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FLUVIOKARST LANDFORMS OF THE CANYONS OF BOSNIA AND HERZEGOVINA AS A TOURIST RESOURCE

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Abstract

In this paper, deep fluviokarst canyons reshaped on limestones and dolomites of the Dinarides of Bosnia and Herzegovina were analyzed from the geomorphological and tourism aspects. In the geomorphological sense, fluviokarst canyons of Bosnia and Herzegovina are diverse in the morphogenetic, morphotectonic, and morphological aspect. Mostly, these relief line depressions are most common in the Dinaric mountainous part of central, eastern, southeastern, and western Bosnia and Herzegovina, where the karst terrains prevails. In addition to the geomorphological characteristics of canyons, we highlighted their natural possibilities for the development of various types of tourism.

Keywords: Dinarides, fluviokarst canyons, tourism, Bosnia and Herzegovina.

1. Introduction

"Fluviokarst may be defined as a landscape in carbonate rocks are valley cut off surface rivers" (Gun J., 2004.). Sweeting, M. M.(1972.) points out that fluviokarst is the combined action of fluvial and karst geomorphological processes. According to Field M. S. (2002.):" The Canyon is a steep-walled chasm, gorge, or ravine cut by running water." Lepirica, A. (2013) states that the canyon is a deeply fluvially cut river valley, with subvertical sides, in solid, more resistant rocks. Canyon valleys in Bosnia and Herzegovina are dominantly geomorphologically reshaped by fluvial erosion of fluids (mechanical and chemical) on tectonically jointed limestones and dolomites and belong to the morphogenetic type of fluviokarst (Lepirica, A. 2013, 2005). In canyons, in addition to fluviokarst processes, slope-gravity processes prevail over collapse and shedding, followed by karst-corrosion and fluvial processes. Thus, canyons are polygenetic forms. Gorges offers the ideal setup for practicing various forms of nature-based tourism, from different active outdoor activities practiced by certain categories of tourists, like canyoning, climbing, and mountain biking, to hiking over different distances or levels of difficulty. The interesting genesis and evolution of karst gorges have left expressive traces in some cases, especially in the karstic capture scenario, caves and pits on gorges sides which renders them perfect observation places and didactic destinations. In many gorges, other types of tourism, especially cultural and ecumenical tourism, developed due to various well-known sacred places and monasteries. (Munteanu Gabriela, 2021.) Thus, the gorges are important resources for geotourism, speleotourism and cultural tourism.

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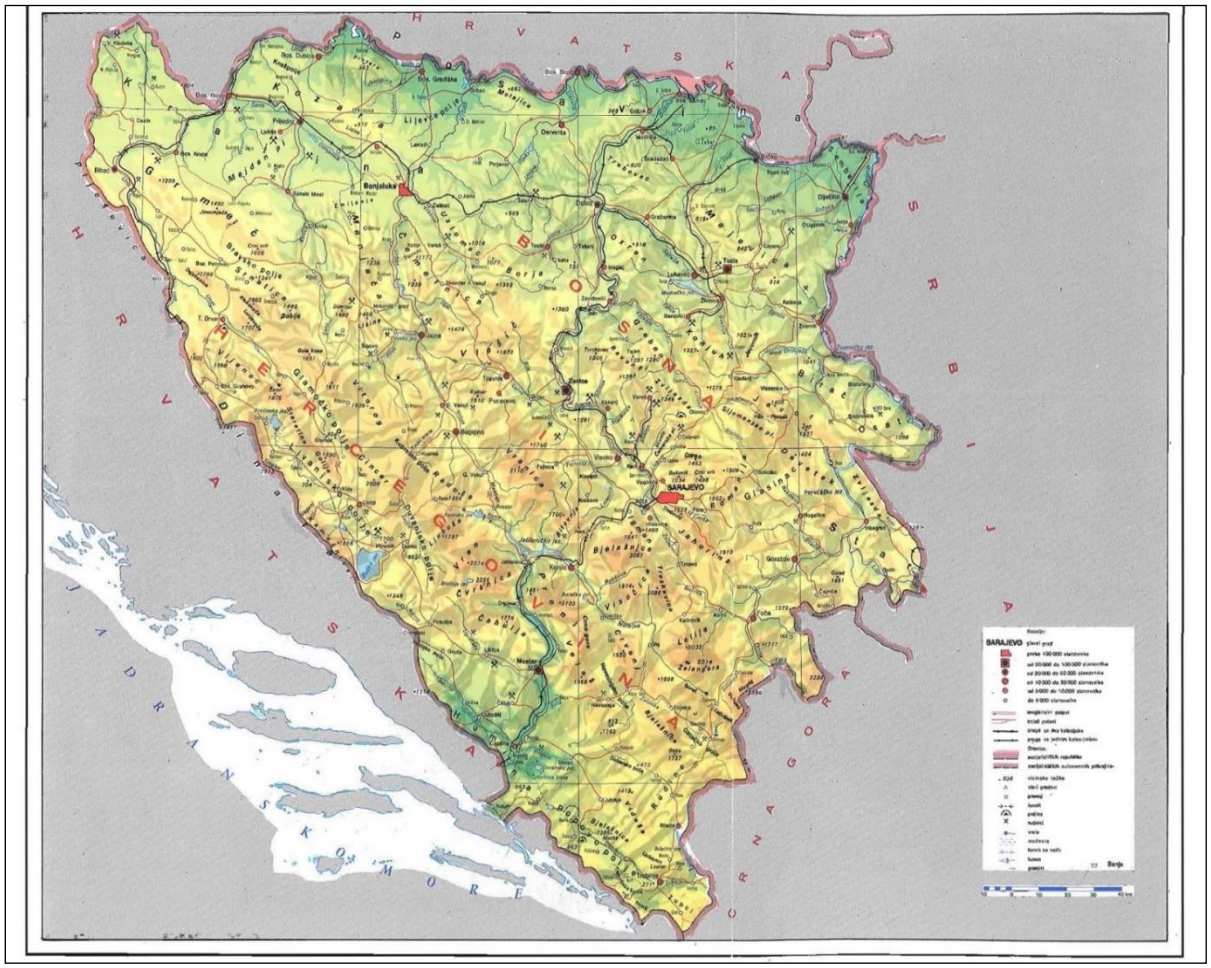

