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GEOHERITAGE SITE TUBIĆA CAVE (SW SERBIA) – MAIN CHARACTERISTICS, VALUATION, CATEGORIZATION AND GEOCONSERVATION

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Tubića Cave, one of the major speleological sites in Serbia, is located within a short distance of Sjenica, on the Pešter Plateau (Pešterska visoravan). It has been explored on several occasions since 1914. In the period 2018–2024, the authors of this paper conducted field research of Tubića Cave, with a focus on the cave's hydrographic characteristics. Considering that the Cave was listed in the Inventory of Geoheritage Sites in Serbia in 2004, the aim of this paper is to define its qualitative and quantitative characteristics in order to carry out its geoconservation as successfully as possible. The methodology used in the paper is based on determining the total value of geoheritage site Tubića Cave according to the following criteria: scientific value, other values, the functional value and vulnerability. Research results show that there are possibilities for increasing the total value of the cave and its importance from the current, regional level to a higher level, as well as for sustainable development of the entire region by connecting the cave to other geoheritage and cultural-historical sites in the vicinity through geotourism.

Keywords: Tubića Cave, geodiversity, geoheritage, geoconservation.

INTRODUCTORY REMARKS

The term geodiversity first appeared in a Tasmanian Forest Commission document, intending to describe the diversity of phenomena, features, processes and systems on Earth (Sharples 1993). The second recognized use of the term as it relates to the description of the geotope conservation in German-speaking countries (Wiedenbein 1993, 1994).

Geodiversity can be defined as the variety within the entire abiotic world, which encompasses the natural range of geological, geomorphological and soil features, assemblages, systems and processes. It also includes evidence of the history of the Earth - the history of past life, ecosystems and environments as well as the range of biological, hydrological and atmospheric processes currently acting on rocks, landforms and soils (Gray 2004, Kozlowski 2004, Artugyan 2016, Palacio-Prieto 2016). Stanley (2000) explained geodiversity as "*the link among people, landscape and their culture: it is the variety of geological environments, phenomena and processes that make those landscapes, rocks, minerals, fossils and soils which provide the framework for life on Earth*".

Dixon (1996), recognized geoheritage as "*…those components of natural geodiversity of significant value to humans*" whereas Wilson (1994) considered it "*…as the inheritance of rocks, soils and landforms (active and relict) and the evidence they contain that enables the history of the Earth to be unraveled*".

Geoheritage phenomena can be grouped as immoveable and moveable (Maran Stevanović 2018). Immoveable or *in situ* geoheritage refers to the areas or localities with clearly pronounced geological, geomorphological and pedological characteristics, including geological and soil profiles, ore and fossiliferous sites, surface and underground forms of relief, structural and tectonic elements, relict and active hydrogeological features and processes, types of soil and their relict and active processes of formation. Moveable or *ex situ* geoheritage objects are representative specimens of minerals, rocks and ores, fossilized remains of plants and animals, as well as the traces of their life activities, kept within the geological and natural history collections in museums and other scientific, educational and cultural institutions.

Geoconservation plays a considerable role in helping to deliver sustainable development through conserving and promoting scientifically, educationally and culturally important geoheritage features, sites and specimens of an individual region, a country's economic wealth or cultural identity (Burek & Potter 2004, 2006). Geoconservation involves a set of actions focus on protecting, conserving, presenting and promoting the geodiversity and geoheritage for their intrinsic, ecological and heritage values. Beside the preventive protection, geoconservation also includes development and improvement in the field of scientific and professional research, legislation, education, spatial and urban planning and tourism (Maran Stevanović 2014).

PREVIOUS AND RECENT INVESTIGATION OF THE TUBIĆA CAVE AND ITS MAIN MORPHOLOGICAL CHARACTERISTICS

Tubića Cave, one of the major speleological sites in Serbia, is located in the northwest part of the Pešter Plateau, five (5) kilometers from Sjenica, inside the village of Donje Lopiže, the Repište hamlet (Fig. 1).

