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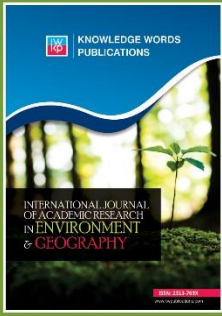
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The Touristic Potential of Calcareous Geomorphosites along Bahna - Baia de Arama Mesozoic Limestone Bar

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Abstract

The Mehedinți Plateau is divided into two parts by a central structural calcareous bar, named Bahna-Baia de Arama Depression. This central area consists of a Mesozoic limestone bar that includes the main cave systems of the Mehedinți Plateau. These represent the geomorphosites with high scientific values, including numerous subsystems that will be analyzed as geomorphosites themselves.

This paper determines the touristic potential value by calculating the Global Touristic Value (GTV) using an international method for each of the most important calcareous complexes along the limestone bar and some of their components. The Global Touristic Value includes the scientific, aesthetic, economic, historical and cultural values of the geomorphosites, each of these values being calculated according to some criteria.

Another goal concerns the analysis of the impact of several factors, both on the touristic caves and on the caves with high touristic potential, these being important elements in the karst landscapes of the area. The main karst systems analyzed are Epuran-Topolnița, Zaton-Ponoare-Bulba karst systems and Balta karst area.

Keywords: Geomorphosites, Karst, Mehedinți Plateau, Touristic Potential, Caves, Global Touristic Value, Scientific Value, Aesthetic Value, Economic Value, Historic and Cultural Value.

Introduction

Mehedinți Plateau is one of the smallest geographical area in Romania - 78.5 square kilometers (Balteanu, 2006), Mehedinți County, south-west of Romania, near Serbia, between the Danube and the Motru rivers. This is one of the most representative areas for the beauty and uniqueness of the karst landforms in Romania even if limestone represents less than 40% of its petrographic composition. Generally, in a percentage of 50-55%, Mehedinți Plateau is composed of metamorphic crystalline rocks, the rest of it being covered by sedimentary rocks and a very small percentage representing granite (Ielenicz & Sandulache, 2008). Water from precipitations

and rivers has created, during million years, amazing surface and underground geomorphologic forms in Mehedinți Plateau area - hydrological breakdown in the limestone beds where the processes of dissolution and precipitation are continuous.

Methodology

This study underlines the present situation of the main calcareous geomorphosites – caves - situated along the center of the Mehedinti Plateau and included in the main karst complexes, according to the touristical phenomenon which has an increasing importance.

This work is based both on a quantitative and qualitative evaluation of the calcareous natural heritage from the center of the Mehedinți Plateau. This paper aims to establish the touristic potential of these landforms, using the Romanian method (Ielenicz & Comanescu, 2013) regarding the assesment of the geomorphosites. So, based on four characteristics - scientific, aesthetic, cultural and economic - subsumed under several criteria, it was assigned to each of them a score between 0 and 1 (Table 2). It is necessary to have a deep knowledge of these geomorphosites, to assign a value for each criteria and subcriteria according to the geomorphosites evaluation. Data related to those features are included in the inventory sheet that describes these geomorphosites based on field data and an extended bibliography.

A possible touristic exploitation of certain sectors of the caves involves numerous studies and a continuous monitoring of the biotic and abiotic parameters, as is the case of the Topolnița Cave. According to researchers from „Emil Racovița” Institute of Speleology, Romanian Academy (Constantin S. *et al.*, 2017), it requires 3 phases of monitoring:

1. Preliminary monitoring;
2. Monitoring during planning project implementation;
3. Before and all the time after the opening of a cave for tourism.

The measurements are made with the help of data loggers (Figure 1). The monitoring is performed on the cave ceiling, walls and floor. The main parameters are: temperature, radon levels, absolute humidity, CO2 concentration, air circulation, bats colonies, water properties, water percolation rate, guano deposits, fossil deposits, speleothems. The entire area above the caves included in A or B protection classes is carefully observed by the Mehedinți Plateau Geopark Administration.