Figure 1. Map of Bosnia and Herzegovina (Source: J. Đ. Marković, 1988.)

2. Methodes and materials

Field methods of direct process observation and form measurement, in situ, during multi-year research, in all seasons of the year, were applied in the work. Also, in the preparation of this work, in addition to the use of a manual compass M-53 and geological compass of the Clar type, in addition to extensive literature, the following were used: OGK 100, Geological interpreters for Basic Geological maps 100, topographic maps TK 25, 50 and 100, Google Earth Satellite 2020, program and the author's photo documentation. Several hundred-meter-deep canyons in Bosnia and Herzegovina were recorded in the work. Then the results of the applied geomorphological methods are listed: morphological, geomorphometric, morphotectonic, and morphogenetic analyses of these linear fluviokarst forms.

Figure 2. The Rakitnica canyon is cut deep into the tectonically fractured Triassic dolomites and limestones of Bjelašnica and Visočica structural unit. Photo: A. Lepirica

3. Discussion and results

The mountainous area of our country is characterized by compressional structures of folded layers, faults, and, neotectonically destroyed thrust belts, generally directed in the southwest direction, towards the Adriatic foreland (Lepirica 2013). The Plioquaternary neotectonic uplift of the Dinaric mountain morphosystem influenced the increase in the gradient of the longitudinal profiles of the river courses and their deep cutting, which resulted in deep canyon valleys with sub-vertical sides. It is a frequent relief appearance that the mountains of Bosnia and Herzegovina, with a dominantly tectonically fissured limestone-dolomite rock, are morphologically separated by deeply incised canyon valleys. Canyons are mostly microtectonically intersected by fissures and paraclases of active faults, and different kinematics, and generally oriented NW-SE and NE-SW. In the morphotectonic sense, our canyons are transverse valleys that cut through the older folded structures of the surrounding mountain elevations at sharper angles.

„Transverse drainages cut perpendiculaty across geological strictures and different formations“(De Waele J.& Gutierrez, F. (2023). In the canyon areas of the Dinarides, this type

of drainage prevails, where deep valleys cut geologically older folded layers at sharp angles due to active fault neotectonics that directed the runoff and fluvial erosion of mountain rivers.
The deepest canyons are the Drina Canyon River Valley and its tributaries Sutjeska in southeastern Bosnia, Neretva Canyon River Valley, and Rakitnica Canyon River Valley in mountainous northern Herzegovina. More precisely, the Rakitnica Canyon, a left tributary of the Neretva, is 930 meters deep and 23.5 km long (Fig. 2). The Neretva Canyon River Valley downstream from Donja Jablanica, between Prenje and Čvrsnica mountains, is about 1200 m deep. Then the 50-kilometer long, lake-filled Drina Canyon, which is more than 1,000 m deep and steeply cut between the mountains of Sušica, Bokšanica, and Tara on the Serbian side. In those parts, the sharp elbow bends of the Neretva and Drina rivers and the orientation of their canyons are caused by fault neotectonic movements (Lepirica A. 2013). (Fig.3.)