The earliest exploration of Tubića Cave was carried out by Borivoje Milojević in July 1914. Due to the fact that his notes from those explorations had been destroyed by fire during the First World War, Milojević stated only some general facts about this topic from his memory in his paper "On caves in Uvac Canyon and area of Donje Lopiže village", which was published in 1921, and focused more on the hydrological rather than to the morphological characteristics of the cave. Milojević states that the cave begins with a chamber and ends with two chambers, as well as that there are two cave passages, stretching in two directions, northwest and northeast. In addition to the main channel, there is also a side channel that branches off to the left from the main one, bends in a semicircle, and after another 200 *m* rejoins the main channel. The main channel is four meters high (at some places it is up to 10 *m* high), around two *m* wide and 1,000 *m* long. The height of the side channel is one *m*, and its width is 0.5 *m* (Milojević 1921).

Miloš Zeremski explored Tubića Cave in 1956, and the results of his explorations were published in 1967. Zeremski places far greater importance on the morphological characteristics of the cave than on its hydrological characteristics. He states that the cave entrance is between eight and 10 meters high and three meters wide at the base. An egg-shaped daylight hole can be observed to the left of the entrance, measuring 1.5 – 2 *m* in diameter. Zeremski made the first cross section of Tubića Cave, which shows four additional side channels that were not recorded by Milojević. Those include two right-side channels located at the very entrance to the cave, at the seventh and twenty-seventh meter, which are rather small in terms of their length (25 *m* and 18 *m*, respectively), and two left-side ones, one of which is located near the cave entrance and the other one is located near the exit.

Fig. 1. – Geographic position of Tubića Cave.

Zeremski explored only 35 *m* of the first left-side channel, because the rest was covered in river silt, clay and sand. That channel was mentioned by Milojević as well. The other left-side channel was also explored by Zeremski, a 100 *m* of it to be precise, because the rest of it was filled with water. Zeremski also concluded that the fluvial process had been completed in the first two side channels (the right-side channels), that it was in its final phase in the third one (the first left-side channel), while in the fourth one (the other left-side channel), the fluvial process was still being active and dominant compared to the karst process due to the absence of speleothems.

He states: "*Such a morphological and hydrological state of the side channels of the cave is consistent with the law of development of the fluvial – karst process taking place on the longitudinal section of recent caves, when the fluvial process is being replaced by the karst one first in upper parts of the cave, and then gradually moving to the lower end of the cave, towards the local erosive base*". *In this particular case, it shows processes' total dependence on the local erosive base, namely Uvac.*" (Zeremski 1967, p. 250).

Zeremski noticed four cave chambers in Tubića Cave, but unlike Milojević, he did not mention two chambers at the end of the cave, but only one. In observing the chambers, he arrived at the same conclusion regarding the fluvial – karst process and its dependence on the position of its local erosive base – Uvac, given that speleothems appear only in the first and partially in the second chamber, while they are completely absent from the third and fourth. According to Zeremski's measurements, the main channel of Tubića Cave is 820 *m* long, while its side channels measure 180 *m* in length. The absolute height of the cave entrance is 1,020 *m*, and the absolute height of the cave exit is 980 *m*. accordingly, the average slope of the main channel is 48.7%. In addition to making a drawing of the cross section of the cave, Zeremski drew the longitudinal section of the cave. Five fractures can be observed in the longitudinal section of the cave, of which the ones in the lower section of the cave measure around 3 *m* in height, and the ones in the lower section around 1 *m*. He states: "*Each fracture indicates the stage reached by the rearward alignment of the longitudinal section of the cave, counting from the local erosive base. This is confirmed not only by their presence, but also by the gradual reduction in their relative height going upstream from their base*" (Zeremski 1967, p. 251). Tubića Cave is characterized by a large number of terraces that appear on both sides of the cave channel. The height of the terraces decreases from the lower to the upper part of the cave, which also supports the claim of rearward alignment of the longitudinal section of the cave with the local erosive base. Zeremski considers this cave a distinctly composite river cave since chambers and narrows alternate inside the cave, resembling basins and gorges in composite river valleys (Zeremski 1967).

Members of the speleological and mountaineering club "ASAK" from Belgrade carried out explorations of Tubića Cave from April 1982 to August 1984. Those explorations showed that the main cave channel is 797.5 *m* long, while the total length of the side channels amounts to 1,131 *m*, which means that the total length of all channels in Tubića Cave is 1,928.5 *m* (Fig. 2).

The first left-side channel is situated at a distance of seven meters from the entrance in the wide part of the main channel on a 2.5 *m*-high terrace.

