RELIEF CHARACTERISTICS OF THE SANICA RIVER BASIN

Emir Temimović
University of Sarajevo, Faculty of Science, Department of Geography, Zmaja od Bosne 33-35, Sarajevo, Bosnia and Herzegovina
emirtemimovic@yahoo.com

Ahmed Džaferagić
Student of Master studies, Faculty of Science, Department of Geography, Zmaja od Bosne 33-35, Sarajevo, Bosnia and Herzegovina
ahmed_dz@windowslive.com

Based on current data and the results of original research, the paper describes the basic features of the reliefof the Sanica River basin. By using modern computer programs for data processing and field research, a complex geomorphological analysis of relief has been conducted. Based on the obtained data and data from secondary sources, a geomorphological synthesis has been conducted. Also, a geomorphological map of large scale has been made and presented. The paper describes the dominant genetic types of relief and landforms. Special attention is dedicated to the research of karst topography, which features most of the basinand which is characterized by polymorphism and the rare forms. Research of relief is preceded by determining the Sanica River basin, which represents the area of research.

Keywords: *Bosanska Krajina, Sanica drainage basin, Sanica river, relief charactristics, geomorphological map*

INTRODUCTION

Relief is the main component of geographical space. Its design is influenced by many processes, and its impact on other components of the geographic space is expressed in different ways. It is defined by the totality of shapes represented in the Earth's surface that have been incurred and that are constantly changing under the influence of internal and external forces. The characteristics of the relief are determined by the influence of various external forces whose influence manifest geomorphological agents acting on the rock mass in a given time period. Spatially uneven effects of the factors mentioned causes spatial differences. They are manifested in the existence of various geomorphological processes that shape the various forms of relief. Relief, as the most significant component, directly impacts other components of the geographical environment and the physiognomy of the landscape. The study of the relief, in this regard, also has applied importance for many social activities.

Former geomorphological researches in the Sanica river basin were scarce and fragmentary. Prospective descriptions of some forms of relief in the Sanica basin refer to the most accessible works. More extensively, the relief of the Sanica river basin is described in several regional-geographical studies about the river basins of the Una or Sana. Because the knowledge of the relief in the the Sanica river basin is modest, the main objective of this paper is to summarize its basic characteristics. The paper presents results of research conducted for the purpose of the graduate thesis "Geomorphological features of the Sanica

river basin", which A. Džaferagić defended in 2016 at the Department of Geography of The Science Faculty in Sarajevo.

The study is based on the results of the original - field and cabinet research. During the research many scientific methods were used. For the purpose of defining the Sanica river basin, cartographic methods and available data obtained by hydrogeological rerouting of waters were used. For relief studies, among others, were used methods of quantitative and qualitative geomorphological analysis and the method of geomorphological synthesis. Using a modern computer program for processing and presentation of data, ArcGIS ArcView 10.1, analytical geomorphological map was obtained from a digital terrain model. Classification of slope angle and vertical relief dissection was performed according to predefined criteria. Interpretation of analytical geomorphological maps, geological maps, data from secondary sources and data derived from the field research, a geomorphological map was created (in the original scale of 1: 100,000), which was adapted for this study.

CASE STUDY

The subject of this study are the relief features of the Sanica river basin in the northwestern part of Bosnia and Herzegovina. The backbone of the Sanica river system makes up the Sanica river with its tributaries - Korčanica, Sanička river, Trebunj, Biljanska river, Šikmanska and Glibaja. In addition to the above, smaller periodic streams Suhaja and (Smoljan) River in the southwestern part of the studied area belong to the Sanica river system. The available data on spatial coverage and the surface of the basin are different. Because of the different data on the surface of the basin, this study attempts to precisely determine the drainage divide and spatial coverage of the basin. In addition to different data about the surface, one of the problems was determining the belonging of the watercourse Glibaja to the hydrographic system of the Sanica. After examining the available large scale topographic maps from different periods, it is evident that the Glibaja can be considered a tributary of the Sanica, although it now flows into the Sana river. In fact, older cards show that the Glibaja branches before the mouth of the Sana river and partly flows into the Sanica river. Watershed, limited by the drainage divide, encompasses the area between Golaja and Ošljak on the east, Grmeč in the south and southwest and Čelić Kosa and Mrežnica in the west and northwest. Catchment area of Sanica, limited by surface watershed, is approximately 190.74 km^2 (Džaferagić, 2016).

The Sanica river basin is geologically constructed mainly of karsted carbonate. That is the reason of significant deviation between the surface and the underground drainage divide. By tracing undercurrents, it was determined that parts of Bravsko and Petrovac plain drain towards springs of rivers Sanica and Korčanica. Immediate hydrological connection has been established between the watercourses of Suhaja, Smoljan River, Ograđenica and Kozilska Slatina with the springs of Sanica (Project of protection of drinking water sources Sanica municipality of Bosanski Petrovac and Ključ, 2005). Due to the unavailability of data, the underground watershed in southeastern parts of the Bravskog fields is approximate. That part of the plain drains partly towards Korčanica and partly towards Okašnica. In addition, it is assumed that the water from the part of Krasuljska plateau in the east and Hrustovacka plateau in the northwestern parts of the basin drain towards the Sanica river basin (see pic. 1). It was determined that the total area of the Sanica river basin charges is approximately 514.21 km^2. Areas of underground drainage cover 62.91% of the basin (Džaferagić, 2016).