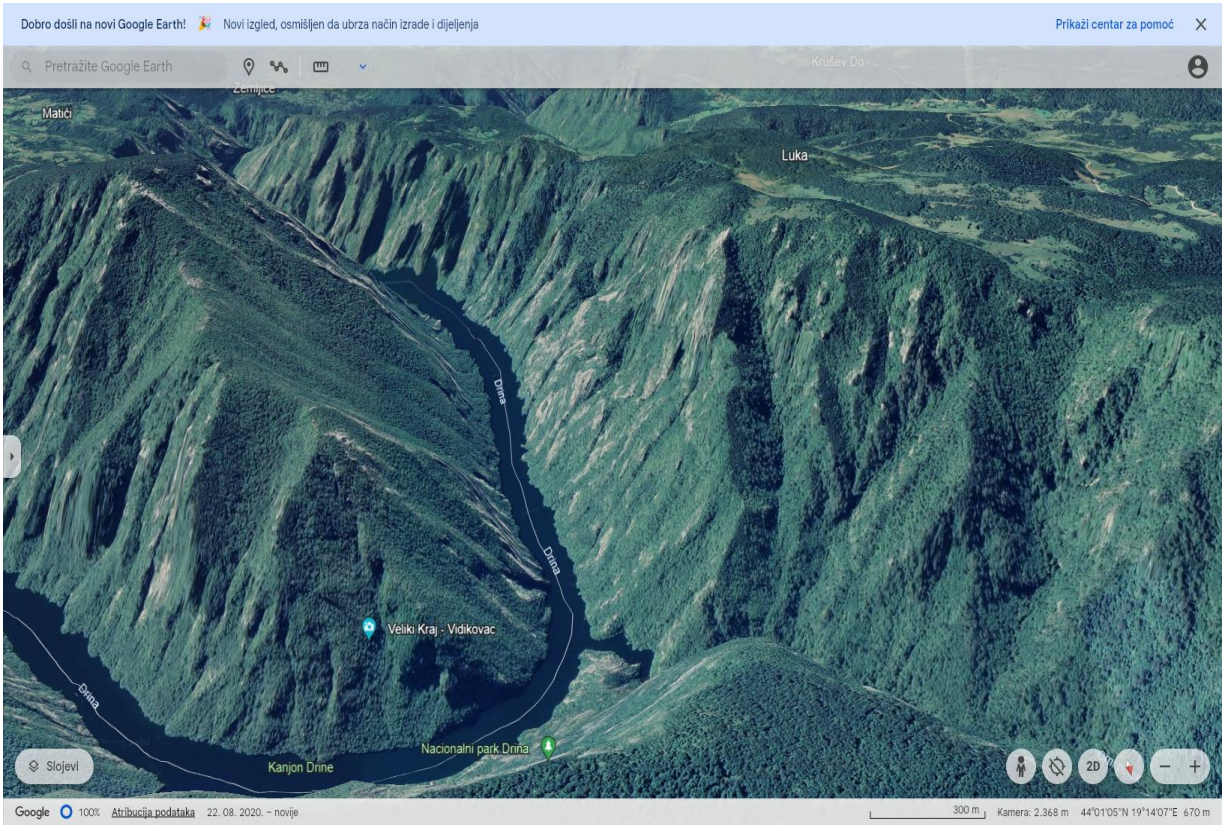

Figure 3. Faulty "elbow" bend of the Drina fluviokarst canyon, cut 1000 meters deep between Sušica and Tara mountain. The left side of the canyon within the "Drina" National Park belongs to Bosnia and Herzegovina (front and center of the picture); the right side of the canyon belongs to the "Tara" National Park in Serbia (left part of the picture); Black Stream Canyon in the lower right part of the picture. Google Earth 2020.

The deepest canyon of the river Sutjeska, between Volujak and Zelengora mountain, called "Prosječenica" - which exceeds 1500 meters in depth. Its tributary Hrčavka also cut a deep canyon with relief energy values (> 800 m/km²). Other canyons in BiH with high subvertical rocky sides are: Ugra and Unca canyons up to 600 m deep. The canyons: Prača, Drinjače, Sana, Stupčanica, Ljuta, Volujčica and others are up to 400 meters deep.