Its ordinal direction is northeast, and its total length is 89 meters. The channel has an average width of one *m*, while its height decreases from nine *m* to 0.7 *m* from the entrance to the end. Two side channels have also formed; the first one at the height of two meters, and the second one at the level of the cave floor. An entrance to the second channel is located on a 1.7-*m* height terrace, at 151.5 *m* from the entrance to the cave. The difference between the highest and lowest point of the channel is 10 *m*, and its total length is 16.5 *m*. The first right-side channel is located at 171 *m* from the cave entrance, to the right. Its total length is 6.5 *m*, and at 2.5 *m* it goes under the main channel. At 238.5 *m* from the cave entrance, you can enter the third left-side channel via a 1-meter-high step. This channel's ordinal direction is northwest. It is 44 *m* long, around 3.5 *m* wide and 1 *m* high. Its height changes significantly only at 41.5 *m*, where there is a 20-meter-high chimney along the right-side wall. There is clay on the floor, and small-size speleothems occur only sporadically.

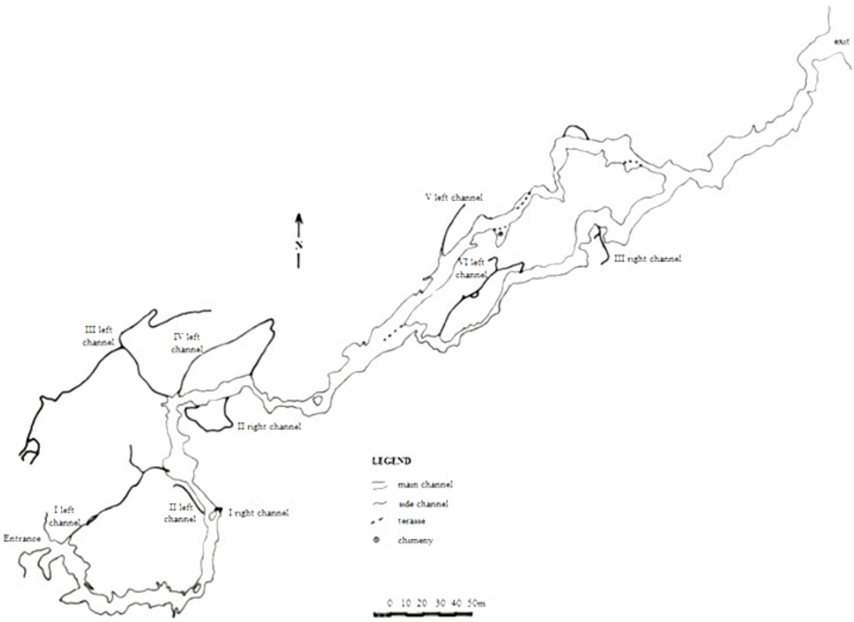

Fig. 2. – Cross-section of Tubića Cave (Zlokolica & Ivošević 1984).

At 45 *m*, there is a crossway, from where the right branch extends towards southwest, and the left branch towards east – northeast. The right-side channel is 76 *m* long, 1–1.5 *m* wide and 1 *m* high, with the height decreasing towards the end, making the channel impassable. The left-side branch has the total length of 154 *m*, its average width is 2 *m*, while its height increases towards the end, and reaches 8 *m* at the 74th meter. The fourth left-side channel is shaped as a semi-circle, its entrance is at 240 *m* from the entrance to the cave at the level of the main channel, and the exit is located at 283.5 *m* from the cave entrance, also at the level of the cave floor. The average width of the channel is 1.5 *m*, and its height is 1 *m*.

Two chimneys, which measure 17.5 *m* and 15 *m* in height, can be observed in the channel. The floor of the channel is covered in sand, gravel and debris along its entire length, and speleothems are mostly formations hanging from the ceiling. Two side channels branch off from the fourth channel. The first represents a higher level with a chamber that has 10 *m* in diameter and 10 *m* in width. Speleothems are clean, white and active due to intense water seepage.