BASIC GEOLOGICAL CHARACTERISTICS OF THE STUDY AREA

Lithospheric complex of the basin area of the Sanica river, in spatial and temporal terms, is very complex. The oldest are permotrias formations that are found in the Biljanska river basin and Gornjosanička valley, and which represent fragments of the so-called "Kljuc Paleozoic". These are allochthonous creations drawn from the northeast. During the pioneer geological studies of the Kljuc Palaeozoic areas they were determined as carbon-permian. Permotrias creations were not paleontologically documented and were selected on the basis of similarities with the creations of Sana-Una Palaeozoic areas. They are presented by porous sandstones and limestones with gypsum and clay (Vrhovčić & Mojićević, 1983).

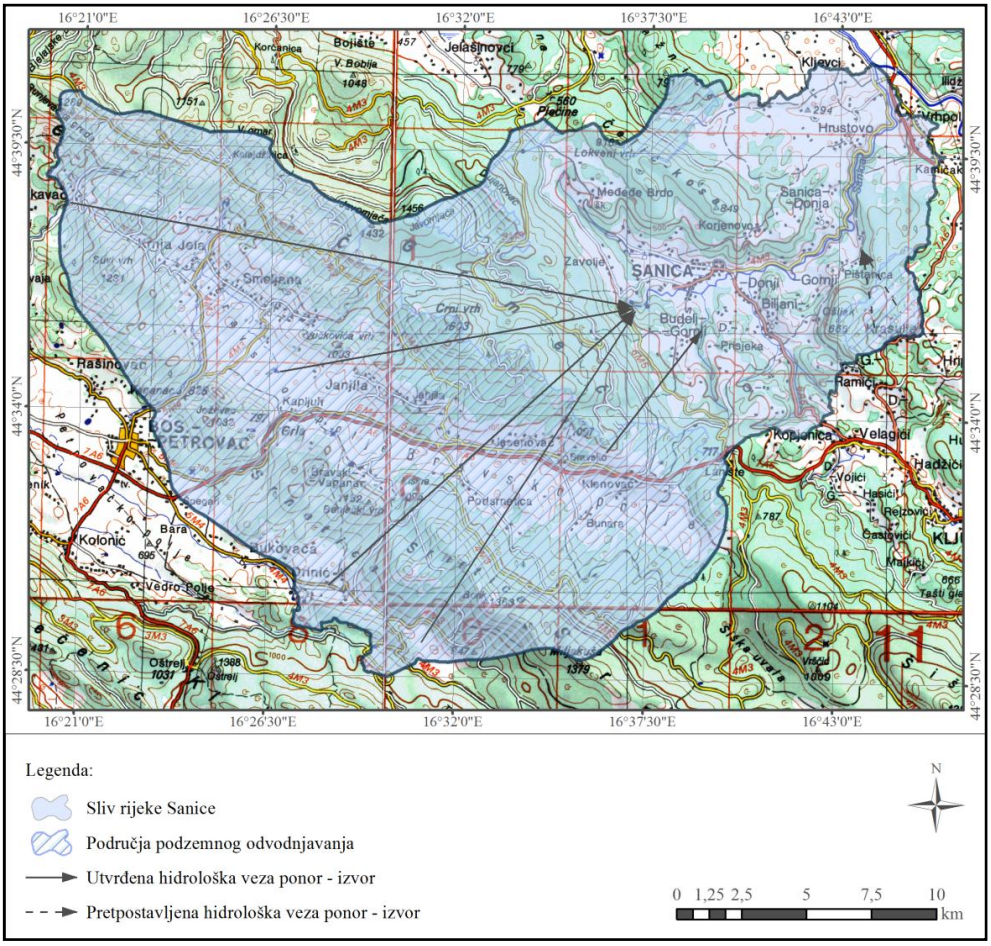

Fig. 1. Sanica River basin including areas with underground drainage

Mesozoic, mainly carbonate, sediments create most of the Sanica river basin. In addition to large spatial representation, Mesozoic formations are characterized by the large thickness of sediments. This is a reflection of the favorable conditions in the sedimentation

period of about 180 million years. Deep-sea conditions of sedimentation have repeatedly been interrupted by the regression of the sea which is indicated by the occurrence of bauxite. The entire Mesozoic column is characterized by significant facial diversity. Jurassic and Cretaceous formations are, in relation to the Triassic, more complete and more developed. In the area of Bosanski Petrovac spatial continuity is present. From Upper Triassic formations located in the center of Petrovac anticline, laterally to the north, continue Jurassic and Cretaceous creations (Šušnjar & Bukovac, 1979). During the Mesozoic, mainly limestone was precipitated. Subsequently, by processes of dolomitization, dolomites sometimes derived from them. From the Triassic date tuffs which indicate volcanism, but from the Upper Cretaceous flysch-like creations. In the southern part of the basin are creations from the Anisian that are part of Petrovac anticline, which are represented by carbonates. On the grounds of Vrhpolje are limestones, tuffs, cherts and sandstones from the Ladinian. In the basin of the Biljan river are allochthonous Carnic and partly Noric black plate and layered limestone, marl, tuff and slate. In the Zavalja area is an areal of younger Upper Triassic or Noric-Rhaetic dolomites. Slopes of Čelić Kosa and Sanička Kosa to Gornjosanička basin and most of the Korjenovo surface make up Upper Triassic dolomites. Dolomites from the same period are found in the western edge of the Kozila bay. Also from this period dated the dolomites that are found in the nucleus and the north-western wing of Petrovac anticline (Šušnjar & Bukovac, 1979).