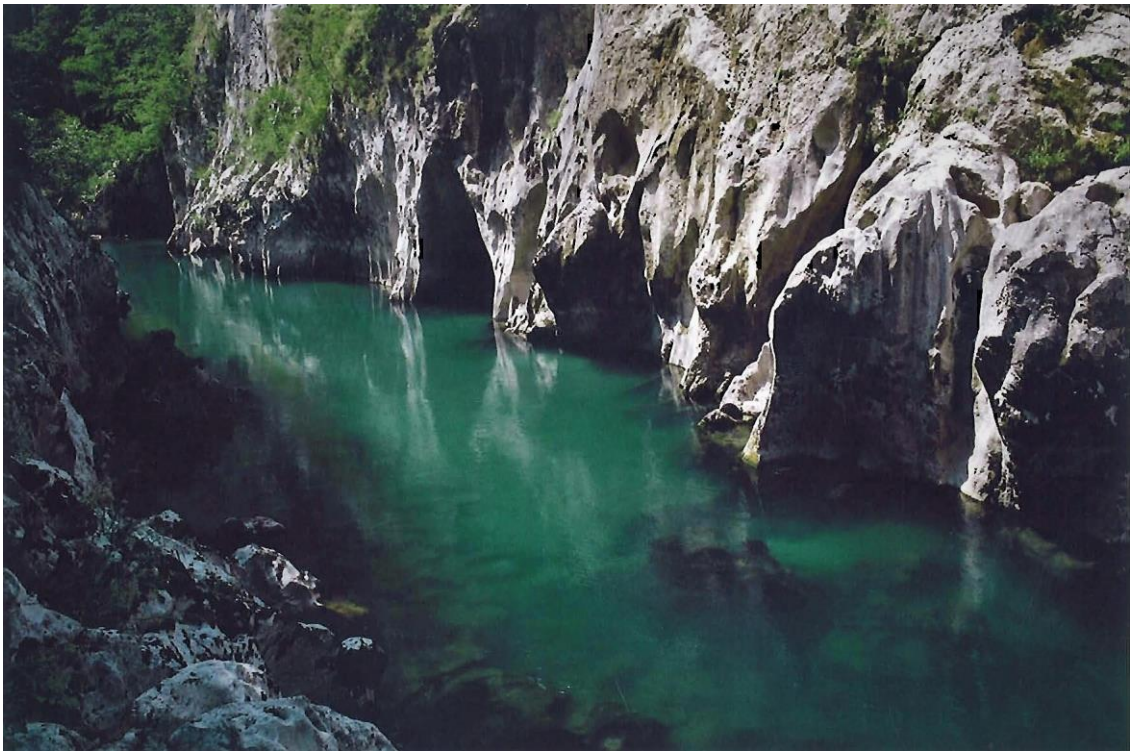

Figure 4. Natural beauty and tourist values are the evorsion potholes in the riverbed of the Neretva Canyon Valley, Photo: A. Lepirica

The fluvio-karst relief is spatially most represented in the central, western, eastern, and southeastern parts of the karstificated mountain areas of Bosnia and Herzegovina. Fluviokarst relief is represented by narrow canyon valleys, inner gorges, and riverbeds shaped by fluvial erosion of rivers in Mesozoic carbonates but also in Quaternary tufa deposits. The canyon sides morphologically represent the lower slopes of surrounding mountains and high plains. Thus, the mountain's lower sides and foothills are orographically represented by tourist attractive canyons. These are local erosion bases at the canyon bottoms which are rocky, often narrow and deep riverbeds with the occurrence of microforms of karrens, kamenitzas, and potholes." The process by which they become giant potholes, the movement of stones or gravel into a vortex and deepening, is called evorsion." (Cvijić, J. , 1924) A special aesthetic note of the geodiversity of our canyons is given by evorsion potholes (evorsio-overturning, lat.) in limestone and dolomite riverbeds: Neretve, Rakitnice, Željeznice, Unca, Vrbasa, Tara, Bistrice, Drinjače, Hrčavke, Stupčanice, etc. (Fig 4.). These microforms visually enhance the natural aesthetics of the environment and represent a tourist attraction. These are the beds of the blue-green river courses: Neretva, Drina, Una, Sana, Vrbasa, Sanica, Ugra, Janja, Unca, and their tributaries. (Fig. 4.)