The other side channel has a westward direction and is 7 *m* long. The total length of the fourth left-side channel is 119.5 *m*, and together with two side channels, it measures 164.5 *m* in length. The second right-side channel is located at 248 *m* from the cave entrance. Its entrance is situated on a 4-meter-high terrace, and the main channel resurfaces again at 273 *m* from the cave entrance, 7 meters above the cave floor. The floor of the cave is covered in dust, and speleothems include columns and stalactites. The channel measures 71.5 in length in total. The entrance to the fifth left-side channel is located at 379 *m* from the cave entrance. It can be reached from the chamber. The floor of the fifth left-side channel is 7 *m* above the floor of the chamber. Its channel measures 234.5 *m* in length, and side-channels are 86.5 *m* long. The first section of the channel, at the distance of 56.5 *m*, varies slightly from the northeast direction; it measures 6–8 *m* in width; the height of its ceiling exceeds 8 *m*, and in certain places it reaches up to 18 *m*. The channel then bends in the form of an elbow, and its width suddenly decreases and reaches 1 *m*. At that point, the height of the channel ranges from 4 *m* to 10 *m*. The channel widens again when it takes an eastward direction. There, its width reaches 14 *m* and height between 8 *m* and 10 *m* at certain places. The channel rejoins the main channel via a 12.5-meter-long narrowing at 637 *m* from the cave entrance. The entrance to the sixth left-side channel is at 526 *m* from the cave entrance. It can be reached via a 0.5-meter-high step. The channel takes the northeast direction at the length of 74.5 *m*. Its height ranges from 0.3 *m* to 2.5 *m*, and width from 0.4 *m* to 3 *m*. There are rimstone dams and debris in the central part and small gravel deposits at the entrance and exit. Three side channels measuring 30.5 *m* in total branch off from this channel, and therefore its total length is 105 *m*. The third right-side channel is located at 567 *m* from the entrance to the cave. It measures 24.5 *m* in length in total. The first half of the channel is 0.5 *m* wide and 1 *m* high. Thereafter, the channel makes a sharp turn to the right and ends with a 4-meter-deep shaft, whose top opening has 0.5 *m* in diameter (Zlokolica and Ivošević 1984).

Through latest exploration activities, it has been determined that the Cave has the main channel 797.5 meters long and several side channels (six left-side channels and three right-side channels), whose length totals 1,131 *m*, which together with the main channel amounts to 1,928.5 meters in length. It consists of a number of cave narrows and wide parts. Since those formations resemble erosive expansions and gorges in composite river valleys, the cave thus belongs to the category of composite river caves.

Fig. 3. – a) Sinkhole of Maljevinski Stream; b) entrance in the hamlet of Repište; c) entrance in the Uvac Canyon (photo: Nj. Tubić).

The authors of this paper carried out hydrological research of Tubića in the period from 2018 to 2024. The Maljevinski Stream that disappears underground at the entrance to Tubića Cave originates from two sources. The first, longer branch, originates at the foot of Babinjača Peak, whereas the second one originates at Tubića Mala. The two branches join together in the hamlet of Repište. The valley of Maljevinski Stream has characteristics of a steephead (blind) valley since the stream sinks when it comes into contact with carbonate rocks (Fig. 3a). In its upper and middle course, Maljevinski Stream flows over non-carbonate rocks all the way to Tubića Cave, where it plunges into the depths of a limestone mass. A dry, relict valley of Maljevinski Stream (Suvido) stretches almost parallel with Tubića Cave.

In its pre-karst phase, the stream used to flow through the valley towards Uvac. After running underground, Maljevinski Stream resurfaces as a spring 50 *m* to the left of Tubića Cave exit at 980 *m* a.s.l. However, after the construction of Lake Sjenica in 1979, the spring was submerged by the water in the lake, which is why it can presently be seen only rarely, when the level of the lake drops. During such periods, no water comes out of it due to the low water level of Maljevinski Stream, which does not reach the sinkhole, but dries up upstream.

The sinkhole of Maljevinski Stream is located at 1,020 *m* a.s.l., adjacent to the entrance to Tubića Cave, to the right (Fig. 3a). However, today, during periods when there is no high water, Maljevinski Stream sinks around 100 *m* upstream in the newly formed sinkhole, which is why the water reaches the former sinkhole only during heavy rainfall, when the new sinkhole is not able to receive all the rainwater.