Jurassic formations on the surface are determined in the southwestern and northwestern part of the Sanica river basin. In Petrovac field and Kozila bay, they are presented by dolomites and limestones. These deposits are part of Petrovac anticline, they are waterproof and are underground drainage dividers of the Sanica river basin. In the northern part of the basin, formations from the Jurassic period are presented by limestones with a significane share of dolomites (Juric, 1977).

The greatest distribution in the Sanica river basin have creations from the Cretaceous period (present in about 70% of the catchment area). Carbonate facies date from Pre Senonian, and in Senon flysch-like sediments were formed and accumulated further in the Paleocene-Eocene. Normal marine shallow-water carbonate sedimentation regime in the earlier period and during the Cretaceous period was maintained by long-term subsidential movements. Immersion phases during this period marked the emergence of bauxite. It was found that the sediments of Cretaceous periods, generally, have a spatial and temporal continuity of sedimentation (Vrhovčić & Mojićević, 1983; Šušnjar & Bukovac, 1979). Lower Cretaceous formations characterize most of the Krasuljska and Hrustovacka plateau, the Čelić Kosa, most of the Grmeč and Srnetica and Bravsko field. They are dominantly represented by limestones, somtimes by dolomites and breccias. Upper Cretaceous formations characterize hypsometrically higher part of Grmeč and are part of the complex Grmeč syncline. They are presented by the flysch-like and flysch formations, or limestone, conglomerates, breccias, marl and sandstone.

Paleocene-Eocene flysch formations are found in the nucleus of the synclinal structure of Grmeč or hypsometrically higher parts of the Grmeč massif. They represent the last pelleted formations in marine conditions before there was an uplift of the terrain and the narrowing of the sedimentation area. Development of clastic deposits of Grmeč is characterized by rhythmic sedimentation of calcareous clastic rocks and breccia, limestone and marl. At several locations in Gornjosanička valley, valley-type widening of the Sanica river at Vrhpolje and Krasuljska plateau are Miocene freshwater sediments. It is believed that these deposits are the remains of a destroyed Neogene basin. Petrographically, they are

presented by limestone, marl, sandstone and clay with coal. In the valley widening of the Sanica and its tributaries are thicker alluvial sediments made up of gravel, sand and silt. On the steep slopes of Čelić Kosa and Ošljak are talusial and proluvial sediments. In the lower part of the flow of the Sanica and spring zone of the Smoljan river there are recent tufa deposits (Džaferagić, 2016).

The Sanica river basin is located in the contact zone of maco-tectonic units External and Central Dinarides. Contact of these two tectonic units is marked by Ključ onlay by which the creations belonging to the tectonic unit Central Dinarides, from the northeast, were drawn to the creations of the External Dinarides or Grmeč massif. Tectonic processes of levying, pulling and faulting during the geological history were very intense. Levying created large anticlines and synclines, which generally are not conformal with relief. These structures were subsequently, by the intensification of radial tectonics, significantly split and broken into smaller blocks. Significant splits are Sanica-Ključ-Medna, by which is predominantly predisposed emergence of Gornjosanička basin and Bravsko-Gornji Ribnik split, which is predisposed to the formation of Bravskoo field (Vrhovčić & Mojićević, 1983; Šušnjar & Bukovac, 1979).

GEOMORPHOLOGICAL CHARACTERISTICS OF THE STUDY AREA

Geomorphological research of the study area is based on morphographic, morphometric, morphogenetic and morphochronological approach, in the context of geomorphological subdisciplines. For the purposes of this study, research is limited to the morphometric analysis and morphogenetic analysis of the relief. On the basis of this are defined the basic morphological characteristics of relief.

Morphometry characteristics

Morphometric analysis of relief of the Sanica river basin includes analysis of primary morphometric parameters - height relations (hypsometry), then tilt and vertical relief dissection, analysis and exposure of the relief, which define the morphology of the terrain. The highest point presented by trigonometric point 1605 m (black top, mountain Grmeč) and the lowest point presented angle 177 m (mouth of the Sanica and the Sana) indicate a high expansion (amplitude) of the relief of the Sanica river basin (1428 m) and expressed relief dynamics (horizontally between the highest and lowest point, approximately 18.81 kilometers). The Sanica basin is characterized mainly by low relief (about 52% of the basin), which includes hypsometric band from 500 m to 1000 m above sea level. In this hypsometric belt are basins of fields and bays in karst, and the peaks of the individual spines and lower parts of the massif. A significant part of the basin (about 20%) is characterized by mountain or subalpine relief. It includes a hypsometric belt 200-500 m and refers to the foreland step, low karst plateau in the foothills. According to hypsometric characteristics, appropriate hypsometry relief of Bosnia and Herzegovina, the study area is characterized by predominantly mountainous and hilly relief.