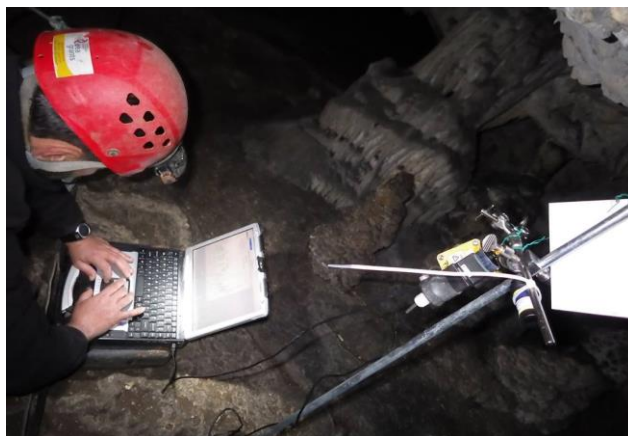


Figure 1. Researcher from „Emil Racovița” Institute of Speleology, Romanian Academy, performing measurements with the data logger in the Topolnița Cave (2018).

Source: Alexandru Petculescu („Emil Racovița” Institute of Speleology), personal archive.

General Presentation of the Central Limestone Bar from Mehedinți Plateau

The limestone median depression of the Mehedinți Plateau is divided into two almost equally parts starting from a narrow area situated in the south of the plateau between Bahna and Topolnița: Bahna Depression and Cireșu-Baia de Arama Depression (Figure 2). Bahna Depression, oriented NE-SW, is open towards the Danube and connected with Orșova Depression, while Cireșu-Baia de Arama Depression has been developed as a bar longer than 30 km, 3-4 km wide between Baia de Arama and Nadanova, and narrower between Sfodea and Cireșu (Badea *et al.*, 2010).

A karst geomorphologic system is developed in a plateau or in a calcareous area by dominant processes of dissolution and precipitation, and, depending on the stage of development, involves endo - and exokarst forms, that shape the specific landscape (Ielenicz *et al.*, 2013). Karst complexes defined here represent systems with elements which communicate with each other.

The Jurassic-Cretaceous limestones belong to Danubian Autochthonous (Mutihac, 1982). The Eastern limestone strip which develops in the center of the Mehedinți Plateau, between Cireșu and Baia de Arama, is parallel to the western strip, belonging to the Mehedinți Mountains, characterized by an increasing tectonic (Stroe & Peptenatu, 2011).

Even if limestone represents a small weight in the geological structure of the Mehedinți Plateau, only 5% (Codarcea, 1940), karst phenomena raise the scientific and touristic importance of this area, at regional and national level. Mehedinți Plateau is an important karst area from the point of view of number and uniqueness of the caves and other karst landforms, being comparable only with the Apuseni Mountains karst. The carbonate succession from north-central Mehedinți Plateau is 200 - 300 m thick, consisting of 4-10 m thick bedded limestones, generally dipping toward the southeast (Badea, 1992). The exokarst landscapes from the Bahna-Baia de Arama Depression area are spectacular, including limestone hills (locally named „cornete”), slopes, sinkholes, caves, springs, gorges, valleys, microdepressions, temporary lakes, karren fields, specific vegetation. There are also karst intermittent springs and water streams with mineral content. As endokarst features, there are developed over 200 hydrologically active or inactive caves and potholes, as well as numerous rock shelters. Within caves, abundant and diverse stalactites and stalagmites, important as mineral forms, generated by the calcium carbonate precipitation, have been developed. Along with these features, karst lakes in calcite crust or ponds sheltered by limestones, subterranean waterfalls, streams, huge halls populated by various species of bats, corridors with guano deposits, can be often observed.