Tubića Cave is occasionally hydrologically active. Water enters the cave after extreme rainfall, when the cave becomes a flow tunnel for Maljevinski Stream. Tubića Cave begins with a triangular opening under a 25-meter-high rock ridge. The maximum height of the entrance is 11 *m*, and base width is 3 *m* (Fig. 3b). The cave exit is located under a 30-meter-high cliff. It is elliptic in shape, with the maximum height of 10 *m* and the maximum width of 18 *m*. It is situated in the Uvac Valley and was submerged after the construction of Lake Sjenica in 1979 (Fig. 3c).

Due to a rather gentle slope of the cave channel, Lake Sjenica has penetrated into the cave. In August 2018, the last chamber as well as the place where the longest left-side and main cave channels meet were submerged since the lake penetrated into the cave more than 200 *m*. That is precisely the farthest point to which the lake water can reach in the cave since the last chamber ends with a 3-meter-high fracture. This can be inferred from lack of lake sediments in the upstream part of the cave. The situation was completely different in August 2019, when the level of the lake was lower because the summer was much drier. The last chamber was dry, and its floor was cowered in lake sediments, with a lot of branches brought there by the lake.

During the summer months of 2023 and 2024, when Zlatarsko Lake lacked water, the water was transferred there from Lake Sjenica to ensure the functioning of "Kokin Brod" hydropower plant. The Uvac River ran then just outside Tubića Cave as it used to run before the lake was constructed, and for that reason Tubića Cave was dry and passable along its entire length. In the central part of the cave, on a 2-meter-high terrace, there is an eversion pothole which is connected to the lower floor of the cave, through which Maljevinski Stream currently runs underground. During high tide, the water from Maljevinski Stream recrudesces through it into the

Fig. 4. – a) Deposit of non-carbonate sediments (sand) around the erosion pothole; b) fossil speleothems in the upper part of the Cave; c) recent cave-speleothems in the Cave central part; d) remains of non-carbonate sediments (sand, gravel) on the sides of the cave channel (photo: Nj. Tubić).

cave, which is demonstrated by deposits of non-carbonate sediment (sand) found in its surroundings (Fig. 4a).

When the longest left-side channel branches off, the cave has minimum width, which does not exceed 1 *m*. During periods of heavy rainfall, a rather small lake is formed there. In August 2018, its length exceeded 50 *m*, and in some parts, its depth was more than 1.5 *m*. In August 2019, the lake was considerably smaller, and could easily be crossed over on foot, while in 2023 and 2024, it was no longer there. Lake water is crystal clear and has low temperature, which leads to a conclusion that it is formed from water seepage. Tubića Cave is rich in speleothems, whose abundance decreases from the entrance to the exit. Speleothems are most numerous in the upper part of the cave. However, there are almost no recent formations there, which is indicative of the fact that the karst process is in its final stage. Shallow, relict rimstone dams are also present at some places. This part of the cave features stalactites and stalagmites of considerable size and in certain places there are also cave columns (Fig. 4b). Individual stalactites and stalagmites have been broken, or destroyed by visitors.

The karst process is most intense in the central part of the cave. There are numerous stalactites hanging from the cave ceiling, and somewhat shorter stalagmites rise towards them (Fig. 4c). There are no cave columns in this part of the cave and no relict formations. The bottom part of the cave is very deficient in speleothems. The karst process is just beginning there and is represented by thin stalactites, but without any stalagmites.

During the evolution process, the cave was going through both erosion and deposition phases. In the course of the erosion phases, the cave channel cut into carbonate rocks, whereas the deposition phases were characterized by partial filling of the cave channel with non-carbonate sediments. This is evidenced by remains of non-carbonate sediments (sand, gravel) on the sides of the cave channel located 3–4 *m* above the cave floor (Fig. 4d). During the deposition phase, the cave channel was filled with sediments up to 4 *m* high. Speleothems settled over those sediments as flowstone – stone waterfall formations and calcareous crust. The renewal of the fluvial process resulted in the sediment materials being washed away, while the remains of the calcareous crust on cave walls serve as proof of the height of the buildup.

The air temperature in the main channel is 11.9^{o} C. It is affected by the outside temperature near the entrance and exit, which is why it is slightly higher during the summer months and slightly lower during the winter months than the temperature of the air in the main channel. During the summer, in years when Lake Sjenica goes deep into the interior of the cave, the air near the exit is oversaturated with water vapor, which can be explained by the contact between the low-temperature air in the cave and higher-temperature air above Lake Sjenica, which results in intense evaporation.