The slope angle is considered to be often the most important parameter of relief. From the geomorphological point of view, the slope angle is an indicator of the potential intensity of exo-geomorphological processes. Analysis of the structure of the sloping site indicates that gentler slopes prevail. By the angle, the largest part of the slope make up the second category of slopes (3-5°), about 28% of the basin. Just like sub-horizontal slopes, they are

marked by the prevailing accumulation processes. Small slopes (slope values 6-12°) make a significant part of the basin and are generally characteristics of the peripheral parts of basins of fields and plains in the karst. They are marked by destructive slope and fluvial-denudational processes which cause landslides and rockfalls, extractors and gullies. The slopes of the fourth (the value of slope angle 13-32°) and the first category are almost equally represented. Sub-horizontal slopes and flattened surfaces (0-2°) are features of the expansion of the river valley of the Sanica and its tributaries, and the central parts of the basin and bays in karst, and partly in the karst plateau. Very steep slopes (33-55°) are a feature of areas of intensive levying. Slopes of specified interval value predominantly mark slopes of Čelić Kosa and Ošljak to Gornjosanička valley, Sanica canyon, spring zone of the Sanica and partly reefs of Grmeč massif, where attrition is expressed, so thinner or thicker scree and talus cones are formed. Extremely steep slopes, with angles over 55°, are spatially also related to the previously mentioned areas.

Relief energy is a component of the overall relief articulation. Morphological determinant of relief energy represents the height difference between the highest and lowest points in a given unit area. From the geomorphological point of view, it represents a parameter of intensity of development of geomorphological processes. Lowest (6 m/km^2) and highest (518 m/km^2) value of relief energy, indicate that the studied area does not have flattened or very highly articulated relief. It can be seen that the accumulation processes also prevail in the second category of relief energy, and that denudation processes prevail in other categories. Spatially, the largest area (72.4%) has the fourth (values from 101 to 300 m/km^2) category of relief energy, so the relief of most of the Sanica river basin is moderately articulated. Slightly articulated relief (31 to 100 m/km^2) also marks a significant portion of the basin, mainly most of the plateau in the karst, the bottom of Gornjosanička basin, and the edges of fields (Bravsko, Petrovačko) and spacious bays (Bravsko) in the karst. Extremely articulated relief (with values of articulation 301-800 m/km^2) is a characteristic mainly of the contact zone of Gornjosanička valley with the surrounding ridge and Grmeč massif (Džaferagić, 2016). Those expressed values of vertical articulation marked by steep slopes that have expressed destructive slope processes are a consequence of expressed Neotectonic breakout and denudational transformation of the terrain.

An important parameter of the relief is the exposure of slopes. Exposure implies the position of the relief forms whose contour line direction is perpendicular to certain parts of the world. Exposure of slopes affect the intensity of geomorphological processes. The unexposed (without significant exposure) flat surfaces comprise about 11% of total catchment area of the Sanica river basin. North (0 to 22.5° and 337-360°) spatially oriented slopes are the most common (21% of total catchment area) because the shady slopes are generally milder and longer than sunny slopes. Unsuitable slopes with cold (N) and moderately cold (NE, NW) exposures characterize 39.34% of the studied area. This is due to the spatial position of the Sanica river basin, or morphostructural relief features. Slopes with neutral exposures (I, Z) characterize 18.52% of the studied area. Slopes with very warm (S) and warm (SE, SW) exposures characterize 30.81% of the Sanica river basin. Sunny slopes characterize mostly destructive denudation processes. Steep slopes of Čelić Kosa towards Gornjosanička basin are marked by several meters thick proluvial curtains and talus cones. Their development, with the angle of the hillsides, is very significantly influenced by the exposure of the hillside.