"Fluviokarst riverbeds in canyons are characterized by the fluid mechanics of the upper watercourses with increased turbulence, which results in an increased mechanical process of corrasion (river abrasion) that erodes narrow and deep rocky beds."(Lepirica,A.,2015.) This is precisely why fast and clean mountain streams with rapids, cascades, and rocky slopes are suitable for rafting, kayaking, and canyoning, so primarily adrenaline sports. The over 1,000-meter deep Tara valley (below Meštrevac on the right, state territory of Bosnia-Herzegovina in the border area with Montenegro), the Neretva canyon, the Una (upstream and downstream from Bihać) are famous for massive rafting, but also for kayaking, canoeing, fly fishing and sport fishing. Special mention should be made of the World Cup in rafting in "Tijesno" - the canyon of Vrbas, which is held every year. Canyons: The rivers Sana near Kljuc, Krivaje near Olovo, and other canyons are famous for massive rafting regattas. Vertical rocky canyon cliffs,

with attractive endemic black pines, rise directly above the fluviokarst canyon river bed. They are often interspersed with fissures and active channels whose sharp-edged colluvial deposits end directly in narrow riverbeds. Due to frequent collapse, large rock blocks cover the canyon beds, which is especially evident in fault zones. These are extremely risky areas for mass canyoning, rafting, climbing, fishing and mountaineering. Subvertical slopes are often represented by rocky cliffs over 300 meters high (Canyons: Neretva, Sutjeske, Drine, Rakitnice, Vrbasa) which is an excellent predisposition for climbers. There are rocky pillars,monoliths (such as Zub in the Miljacka Canyon, monoliths near Grabovica in the Neretva Canyon, Hrčavka Canyon, Rakitnica or Ujče near Kladnje).
Touristically attractive fluviokarst relief forms of rocky windows (fragments of former cave systems) can be found directly above the rivers: Miljacka, Paljanska Miljacka, Čehotina, Dobropoljska Rijeka, Mostarska Bijela (Fig. 5.). "Sometimes cavern collapse has been the principal process producing a gorge." (Ford. & White, 2007.)

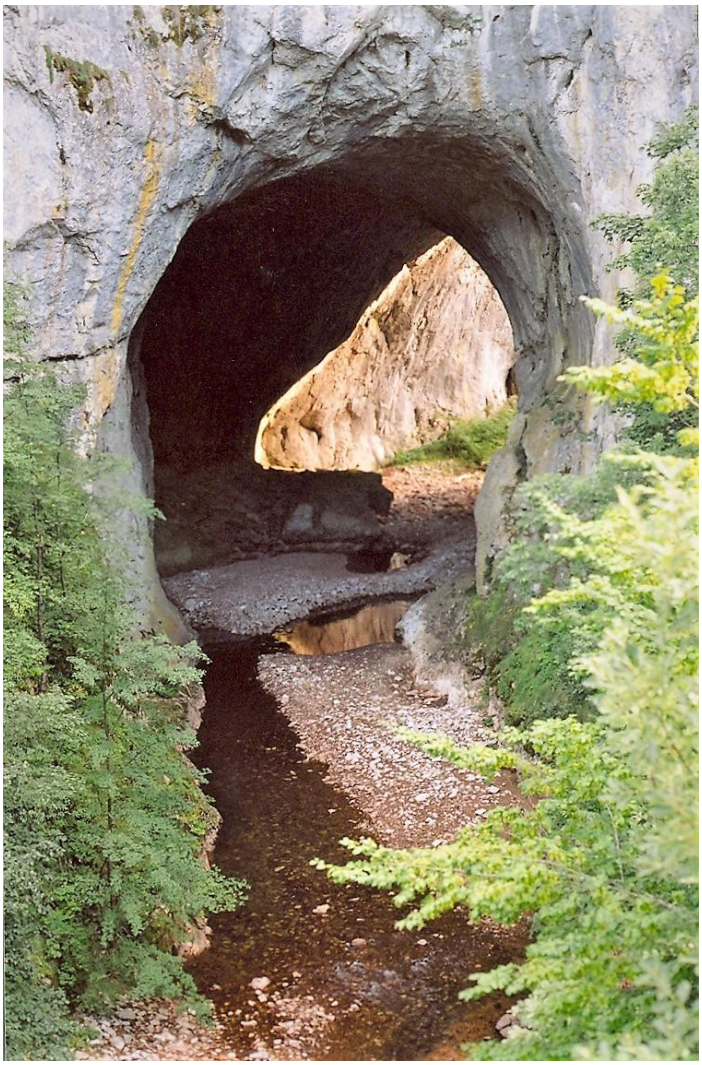

Figure 5. Rocky arch in the Dobropolj Canyon River Valley in the Drina drainage basin, Photo: A. Lepirica