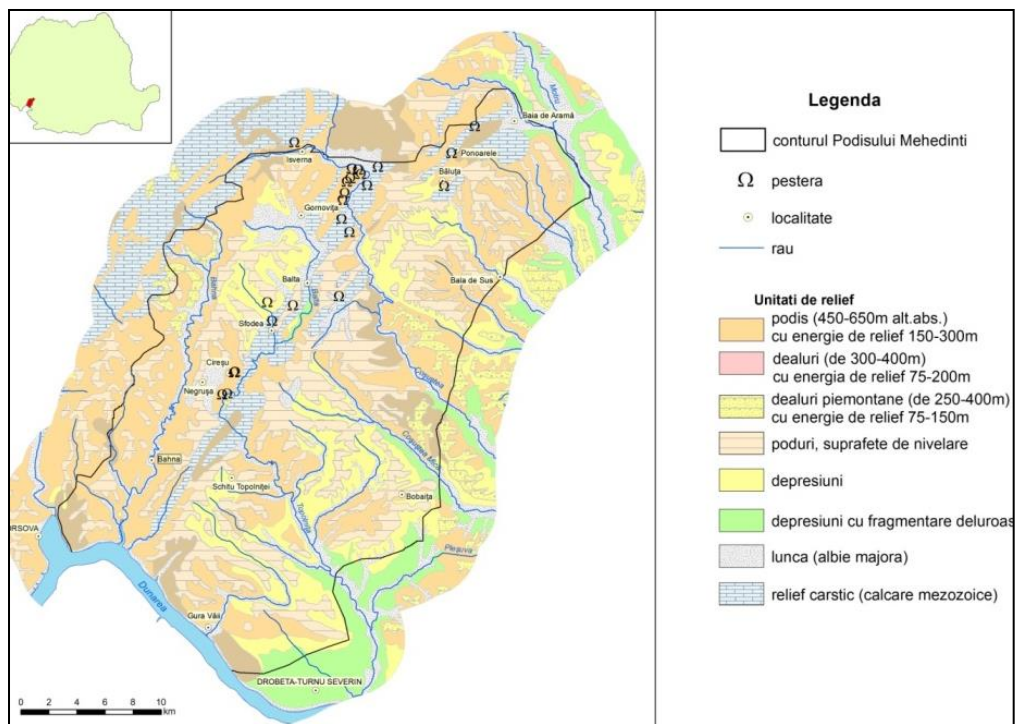


Figure 2. Mehedinți Plateau - geomorphological map.

Source: Iamandei, M., Faculty of Geography, Bucharest University, Dimitrica, C., The Institute of Geography, Romanian Academy.

The entire area, managed by Mehedinți Plateau Geopark is included in special protection programs. The Mesozoic limestone from Mehedinți Plateau has a high potential to develop new landforms, as attested by the numerous exokarst features and caves of various shapes and sizes, some of which are still unexplored.

The karst phenomena from Mehedinți Plateau have a very close connection with the movement of the water supplied by western rivers. Almost all are sinking at the contact with the Mesozoic limestone bar. Downstream of the sinking point, the valleys remain dry, forming in time antithetical steps (as is the case for Topolnița, Ponoaraț, Ponoarele rivers), while upstream of the sinking area, the meadows are alleviated so heavily that closed depressions, hundreds of meters wide, with a flat bottom and an overall aspect of a polje, are formed. The hydrokarstic system from Ponoarele led to the formation of Zaton and Ponoarele depressions (Bleahu *et al.*, 1976). In the same area, significant karren fields and the Natural Bridge from Ponoarele have been developed.

The water which have shaped these karst depressions has a variable flow rate: during long dry periods they disappeared from surface, flowing through alluvial deposits (even for rivers, such as Topolnița and Coșuștea), while in wet periods, the water covers large areas within them, forming even temporary lakes such as Turcu Lake, Zaton Lake, Gornovița Lake, Balta Lake. The water of Zaton Lake and Turcu Lake is drained only underground towards Bulba stream.

In western villages Balta and Marga, sinkholes are remarkable by the beauty of karren fields. They are common also in the Cireșu village area, related to the Topolnița - Epuran karst complex. The dominant shapes in the Mehedinți Plateau landscape are the limestone hills with

asymmetrical aspect, locally named „cornete” and „cornățele” - smaller limestone hills all over the Cireșu-Baia de Arama area and even in its extension to the SW, near Danube. The hills are situated in Ponoarele, Nadanova, Gornovița, Sfodea and Jupânești villages.

„Cornetele” and „cornățelele” are important in the general karst landscape because in most of these landforms water carved caves or potholes. Also, most of them are deforested or covered with hawthorn, corn crops, juniper and lilac, mixed with isolated beeches. Wild lilac forests exist in the Nadanova or Ponoarele areas, where in May, when the lilac blossoms, the traditional Lilac Festival is organized. This event attracts hundreds of tourists to the touristic objectives of Ponoarele.

A cave is any natural empty space found in the Earth's crust, human - accessible (Lascu & Sârbu, 1987). Even if the Mehedinți Plateau is composed of several types of rocks, the caves are created only in the limestone structural bars.

In the Mehedinți Plateau there are over 200 caves - individual geomorphosites or included in the karstic complexes.