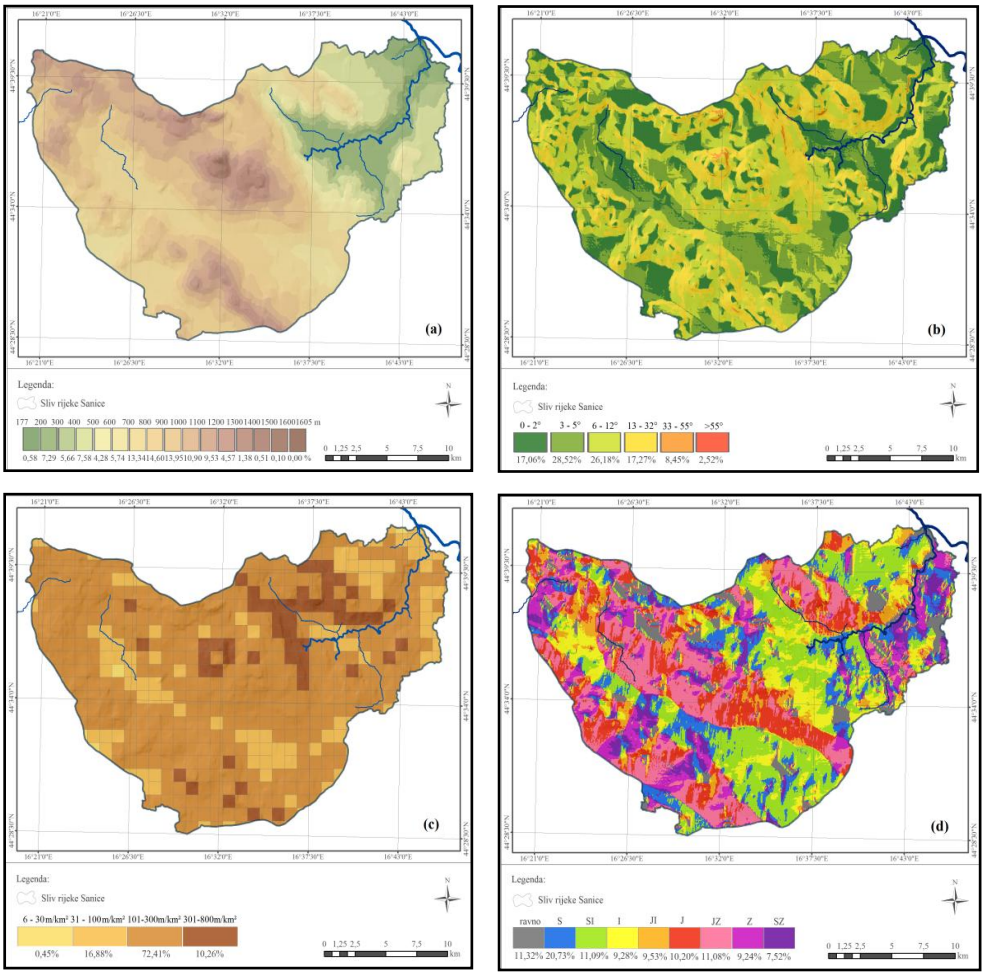

Fig. 2. Hypsometric map (a), slope map (b), vertical relief dissection map (c) and aspect map (d) of the study area

Morphogenetic types of relief

The Sanica river basin is marked by several morphogenetic types of relief. Polygenetics of most landforms caused the difficulty of determining spatial and issuing genetic types of relief. According to the dominant geomorphological processes in the Sanica river basin, karst, fluviokarst, slope, fluvial and sufozioni type of relief are present.

Slope relief spatially is least present (1.85% catchment area) and it mostly forms subvertical slopes of Čelić Kosa and Ošljak towards Gornjosanička basin. Slope processes have been developed on clastic sediments, steeply sloping, sunny and vegetatively denuded slopes. The steep slopes of Čelić Kosa and Ošljak mark a striking extractor on whose ends are, by deposition of colluvial material, formed scree cones, which are several meters thick. On the slopes of the mentioned elevations there are ravines with proluvial sediments and

curtains in the flatter parts of the slopes. Slope processes like colluvial creep, landsliding and slipping are developed on Permotrias and Miocene clastics with a significant portion of clay. They are a characteristic of the upper basins of Biljanska and Sanička river. The most common form of sloping terrain in these areas have been landslides. They are developed on steep slopes, dissected and cupped narrow creek valleys. Their occurrence is mostly anthropogenically initiated. The long-lasting sloping processes, in terms of pronounced tectonic stability, shape pediments and gentle slopes at the foot of the hill. In the studied area pediments are most striking in the peripheral parts of Gornjosaničk basin, and in the contact zone of the valley with the surrounding ridge and Grmeč massif (Temimović, 2009).

Fluvial relief is formed by the action of fixed line flows on insoluble rock mass. Depending on the mechanism of the process, fluvial-erosional and fluvial-accumulation reliefs exist. Forms generated exclusively by fluvial erosion do not exist because they are polygenic. Unlike the above mentioned fluvial-accumulational relief, which is determined by the alluvial plain, it is much easier to sort out spatially. Although fluvial-accumulation processes are dominant in only about 2.41% (or 12.51 km^2) of the studied area, fluvial-accumulation relief is, in terms of anthropogenic utilization, the most valuable. Riverbed is the basic form of fluvial erosion process. The Sanica riverbed is, by the line of longitudinal profile, mostly in tune.Small breaks in the hull are caused by the emergence of accumulation of fluvio-karst travertine barriers (thresholds) with waterfalls. Behind the rocky barriers are formed smaller flow lakes, which resulted in a reduction in flow speed and decreased intensity of fluvial erosion. The depth of erosion is prevalent in spring zone and canyon of the Sanica. In much of the flow, sideways fluvial erosion is dominant, which cuts the coast and expands the riverbed. Larger fluvial-erosional relief forms are the river and stream valleys. Valley of the Sanica is composite and perpendicular to the Sana valley. It is marked by a succession of bay-basin extension and gorge-canyon narrowing. The largest valley expansion is Gornjosanička basin. In the middle and lower part of the river, the Sanica valley is gorge-canyon, deeply cut between Krasuljska and Hrustovacka karst plateau. Fuvial-accumulational processes are a characteristic of the valley expansions. In the studied area there are several alluvial plains formed by the river basins of major rivers. The largest alluvial plains are Sanica plain and Polje in Gornjosanička basin. Alongside the Sanica, there are alluvial plains like Potkosa at Pištanica, Bare at Vrhpolje and Sastavci at the confluence of the river Sanica in Sana. Alluvial plains with thin alluvium distinguish the bottoms of Bravsko and Petrovac plain.