The arch landforms of stone windows are more common on the canyon sides such as: Petera Vrata on the higher sides of the Drina Canyon, above the lower Rakitnica Canyon in Presli, in the lower slopes of Glogovo in the Neretva Canyon, and high above the stream of Mostarska Bijela, in Studešnica in Konjuh, high above the Neretva Canyon in Donja Jablanica and Gornja Grabovice in Glogovo, above Duboka Tajašnica in Tajan, above Misoča. In terms of scenery

and geotourism, the landforms of the rocky arch in Prosječenica canyon above Sutjeska, in the Vrbas valley near Krupa on Vrbas, and Vranić above Drežanka are also attractive.
Especially from the geological point of view and the development of geotourism, the 1000 meters high geometrically regular folded Jurassic and Cretaceous limestones and dolomites of the Neretva Canyon between Grabovica and D. Jablanica and the facet of the northern slopes of Čabulja above the Drežanka valley are very interesting. The Neretva Canyon downstream from Donja Jablanica is also a perspective geopark with distinctly regular sedimentary bank folded layers. We find similar geosites in northern Čabulja and its higher canyons. Then the erosion-covered bank folded layers in the Zgošće Canyon in the Bosnian flysch zone. These are natural geosites that should certainly be a priority offer of geotourism.
The Neretva Canyon, which from a biological point of view is located in the center of the Herzegovina Endemic Center, is connected to specific refugio-relic flora ecosystems that are one of the most important European biodiversity hotspots. (Berberović, A. et al., 2022.)
Powerful karst canyon springs: Sanica, Crnog vrela (tributaries of Una, Una, and Neretva), Sanica, Krušnica, Dabra, Janja, Krupac, Humski vrela, Skakavac and others on the canyon floor or canyon slopes at the foot of our rugged mountains are an important hydrogeological feature, especially with from the aspect of water supply, but also from the aspect of river tourism and recreation. Directly in hydrological connection with them are estavels such as Mračaj near the Sana canyon or abyssal zones in the upper canyons of Hrčavka, Unca, Bregava, Ugrovača. The mentioned karst springs are hydrologically connected with mountain sinkholes and pits whose morphological development is caused by cracks and fissures that tectonically jointed the limestone-dolomite layers.
Geomorphologist Jovan Cvijić (1924, 1926), the founder of World Karstology, called the high and deep karst of the Outer Dinarides with large karst fields the Dinaric holokarst because of the wealth of exo- and endokarst relief landforms and phenomena (surface and underground).
The rocky sides of the canyons are often marked by the appearance of a subvertical height succession of cave openings, which often, at the bottom of the canyon, represent hydrogeologically active zones of karst springs. The appearance of a height succession of cave openings geomorphologically indicates a neotectonic uplift of the terrain with simultaneous deep erosion cutting of the canyon watercourse. According to recent results of speleological research in the mountain zone of Bosnia and Herzegovina, the second longest cave system are the Mokranjska Miljacka. The spring cave and the Dugovještica cave. Govještica or Dugovještica with an entrance in the Prača canyon (below Gosina mountain) is the longest in BiH with 9682 m so far measured (researched by Dr. S. Milanolo). Unfortunately, the Prača canyon, where the cave opening of the mentioned longest Dugovještica cave is, was mined in the last war, which requires additional demining of the canyon terrain! The mentioned speleo-objects are extremely interesting for various types of specific scientific and research tourism - geotourism. Primarily, it refers to: speleomorphologists, karstologists, geologists, geomorphologists, geographers, tourismologists, but also to recreationists and tourists of various profiles.
So, in the canyons, and above them, you can practice sports and recreational adrenaline tourist activities such as: climbing, mountaineering, speleology, paragliding, zip-line and other activities.
In some places, the canyons have stepped profiles with an alternation of steeper and gentler slopes. These are most often landform strath terraces that favor the construction of tourist facilities: restaurants, viewpoints, parking lots, hotels, and other tourist and traffic infrastructure.
Artificial lakes in the canyons: Drina, Neretva, and Vrbasa are relatively warmer in summer (over 20 degrees Celsius), so they are suitable for swimming and other water sports.

Canoeing, rafting, swimming, kayaking, rafting, tourist boats "Lotika", "Zelenika" and a whole host of other activities on the water, in the summer, in the lake part of the deep Drina canyon downstream from Višegrad City to HPP "Peručac" (Fig. 3.). Then the tourist boat "Vodeni Ćiro" which travels through the attractive canyons of Lim and Drina on the artificial lake of HPP "Višegrad".

