas nastanka (Gams 1964; Gams 2001; Sauro 2001; Goudie 2004), kljub temu da je oblikovanje vršajev zelo specifičen proces. Rezultat zmanjšanja hitrosti vodnega toka je sedimentacija večjih frakcij sedimenta v zgornjih delih vršajev in manjših frakcij v spodnjih delih vršajev. Tipični vršaji imajo v zgornjem delu podolžnega profila naklon okoli 10 stopinj, v spodnjem delu pa od 1 do 5 stopinj (Bull 1977; Summerfield 1996; Goudie 2004).

Na proučevanem območju sta dva tipa vršajev (slika 2). Prvi tip vključuje vršaje, na katerih so prisotni procesi fluvialne akumulacije iz flišnega zaledja na kraško površje. Debelina njihovih nanosov, zgradba, oblika in podolžni profili so enaki značilnostim vršajem, ki nastajajo v fluvialnem geomorfnem sistemu. Vršaji imajo v zgornjem delu naklon okoli 5 stopinj, ki z oddaljenostjo od vrha vršaja upada. Zgornje dele vršajev gradi predvsem grušč, pesek in ilovica, medtem ko je v spodnjih uravnanih delih najpogostejši ilovnat material.

Drugi tip vršajev smo opredelili kot reliktne vršaje (Stepišnik in ostali 2007). V tlorisu so pahljačaste oblike. Njihovi podolžni profili so izrazito konkavni v zgornjih delih, v osrednjih in spodnjih delih pa imajo značilno konveksno obliko. V zgornjih delih imajo naklon do 11 stopinj, osrednji del je relativno uravnan, spodnji deli pa doseżejo naklon do 12 stopinj. V fluvialnih vršajih debelina rečnih nanosov upada z oddaljevanjem od zgornjega dela vršaja. V primeru reliktnih vršajev, rečni nanosi prekrivajo le zgornje dele vršajev, kjer je njihov podolžni profil konkavne oblike. Osrednji in spodnji deli reliktnih vršajev so v podolžnem profilu konveksne oblike brez ohranjenega fluvialnega sedimenta. Gostota površinskih kraških oblik se povečuje z oddaljenostjo od roba rečne naplavine, ki prekriva zgornje dele vršajev. Nekaterih reliktnih vršajev niti v zgornjih delih ne prekriva rečna naplavina; njihovi podolžni profili so po celotni dolžini konveksni.

Slika 2: Aktivni in reliktni vršaji na proučevanem območju.
Glej angleški del prispevka.

3.1 Aktivni vršaji

Na južnem delu Vrhpoljskih brd se nahajata dva aktivna vršaja, v severnih delih Gročanskega in Vrhpoljskega polja (slika 3). Vršaj na Gročanskem polju ima površino 0,2 km^2, vršaj na Vrhpoljskem polju pa 0,16 km^2. Erozijski jarki z občasnimi vodotoki, ki so vrezani v flišno in karbonatno matično podlago, se iztekajo v zgornja dela vršajev, ki sta popolnoma prekrita z naplavino flišnega izvora. Zgornja dela vršajev imata največji naklon, ki je okoli 4 stopinje. Spodnja dela vršajev zvezno prehajata v naplavno uravnavo Gročanskega in Vrhpoljskega polja.

Slika 3: Aktivni vršaj v sevenem delu Vrhpoljskega polja.
Glej angleški del prispevka.

Slika 4: Podolžni profil vršaja na Gročanskem polju.
Glej angleški del prispevka.

Slika 5: Podolžni profil vršaja na Vrhpoljskem polju.
Glej angleški del prispevka.

3.2 Reliktni vršaji

Reliktni vršaji ležijo v severnem in vzhodnem delu Vrhpoljskih brd. Imajo pahljačast tloris, njihovi podolžni profili pa kažejo na značilnosti reliktnih vršajev; v zgornjih delih so konkavni, v osrednjih in spodnjih pa postanejo konveksni. Nakloni v zgornjih delih so do 11 stopinj, medtem ko so osrednji deli relativno uravnani. Spodnji deli vršajev dosegajo naklone do 12 stopinj. V konveksnih, osrednjih in spodnjih delih vršajev izdanja karbonatna matična kamnina. Gostota površinskih kraških oblik narašča z oddaljevanjem od roba naplavine v višjih delih vršajev.

V severnem delu proučevanega območja so štirje reliktni vršaji, ki imajo v zaledju enega ali več erozijskih jarkov. Večina erozijskih jarkov je neaktivnih in so vrezani v karbonatno matično podlago, saj je bil fliš popolnoma denudiran. Le v nekaterih erozijskih jarkih na vzhodnem delu je še vedno prisotna flišna matična podlaga, zato po njih občasno tečejo vodotoki.