Karst morfo-sculpture is most common in the Sanica river basin (includes about 83.66% or approximately 430.20 km^2) (Džaferagić, 2016). Karst of the studied area is characterized by different genetic and morphological types of karst. In accordance with the degree of development of karst forms, holokarst prevails. Because covered karst spatially dominates, exo-karst micro-relief forms are rare. It is assumed that the rocks are formed by corrosion under a layer of soil, so they are difficult to spot. Representative oysters are present in the village of Smoljana and Krnja Jela, or in the southwestern part of the basin. Unlike oysters, cracks are more frequent karst features. Mesh cracks dominate, and at several locations during field research in the area of the village Krnja Jela were observed and ribbed cracks smaller. Sinkholes (local name of a small valley) in the studied area the most common exo-karst relief form and at the same time an indicator of spatial presence of karst. Spatially, the largest concentration of sinkholes is in the western part of Hrustovačka plateau (over 90 sinkholes per km^2), and slightly lower in the peripheral parts of Bravsko field and in part of the Petrovac plain belonging to the studied area. These areas, due to the

extreme number of sinkholes (number of occurrences over 40 per km^2) have the characteristics of covered pock karst. The average number of sinkholes in the Sanica river basin is approximately 24 km^2 (Džaferagić, 2016). According to genesis, most of the sinkholes are normal type sinkholes. They also have an active hydrogeological function (strainer sinks), and their bottoms are often covered with ruddle. By their morphological appearance, most dominant are cupped and funnel-shaped valleys, rounded or oval and sinkholes. Type examples of smaller funnel-shaped sinkholes mark by a large bay and the field in Bravsko karst. The bays are larger exo-karst landforms. The largest bays are Bravsko, Majdanska, Kozila, Uvalica, Kotao and Palež. Bravsko bay orographically separates morpho-structures of mountains Grmeč and Srnetica, and Kozila bay separates morpho-structures of Srnetica and Klekovača. Most coves are of polygenic origin. Most dominant are elongated oval and the Dinarides oriented coves, with slightly oblique sides, with tilted and flattened bottoms. Most coves are marked by the presence of a large number of sinkholes in their bottom, especially around the perimeter.

In the Sanica river basin there are two fields in karst: Bravsko plain and the southeast end of the Petrovačko plain. Bravo plain separates the mountain morpho-structures of Grmeč in the northeast and the Srnetica in the southwest. Petrovačko plain from the southeast is surrounded by Srnetica. The emergence of Bravsko plain and the southeastern part of the Petrovačko plain is predisposed. The area which they encompass is marked by relief inversion. Consequently, coves of the fields in karst are formed in places of destructed anticlines (Vrhovčić & Mojićević, 1983; Šušnjar & Bukovac, 1979). In addition to their origin and development being tectonically preconditioned, numerous exo-geomorphological processes influenced their morpho-evolution. In the modern period, corrosion is the dominant process by which they are shaped. The central parts of the fields are characterized by fluvio-accumulational relief, because the fields in the karst represent local erosion bazis of the surrounding hills. Through the northwestern part of Bravsko field, the Smoljana river flows, and through the southeastern part of the Petrovačko plain flows the Ograđenica. These are periodic allogeneic streams which are formed on the flysch or dolomite subjects, which stay thin on alluvium in periods of increased flows and plunge to contact with cracked carbonates.

In the northern part of the studied area there are parts of several vast plateaus - Krasuljska and Hrustovačka plateau. The spatially smaller flattened forms are located in the outskirts of the Grmeč massif (eg. Surface Attic). According to its position in relation to the adjacent ridges, Hrustovačka plateau is considered the sub-step, and is considered Krasuljska the more independent plateau. Structural-geological analysis of a set of areas that the plateau includes indicate that their morphogenesis was most likely caused by thrust tectonics. Krasuljska and Hrustovačka plateau were formed in Mesozoic carbonates and are dissected in by Sanica canyon. Many smaller karstified elevations, barriers, valleys, bays and dry valleys condition the relief articulation at the micro level (Džaferagić, 2016).

In the Sanica river basin are present several dozen caves. By its dimensions, Jojkinovac cave near the village Bravsko stands out the most. It was considered the deepest cave until Nevidna Voda (654 m deep) was discovered. By speleological researches which determined the depth of the pit, were done by members of the Speleological Society "Novo mesto" from Slovenia in the eighties. Cave channel is vertical and sub-vertical to a depth of about 420 meters when it becomes almost horizontal (Bucar, 1992). Caves are more numerous compared to pits. The most important and most famous is Hrustovačka cave which represents a significant archaeological site. The cave is located near the village Hrustovo,

south of the springs of Glibaja. It consists of two cave channels, the main which is about 725 m long, and the minor channel which is approximately 1492 m long (Lajovic & Malečkar, 1983). Because of their size, Vrana, Dvogrla and Čelićka cave on the Čelić Kosa and Ledenica, Racine, Banjčeva, Tunelska, Dragišića and Božića caves as part of Grmeč massif.