RESEARCH METHODOLOGY

As speleological site, Tubića Cave has been listed in the Inventory of Geoheritage Sites in Serbia, whose proposal has been composed by Radenko Lazarević, Predrag Đurović, Jelena Ćalić and Milovan Milivojević. The Inventory of Geoheritage Sites in Serbia was compiled according to the official Archives of the National Council for Geoheritage in Serbia (2004) in order to provide a summary of all geosites relevant to national and international science and education in a systematic manner and based on categories. The aim of this paper is to provide a qualitative and quantitative assessment of geoheritage site Tubića Cave as well as to protect the cave in the best possible way, considering its main characteristics and potential functions.

Geoconservation refers to research of geodiversity of a specific area, evaluating and identifying geoheritage sites, assessment of the as-is state and level of threat to geoheritage sites, proposing appropriate conservation measures, as well as activities aimed at popularization, presentation and promotion of geoheritage sites. In view of that, the paper uses the methodology of scientific and professional research of Tubića Cave in the field in the framework of geoconservation, as well as qualitative and quantitative assessment of that particular geoheritage site.

The following criteria of identification, evaluation, selection and categorization of geoheritage sites were used in the evaluation process: scientific value, other values, functional value and site vulnerability (Table 1). Each criterion has its own sub-criteria with numerical values. This methodology model was created by Maran Stevanović (2015) and implemented firstly in the selection, evaluation and categorization of geodiversity and geoheritage sites within the Djerdap Geopark; the model was based on methodological guidelines prepared by Reynard *et al.* (2007), Reynard (2008) and Pereira & Pereira (2010).

Total site value cannot exceed 100 points maximum and is determined by applying the following algorithm:

$$\mathbf{TSV = (3\times SV + 2\times OV + 2\times FV + 2\times VU) / 2.5}$$

In terms of its scientific value (SV), a geoheritage site can have a score of 50 points maximum, and sub-criteria within this criterion are uniqueness (U), representativeness (R), educative value (E), complexity (C) and level of exploration (LE). The result is calculated using the following equation:

SV = (4 x U) + (2 x R) + (2 x E) + C + LE

With regard to the assessment of other values (OV), a geoheritage site can have a score of 20 points maximum based on ecological (Ec), cultural (Cl) and aesthetic (Es) values as sub-criteria, by applying the algorithm:

OV = Ec + Cl + 2 x Es

Accessibility (A), visibility (V), spatial connection with other natural and cultural assets (Sc), infrastructure facilities, services, products (In) and economic potential (Ep) are all sub-criteria within the functional value of a geoheritage site that account for 24 points maximum, which is calculated by applying the following algorithm:

FV = A + V + Sc + In + 2 x Ep

A geoheritage site is assessed for vulnerability based on the level of threat (Lt) and the level of preservation (Lp), for which it may receive 10 points maximum. An algorithm applied to calculating the vulnerability of geoheritage sites is as follows:

VU = Lt + Lp

Based on the importance and total numerical value of geoheritage sites, the following categories of geoheritage sites have been established (Maran Stevanović 2015):

- **Category 1 – Internationally Important Geosites** are sites whose total score exceeds 85 points. Their scientific value is very high, and their other values, as well as their functional value, are also very high. This category comprises sites whose level of preservation is very high and which are not threatened (a rating of 4, potentially threatened, may be tolerated).

- **Category 2 – Nationally Important Geosites** are sites whose total score ranges between 75 and 84 points, which includes localities and sites relevant to understanding the animate and inanimate nature, development of geosciences, as well as those with prominent aesthetic values.

- **Category 3 – Regionally Important Geosites** are those whose total score is between 60 and 74 points, and they include localities and sites representing a specific natural phenomena, process or formation specific to a given region.

- **Category 4 – Locally Important Geosites** are those whose total score ranges from 40 to 59 points, providing that their scientific value may not be rated less than 25. This includes localities and sites which represent a specific natural phenomena, process or formation, specific to the local area.

Table 1. – Criteria and rating to determine the total value of geoheritage sites.