V zahodnem delu območja, ob severnem vznožju Kokoši, se nahaja reliktni vršaj s toponimom Karamonke, ki obsega območje veliko 0,57 km^2 (slika 6) Vrhnji del vršaja leži ob izteku suhega erozijskega jarka, ki je vrezan v karbonatno matično podlago, saj je bil fliš denudiran. Manjša zaplata flišne naplavine prekriva zgornji del vršaja. Naklon v zgornjem delu podolžnega profila je okoli 4 stopinje, v spodnjem delu pa do 14 stopinj. Zaradi relativno majhne količine fluvialne naplavine v zgornjem delu vršaja, je podolžni profil po celotni dolžini konveksen. V zgornjem delu ni površinskih kraških oblik, pojavljajo se v osrednjem in zunanjem delu vršaja. Spodnji rob vršaja prehaja v uravnavo Krasa, ki je gosto prekrit s površinskimi kraškimi oblikami.

Slika 6: Podolžni profil reliktnega vršaja Karamonke.
Glej angleški del prispevka.

Reliktni vršaj s toponimom Obrovnik leži 1,5 km vzhodno od Karamonk (slika 7). Njegov zgornji del leži na vznožju erozijskega jarka, ki je vrezan v karbonatno podlago. V bližini vrhnjega dela erozijskega jarka je flišna matična kamnina. Vršaj je dolg okoli 300 m. V zgornjem delu vršaja je zaplata flišne naplavine. Karbonatna podlaga izdanja v osrednjem in spodnjem delu vršaja, kjer je površje skalno z veliko gostoto vrtač in škrapelj. Naklon površja je v zgornjem delu do 11 stopinj, v osrednjem delu povprečno 6 stopinj in 12 stopinj v spodnjem konveksnem delu. Spodnji rob vršaja zvezno preide v relativno uravnano kraško površje.

Slika 7: Podolžni profil reliktnega vršaja Obrovnik.
Glej angleški del prispevka.

Največji reliktni vršaj na proučevanem območju se nahaja severno od vasi Lokev in obsega površino 1,8 km^2 (slika 8), Zgornji del leži pod dvema erozijskima jarkoma, ki imata zgornja dela vrezana v flišno matično kamnino. Flišna naplavina prekriva zgornji del vršaja, ki ima naklon do 8,5 stopinj. V osrednjem delu izdanjajo posamezni skalni bloki karbonatne matične podlage. Naklon v tem delu je okoli 2 stopinji. Spodnji del vršaja ima naklon do 9 stopinj. V tem delu izdanja karbonatna matična kamnina v kateri so oblikovane številne škraplje in vrtače. Vršaj se zaključi ob vznožju Taborskih brd na severu, na severozahodu pa zvezno prehaja v kraško uravnavo.

Slika 8: Reliktni vršaj pri Lokvi.
Glej angleški del prispevka.

Slika 9: Podolžni profil reliktnega vršaja pri Lokvi.
Glej angleški del prispevka.

Reliktni vršaj v Zavodih obsega površino 1,1 km^2 in je polimorfen. Zgornji del vršaja leži pod erozijskim jarkom, ki je vrezan v flišno matično podlago. Gre za končno obliko reliktnega vršaja, saj niti v zgornjem delu ni več prekrit s fluvialno naplavino. Podolžni profil je v celotni dolžini konveksen z naklonom okoli 2 stopnji v zgornjem delu in do 6 stopinj v spodnjem delu. Karbonatna matična podlaga je razkrita po celotni površini vršaja, ki je škrapljasta in preoblikovana z vrtačami (slika 10). V zahodni del reliktnega vršaja v Zavodih je vrezana okoli 10 m globoka in 120 m široka dolina, ki sega vse od vrha vršaja do skrajnega spodnjega dela, kjer se zaključi v skupini vrtač. Po dolini občasno teče vodotok in je skoraj v celoti zapolnjena s flišno naplavino.

Slika 10: Podolžni profil reliktnega vršaja v Zavodih.
Glej angleški del prispevka.

Dva reliktna vršaja na vzhodni strani Vrhpoljskih brd sta močno preoblikovana s površinskimi kraškimi oblikami. Identificirana sta bila na podlagi njunega tlorisa in naklona površja.