Fluviokarst relief marks the upper parts of the basins of Suhaja, Smoljanska River, Sanička River and streams Ograđenica and Kozilska Slatina. It is formed on lower-soluble carbonates (grusificated dolomites, marls, marly limestones) which are, according to their hydrogeological function, mostly impermeable. This was reflected in the existence of a relatively dense network of surface streams in these areas. Canyons and gorges are considered flaviokarst forms. The most striking is the canyon of Sanica which is about 2 km long and over 100 m deep. A representative example of a blind valley is the valley of the Smoljan river which plunges into the Brava plain. The occurrence of abundant karst springs in the studied area is conditioned by their contact with the commutator insulator rocks. This contact is very striking and it has marked the emergence of more wells in the peripheral parts of Gornjosanička basin. Springs of the Sanica and Korčanica are the most generous in the studied area. The Sanica springs are interconnected and make a system of springs that are located in more hypso-metrical levels. The system of springs consists of inactive (cave in the department over the Sana Lake), periodically active (Saničko Lake, Varda) and permanent (Sanica) hydrologically active springs (Džaferagić, 2016). Fluviokarst waterbed of the lower course of the Sanica is marked by limestone islands and barriers phenomena waterfalls, cascades and rapids. The most striking are the barriers by which Sanički Buk and waterfalls at the confluence of the Sanica in the Sana River are formed.

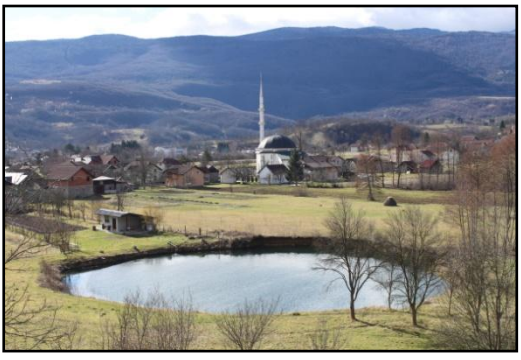

Fig. 3. Šivićevo lake (synkhole)

In the Sanica river basin are present forms of suffosional chamfers, which the locals call “abez”. They have similar morphogenetic and morphographic features like funnel-shaped sinkholes. Two larger “abezes” (sinkholes) are formed in a peripheral, northern, part of Gornjosanička basin. They are located at sites Zolaci and Brkići, which are 2.5 km away from each other. They were formed by the dislocation (faulting) which separates the two completely divergent geological formations. Fault zone is characterized by allochthonous tectonics by which the Upper Triassic sediments are routed over the Permian-Triassic (Vrhovčić & Mojićević, 1983). Suffosional chamfer Šivićevo lake created in November 2013, has a diameter of about 45 m and an assumed depth greater than 70 m.