TOTAL VALUE OF GEOHERITAGE SITES						
Rating	0	1	2	3	4	5
SCIENTIFIC VALUE						
Uniqueness	absent	insufficient	low	medium	high	very high
Representativeness	absent	insufficient	low	medium	high	very high
Educative value	absent	insufficient	low	medium	high	very high
Complexity	absent	insufficient	low	medium	high	very high
Level of exploration	absent	insufficient	low	medium	high	very high
OTHER VALUES						
Ecological value	absent	insufficient	low	medium	high	very high
Cultural value	absent	insufficient	low	medium	high	very high
Aesthetic value	absent	insufficient	low	medium	high	very high
FUNCTIONAL VALUES						
Accessibility	inaccessible	medium	good			
Visibility	difficult to notice	medium	good			
Spatial connection with other natural and cultural assets	absent or weak	medium	good			
Infrastructure facilities, services, products	absent or minimal	medium	good			
Economic potential	absent or low	medium	high	very high		
VULNERABILITY						
Level of threat	not threatened	potentially threatened	partially threatened	threatened	partially damaged	highly damaged
Level of preservation	very high	high	medium	low	very low	not preserved

RESULTS AND DISCUSSION

Following the field research, a qualitative and quantitative evaluation of geoheritage site Tubića Cave was undertaken and the cave was ranked in that regard. In terms of its **scientific value,** Tubića Cave has had a score of 35 points. This cave is certainly not a unique and representative speleological site, considering that a large territory of Serbia is under limestone and dolomite, so underground karst formations such as pits and caves are very numerous here. For this reason, the cave has received a rating of 3 for each of those two criteria. With regard to cave's **educative value** and **com-**

plexity, it has received a rating of 4, considering that Tubića Cave provides a clear example of the evolution of the karst process and the cave itself, as well as its descent towards the lower erosive base, the development of the cave channel from wet, through occasionally flooded to dry, and accordingly the formation of karst landforms through deposition in higher horizons. The level of exploration of the cave has been very high, for which it has received a rating of 5, because research has been carried out on several occasions since 1914.

In assessing **other values** the geoheritage site Tubića Cave received 13 points. The ecological value of the Tubića cave is high, and it thus got a rating of 4, considering that it, like other caves, has specific ecological conditions in terms of microclimate, hydrological and morphological characteristics, as well as the possible living world that inhabits such habitats. The cultural and aesthetic value has a rating of 3 (average rating), because Tubića Cave certainly does not have that representativeness and specificity that would increase its importance in terms of these sub-criteria.

The **functional value** of Tubića Cave is very low and amounts to only 6 points. Such a low assessment of the functional value of this geoheritage site is due to its poor accessibility – a rating of 2, visibility – a rating of 1, spatial connection with other natural and cultural assets – a rating of 1, complete lack of infrastructure facilities – a rating of 0, and very low economic potential – a rating of 1.

The **vulnerability** of Tubića Cave is medium, given that the rating for this criterion is 6. The level of threat to Tubića Cave is medium, a rating of 3, due to the great influence of Sjenica Lake on the hydrological characteristics of the cave after the creation of the reservoir, as well as its great dependence on external meteorological conditions. The level of preservation has also a rating of 3 (medium value), since the cave is impassable due to the creation of Sjenica Lake reservoir during high water and is exposed to the activities of the lake water, which has affected the karst process in and around it, while cave speleothems have been destroyed in some places by being torn off by visitors. In terms of its **total value** as a geoheritage site, Tubića Cave has a score of 62 points, which means that it belongs to Category 3 - regionally important geosites.

CONCLUSION

Tubića Cave is a speleological geoheritage site of regional importance. Based on its appraisal, it has been recorded that it has very high scientific, educational and ecological values, while efforts need to be made to improve its aesthetic and functional value as well as its protection. For that reason, actions should be taken in the future, in the framework of geoconservation, to provide financial resources for implementation of appropriate projects aimed at conservation, presentation and promotion of this geoheritage site, which would increase its total value, and thus its importance. The local community should be engaged in the process of connecting Tubića Cave with the surrounding geosites and cultural heritage localities through the development of geotourism, which would ensure the sustainable development of the wider area. On the other hand, given that the interests of tourists in recent times are increasingly directed towards acquiring new skills and knowledge, popular educational programs in geoscience related to a wider area could complement and raise the entire tourist offer of the region to a higher level.