A specific geotourist attraction is represented by: The Inner Gorges on Rakitnica, on Mostarska Bijela, fluviokarst narrowing "Kazan" on Željeznica River. Then follow the Gudaje River Gorges, the tributaries of the Unca, Korčanica Gorge, and Perišić streams in the Sana basin. We will mention the short gorge near Gornja Grabovica and the inner gorge of the Doljanka in the valley, downstream from Doljana. On the slopes of Majevica, there are fluviokarst gorges with the waterfalls Tavna in Stari Teočak and Bijela near Špionica, and gorges on the river Tinja reshaped in limestone. Also, in the limestone olistoliths of the central ophiolitic belt, we find fluvokarst formations that are attractive to tourists: narrow beds, gorges, and canyons of Stupčanica, near Čuda, Krivaja near Olovo, then Krabanja waterfalls in the narrow fluviokarst bed of Žljeban in the Konjuh mountain.

The canyon sides, above the canyon bottom, are eroded in places by linear forms of fluviokarst beds of "hanging" valleys with tributaries (permanent and periodic watercourses). These are primarily attractive areas with waterfalls (during heavy rains or when the snow cover melts) which are interesting from the point of view of mountain tourism, adrenaline and recreational types of tourism (primarily climbing, canyoning, hiking), and geological, geomorphological and biological research, i.e. the development of geotourism and scientific research tourism. These are the landforms of the" hanging canyons" of Mošćenuša, Ždilac, and Petrajca on the southern slopes of Čvrsnica and Ješevac, Zaomača and Tijesno on the slopes of Čabulja. They are an integral part of the slopes as hanging canyon valleys that morphogenetically belong to the fluviokarst relief. Mountain waterfalls and cascades in hanging riverbeds are a special tourist attraction related to hiking and photography. With its position in the very center of the Peručica rainforest and its wild beauty, the Skakavac waterfall, 75 m high, cascading towards the lower fluviokarst canyon valley of Peručica, captures the attention of tourists and other visitors from the impressive viewpoint on the Dragoš saddle. Mountain waterfalls and cascades in hanging riverbeds are a frequent occurrence. Morphologically, they belong to the hillslope relief, as fluviokarst line landforms of the reshaped hanging valleys (Lepirica, A. 2013.). The periodic Movran waterfalls in Gornja Drežnica and Ješevac are over 250 meters high. The waterfalls of Studeni Potok, with a total height of 350 m, as well as Peruča and Brvošćak are special attractions on the sides of the Rakitnica canyon. There is the "hanging" Međeđe canyon with its waterfalls (Fig. 6.). Somewhat further south are numerous periodic waterfalls of tributaries of the upper Neretva canyon: Jasenice, Šištice. Waterfalls mark the narrow inner fluviokarst gorges of Mostar and Jablanička Bijela at the foothill of the Prenj mountain. In the spring, numerous waterfalls of melted snow and ice are active, hundreds of meters high, which tumble down the mountainsides towards the bottom of the Drežanka valley. The Bliha waterfall in Bosanska Krajina (45 m) beautifies the canyon valley and is arranged from a tourist point of view. The travertine waterfall "fall under the beech tree" of the Janja River tumbles down the canyon bend not far from the karst source of Janj River. North and northwest of the highest Vlašić massif, the Ilomska, Crkvena, and Ugrić waterfalls fall down the rocks into the Ugra canyon. There are also waterfalls in the "hanging" Cvrcika canyon in the Vrbanja basin, not far away. In eastern Bosnia, there are numerous waterfalls in the hanging canyon of the Pršin stream and the travertine waterfalls of Berega flowing into Rakitnica, in the Prača drainage basin. We also find travertine waterfalls of Rijeka in the village of Vrelo in Donji Birč. In eastern Herzegovina, these are the waterfalls: Karakazan in the Radimlja canyon under the Snježnica mountain. Then, the hanging fluviokarst bed of Istup, the right tributary of Radimlja. In western Herzegovina, next to the deep Brina canyon, not far from Posušje, there is the Žukovica

waterfall, and in the vicinity of Široki Brijeg, the Lištice spring with a fluviokarst bed and the 300 m deep fluviokarst canyon Ugrovača. in western Herzegovina. All mentioned waterfalls and canyons should be geomorphological-hydrological natural monuments protected by the state.