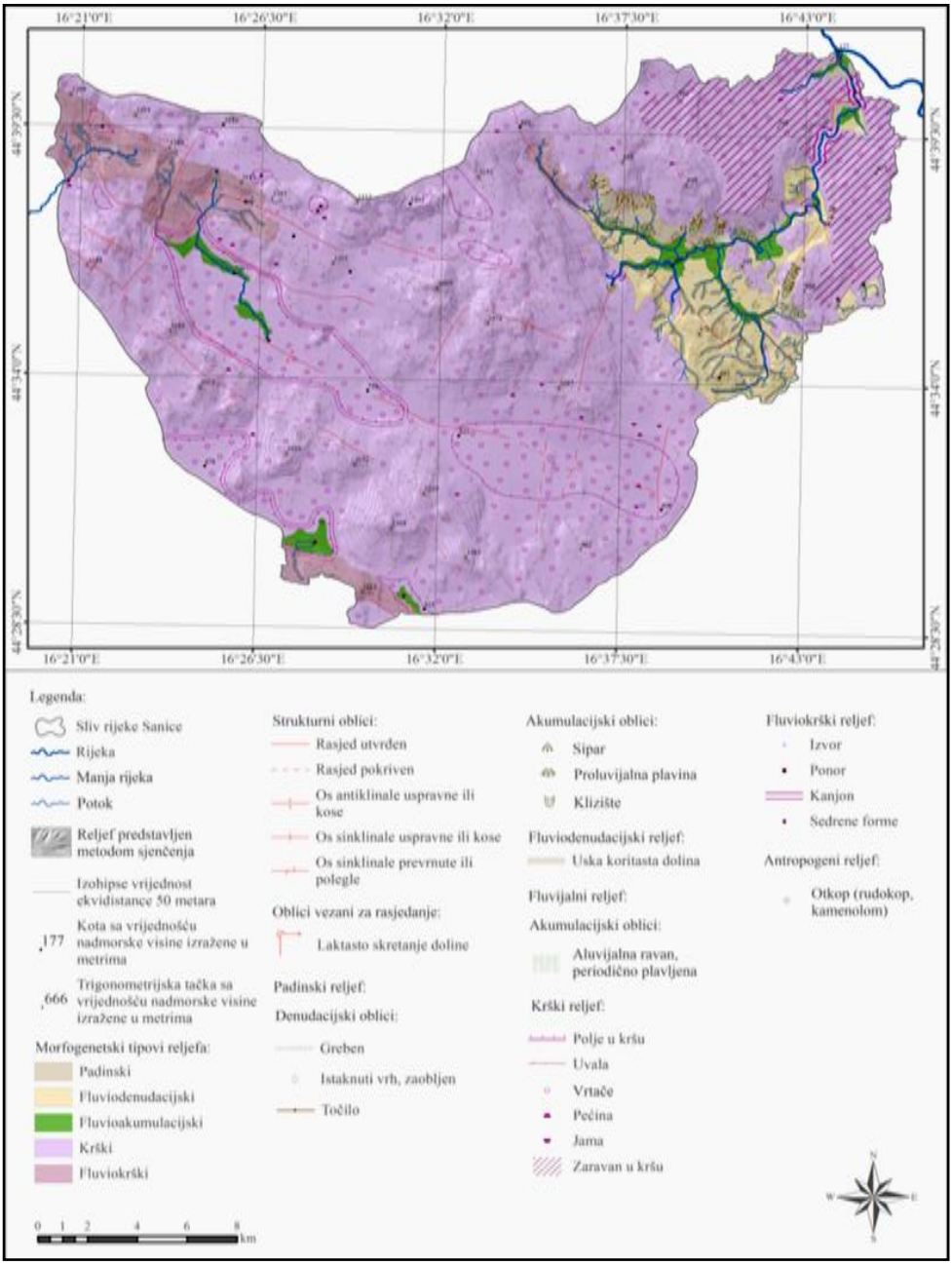

Fig. 4. Geomorphological map of the Sanica River basin made in the original scale of 1:100.000 by morphogenetic principle using the software ArcGIS, ArcView 10.1

CONCLUSION

This research found that the development of the relief in the Sanica river basin is primarily caused by its geological structure. The processes of collecting, pulling and faulting caused the formation of morpho-structures. For modifying morpho-sculptures of primary importance is lithology. Due to the prevailing limestone composition and fissures of rocks karst relief prevails which is marked by polymorphism forms. Some karst and transitional fluviokarst and suffosional landforms are rare (Šivićevo lake, travertine barriers) and very representative (Bravsko plain as an example of green pock karst, system of Sanica springs, cave Jojkinovac). Geomorphological complex, which refers to the Sanica river basin, in addition to the above, also marks slopes, valley and fluvio-accumulational relief. Slope processes like crumbling and collapsing are most pronounced on steep and sunny slopes of Čelić and Sanička Kosa on which large extractor and scree cones and talus are observed. The sliding process in combination with fluvial erosion are the main processes that shape the valley relief that has been developed in the basin of the Biljanska and the Sanička rivers. Fluvio-accumulational relief is represented by alluvial plains that are located along the Sanica river and its larger tributaries and also in Bravsko and Petrovac plains.

Morphometric characteristics of the relief are a reflection of the effects of structural-geomorphological and exo-geomorphological processes. Analysis of the primary relief parameters indicate preponderance of mountain-hilly relief which is characterized by moderate relief dynamics. By analyzing the vertical dissection of the relief, it is evident that the most spatially dominant is the articulated relief and that the studied area has flattened and very highly articulated relief. Areas with more pronounced vertical dissection and slope angles are characterized by high energy relief, and are marked by destructive slope processes. The spatial differences of quantitative values of geomorphological parameters can be traced on the presented analytical geomorphological maps. By comparing it to the geomorphological map, it is possible to predict, to some extent, the development of certain geomorphological processes in a particular area. The presented geomorphological map can be used for the purposes of regional planning and evaluation of the geographical environment for different purposes.

Literature and sources:

Bučar, Z., 1992: Pregled jamarskih raziskav na planini Grmeč = Pregled speleoloških istraživanja na planini Grmeč, Dolenjski kras, 3, 52-57.

Džaferagić, A., 2016: Geomorfološka obilježja sliva rijeke Sanice, Diplomski rad, Odsjek za geografiju Prirodno-matematičkog fakulteta Univerziteta u Sarajevu, Sarajevo

Jurić, M., 1977: Osnovna geološka karta 1:100.000, Tumač za list Prijedor, Savezni geološki zavod, Beograd

Lajovic, A., Malečkar, F., 1983: Jama Hrustovača pri Sanskem Mostu - predlog turistične ureditve = Pećina Hrustovača kod Sanskog Mosta – prijedlog turističkog uređenja, Naše jame, 25, 41- 44.

Projekat zaštite izvorišta vode za piće Sanica, općine Bosanski Petrovac i Ključ, Rudarski institut, Tuzla, 2005.

Šušnjar, M., Bukovac, J., 1979: Osnovna geološka karta 1:100.000, Tumač za list Drvar, Savezni geološki zavod, Beograd

Temimović, E., 2009: Rijeka Sana-potamološka studija, Goldprint, Ključ

Vrhovčić, J., Mojićević, M., 1983: Osnovna geološka karta 1:100.000, Tumač za list Ključ, Savezni geološki zavod, Beograd

Authors

Emir Temimović, doctor of geographical sciences, associate professor at the Faculty of Science, University of Sarajevo, Bosnia and Herzegovina. Editor of the scientific journal Acta geographica Bosniae et Herzegovinae; author of 25 scientific papers and three books from the scientific domain of physical geography.

Ahmed Džaferagić, student of Master studies at the Department of Geography, Faculty of Science, University of Sarajevo, Bosnia and Herzegovina.