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ОБЈЕКАТ ГЕОНАСЛЕЂА ТУБИЋА ПЕЋИНА (ЈУГОЗАПАДНА СРБИЈА) - ГЛАВНЕ КАРАКТЕРИСТИКЕ, ВРЕДНОВАЊЕ, КАТЕГОРИЗАЦИЈА И ГЕОКОНЗЕРВАЦИЈА

ДОБРИЛА ЛУКИЋ, ЊЕГОШ ТУБИЋ

РЕЗИМЕ

Тубића пећина је спелеолошки објекат који се налази у атару села Доње Лопиже, у засеоку Репиште, на Пештерској висоравни, недалеко од Сјенице. Са укупном дужином од 1.928,5 *m*, од чега главном каналу припада 797,5 *m*, пећина је једна од дужих спелеолошких објеката Србије. Геоморфолошки, припада композитним речним пећинама, с обзиром на чињеницу да се у њој смењују дворане и сужења пећинског канала, што подсећа на алтернацију котлина и клисура код композитних речних долина. Пећина је уписана у национални регистар објеката геонаслеђа.

Тубића пећина истраживана је у неколико фаза. Пећину је први истраживао Боривоје Милојевић 1914, фокусирајући се на њене хидролошке карактеристике. Детаљније проучавање морфологије пећине спровео је Милош Зеремски 1956, идентификујући том приликом четири пећинске дворане и више бочних канала различитих димензија и морфолошких карактеристика. Зеремски је уједно и први дао приказ уздужног и попречног профила пећине, а у периоду 1982–1984, чланови Спелеолошко-алпинистичког клуба „АСАК“ из Београда приступили су новим, веома прецизним мерењима пећине, када је дефинисана њена релевантна дужина. Током наведеног периода истраживачи АСАК-а су мапирали и шест левих и три десна бочна канала.

После изградње Сјеничког језера 1979. године, излаз пећине је потопљен, а језерска вода повремено али знатно задире у унутрашње делове пећине, што је утицало на њену морфологију и екосистем. Истраживања спроведена у периоду 2018–2024. концентрисала су се на хидролошке карактеристике, потврђујући да пећина функционише као проточни тунел током високих водостаја. Колебање нивоа воде у језеру такође се значајно одражава на хидролошку активност пећине и видљивост пећинских формација.

За квалитативну и квантитативну процену Тубића пећине као објекта геонаслеђа и његово рангирање примењен је методолошки модел који је првобитно осмислила и применила Маран Стевановић (2015) за селекцију, евалуацију и категоризацију објеката геодиверзи-

тета и геонаслеђа на територији Ђердапа, у оквиру активности за номинацију овог подручја у Унескову глобалну мрежу геопаркова; модел је заснован на методолошким смерницама који су припремили Reynard *et al.* (2007), Reynard (2008) и Pereira & Pereira (2010).

У евалуацији Тубића пећине висока оцена припала је научној вредности, укупно 35 поена, док еколошки, културолошки и естетски параметри у оквиру критеријума друге вредности заједно износе 13 поена. Оцена употребне вредности свега је 6 поена због неприступачности Тубића пећине и неразвијености краја у ком се она налази. Рањивост пећине оцењена је са укупно 6 поена јер је овај објекат изузетно осетљив на спољашње утицаје будући да се осцилација нивоа воде Сјеничког језера директно одражава на његове хидролошке карактеристике.

Сабирањем свих појединачних резултата, а сагласно наведеној категоризацији, Тубића пећина припада групи објеката геонаслеђа регионалног значаја са укупно 62 поена. Предности Тубића пећине су висока истраженост, еколошка вредност и образовни потенцијал, док се слабости односе на ниску употребну вредност.

На основу детаљне анализе може се закључити да Тубића пећина представља природно добро од значаја за науку, па га сходно томе, треба на одговарајући начин и сачувати, укључујући наставак научних истраживања и примену превентивних заштитних мера. Повезивање Тубића пећине са другим објектима геонаслеђа и културно-историјским знаменитостима на датом подручју и укључивање локалне заједнице у промотивне активности допринели би развоју и унапређењу туристичких и едукативних програма и, у крајњој инстанци, порасту интересовања шире друштвене заједнице за целокупан регион.