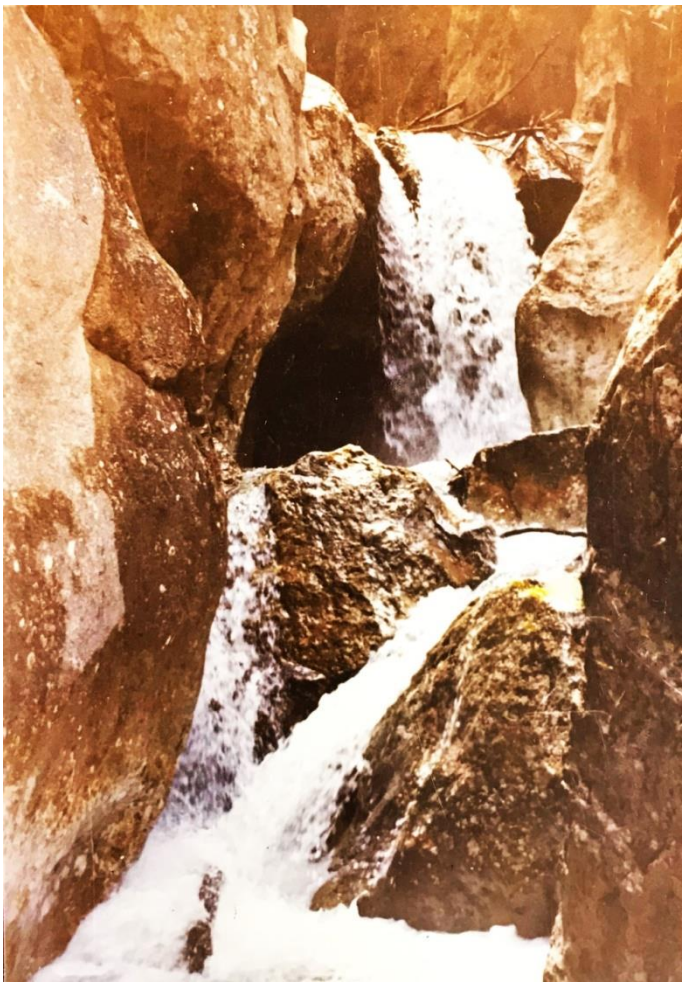

Figure 6. "Hanging" canyon of Međeđe stream cut into the slopes of Visočica, a potential destination for canyoning (photo by A. Lepirica)

Unac, Ugrovača, Radimlja are periodic streams that in their canyons during the year plunge into their sediment in the bed, which is the subject of karst hydrogeology research. In this connection, we should mention Crno Vrelo, the largest karst spring in the Krajina, which emerges in the lower part of the Unca Canyon.

The previously mentioned, lesser-known canyon waterfalls and waterfalls of rivers and streams are less visited by tourists, due to bad tourist promotion, inaccessibility, or poor traffic connections.

On this occasion, special attention should be paid to "care capacity", which refers to excessive visits and noise during rafting in the narrow canyons of Bosnia and Herzegovina, which negatively affects the flora, fauna, and other natural features of the canyon.(Lepirica, A., 2010.) „Their importance as a tourism resource is ensured by their specific landscape and intriguing morphologic features that tourists find appealing: the narrow profile, steep slopes, cave entrances, arches, towers and pillars, waterfalls, rapids, and plunge pools, etc". (Cocean, G. (2013.) (Fig. 7.)

Figure 7. Rafting on the Neretva, Štrojila rapids at the end of May (Photo by A. Lepirica)

4. Conclusions

The fluviokarst canyons of Bosnia and Herzegovina are tourist destinations for active adrenaline sports: rafting, kayaking, canoeing, canyoning, climbing, hiking, speleology. In a visual, landscape-ambient sense, they represent an attractive touristic landscape attractive to recreational tourists. They are also suitable for recreation and rest in wild nature. They are particularly interesting for the development of scientific-research tourism, especially in speleology, karstology, hydrology and geomorphology, and biology because specific refugial communities of flora and fauna have developed there. Recreational and sport fishing is possible in the currently clean watercourses of fluviokarst canyons.

Therefore, it is one of the basic features of mountain tourism, which includes river tourism and geotourism of Bosnia and Herzegovina, which primarily represents tourism focused on the geological and geomorphological characteristics of an area.

If we add to that the neighboring rural settlements, which with their ecotourism, ethnotourism and gastronomic offers, along with cultural and historical landmarks, and have an increasingly attractive recreational function of rural tourism for guests from abroad and neighboring countries, we get the complete content of the offer of the fluviokarst canyons of Bosnia and Herzegovina.

There are many examples such as: Rakitnica River Canyon Valley and the old village of Gornji Lukomir in the central part of Bosnia and Herzegovina, the famous Vrbas River Canyon- near the Banja Luka City because World Rafting Cup (every summer), Žepa and the Drina canyon in eastern Bosnia, Pougarska villages and the Ugra canyon. Janj Canyon River Valley and neighboring villages in western Bosnia. In Herzegovina, these are certainly: Donja and Gornja Drežnica along the canyons of the Drežanka tributary, the rafting centers Đžajići and Glavatičevo not far from the Neretva canyon, as well as many other places.

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