Severnejši reliktni vršaj s toponimom Boršt obsega površino 0,44 km^2 (slika 11). V zgornjem delu vršaja se nahaja veliko globokih vrtač, ki ležijo tik pod erozijskim jarkom, ki je vrezan v karbonatno matično podlago. Podolžni profil vršaja je v grobem konveksen z naklonom okoli ene stopinje v zgornjem delu in do 5 stopinj v spodnjem delu. Karbonatna matična podlaga, v kateri so oblikovane številne škraplje in vrtače, je razkrita po celotni površini vršaja. Spodnji deli vršaja zvezno preidejo v uravnano kraško površje severozahodnega Matarskega podolja (figure 7).

Slika 11: Podolžni profil reliktnega vršaja Boršt, z večjo vrtačo v zgornjem delu.
Glej angleški del prispevka.

Okoli 0,5 km južneje se nahaja reliktni vršaj s toponimom Dukovce, ki obsega površino 0,19 km^2 in je oblikovan pod erozijskim jarkom (slika 12). Erozijski jarek je v celoti vrezan v karbonatno matično podlago. Pod njim je več vrtač. Karbonatna matična podlaga s številnimi škrapljami in vrtačami izdanja po celotnem vršaju. Podolžni profil vršaja je konveksen z naklonom pobočja do 3 stopinje v zgornjem delu in do 6 stopinj v spodnjem delu.

Slika 12: Podolžni profil reliktnega vršaja Dukovce.
Glej angleški del prispevka.

4 Sklep

Podrobna raziskava kontaktnega krasa Vrhpoljskih brd je razkrila, da so procesi oblikovanja vršajev enaki kot na nekraškem fluvialnem geomorfnem sistemu. Aktivi vršaji so rezultat preteklih in sedanjih površinskih procesov nanašanja naplavine. Na proučevanem območju so oblikovani, ker se ostanek flišne matične kamnine na vrhu osrednjega grebena Vrhpoljskih brd, nahaja visoko nad okoliškim kraškim površjem. Rezultat intenzivnih erozijskih procesov na višjih delih je izdatna produkcija flišne prepereline in posledično sedimentacija tega gradiva preko kraškega površja. Zaradi koncentriranega dotoka materiala, občasni vodotoki ne izoblikujejo slepih dolin, pač pa se na kraškem površju oblikujejo vršaji.

Značilen podolžni profil reliktih vršajev je posledica popolne ali delne prekinitve dotoka vodnih tokov in nanašanja flišne naplavine na območje vršajev. Na preučevanem območju je to rezultat delne ali popolne denudacije flišne matične podlage v območjih erozijskih jarkov, ki se stekajo na vršaje. Proces denudacije flišne naplavine z območja neaktivnih vršajev je manj intenziven kot kemična denudacija okoliškega kraškega površja, kjer izdanja karbonatna matična podlaga. Tako je denudacijsko zniževanje vršajev, ki jih gradi flišna naplavina, manj intenzivno od okoliškega kraškega površja. Rezultat različne dinamike denudacije je značilna oblika podolžnih profilov reliktnih vršajev. Ti vršaji imajo tipično obliko fluvialnih vršajev le v zgornjih delih, katere prekrivajo flišne naplavine. Na območjih, kjer je flišna naplavina denudirana, se pojavi kemična denudacija razkrite karbonatne matične podlage, ki je intenzivnejša. Ker se debelina naplavine vršajev zmanjšuje od zgornjih delov proti spodnjim, so nižji deli prej izpostavljeni intenzivnejši kemični denudaciji, kot zgornji. Obseg pokrova flišne naplavine se zaradi denudacije počasi zmanjšuje v smeri vrhnjega dela vršaja. Površina, kemični denudaciji izpostavljene karbonatne matične kamnine, se povečuje, zaradi česar se oblikuje značilen konveksen podolžni profil reliktnih vršajev. Končna oblika preoblikovanja vršajev v reliktne vršaje je, ko je flišna naplavina popolnoma denudirana. Takšne reliktne vršaje v celoti gradi karbonatna matična kamnina, na kateri so izoblikovane površinske kraške oblike. Njihov tloris je pahljačast, podolžni profil pa popolnoma konveksen. Te oblike v matični podlagi so nekakšne podedovane oblike oziroma psevdooblike vršajev na karbonatni matični podlagi.

Razvoj reliktnih vršajev, ki se pojavljajo na karbonatnem površju so v celoti vezani na kontaktni kras. Vršaji in reliktni vršaji na proučevanem območju vsekakor predstavljajo tipične primere teh oblik, na podlagi katerih lahko tolmačimo oblikovanje vršajev in njihovo preoblikovanje v reliktne vršaje na dinamičnem kraškem površju.

Zahvaljujem se recenzentoma in dr. Karlu Natku za koristne nasvete in pripombe. Posebej se zahvaljujem Brunu Tomšiču za pomoč pri terenskem delu.

5 Literatura

Glej angleški del prispevka.