The most spectacular caves in Mehedinți Plateau have been developed as a result of the moving groundwater, which carved numerous caves and potholes well-known by shapes, sizes and decorations. Caves like Topolnița, Epuran, Bulba, Grama, Curecea, Sfodea are the largest and the most known from the central area of Mehedinți Plateau, each of them being included in one of the three main complexes that will be analyzed here as geomorphosites.

A geomorphosite represents a landform and any process of relief with some characteristics that make them a touristic destination - value and importance for tourism, relief morphology, physiognomy, originality in a wide area, link with any forms of tourism, link with other types of geosites, accessibility (infrastructure, accomodation). The attractiveness, uniqueness and visibility give the general touristic value (Ielenicz & Comanescu, 2013).

So, the central calcareous structural bar (formed by Mesozoic limestone) includes 3 major karstic complexes: 1. Epuran-Topolnița complex - one of the most important Romanian karstic complexes; 2. Balta complex and 3. Ponoarele complex. All of these are included in an important natural protected area named Mehedinți Plateau Geopark. It's about misterious underground networks and unique karst landscapes, in a touristic area with a high scientific interest.

Epuran-Topolnița complex is one of the biggest and the most important karst complex systems from Romania, due to its scientific importance, speleological features and unique landscapes. In this area, the natural resources have a high touristic value, but they are less accesible. According to Law No. 5/2000, this complex has a natural protected area status. There are 2 natural protected areas with extraordinary scientific value, with numerous unique natural resources (see Table 1). This complex is representative for national and international speleological heritage.

Table 1. Epuran-Topolnița main complex- general presentation

EPURAN	TOPOLNIȚA
<ul style="list-style-type: none"> • Scientific reservation • A protection class • 3 levels • First level - unique speleothems • 3.560 m • Cannot be modified • Planned scientific research or documentary activities are allowed, based on an authorisation from the <i>Romanian Speleological Heritage Commission</i> 	<ul style="list-style-type: none"> • Scientific reservation • 6 levels - 2 active + 4 inactive • Over 20.500 m • A + B (Prosacului Passage) protection classes • Included in the European speleological heritage • In Prosacului Passage ecotouristic activities are allowed, based on an authorisation from the <i>Speleological Heritage Commission</i>

Source: personal processing based on the Management Plan of the Mehedinți Plateau Geopark.

But for this study, there were analyzed only 8 caves - the most important caves for tourism (scientific tourism or other forms of tourism) that are being located in the center of the Mehedinți Plateau, along the Mesozoic calcareous bars, from south to north. It's about Topolnița Cave as geomorphosite, also about Epuran Cave, Gramei Cave, the Balta Cave (Peștera Mare de la Balta), Criva Cave, Sfodea Cave, „Podul Natural” (Natural Bridge) Cave and Bulba Cave. These results prove that the center of the Mehedinți Plateau has a high Global Touristic Value - respectively 0.49 (see Table 3), so a high touristic potential. That general value is based on each value of the 8 caves - geomorphosites - themselves.

The „geomorphosite” term and the methods for analysis were stated by the International Association for Geomorphology. In Romania this method was applied for the first time in 2013 by the geomorphologists Ielenicz and Comanescu.

The Global Touristic Value includes the scientific, aesthetic, economic, historical and cultural values of the geomorphosites, each of these values being calculated according to some criteria.

E.g. for scientific criteria count paleogeographic interest, representativity, surface (in an area), uniqueness, rarity, integrity, ecological interest. For aesthetic - landscape contrast of colours, altitude, surface in an area, visibility in and over an area. For each criteria is given a score from 0 to 1, according to a method used for geomorphosites and based on a very good knowledge of objectives (Table 2). The total average of all geomorphosites scores gives the final result - GTV (Table 3).

Table 2. Global Touristic Value of Topolnița Cave as a geomorphosite

Value type	Score 1	Score 2	Score 3	Score 4	Score 5	Score 6	Total average
Scientific	1	1	1	1	0.50	1	0.91
Aesthetic	0.50	1	1	1	0.50	-	0.8
Historical-cultural	1	1	1	1	1	-	1
Economic	0.25	0.50	0	0	1	-	0.35
GTV							0.76

Source: personal processing.

Table 3. Global Touristic Value for the most important speleological geomorphosites from Mehedinți Plateau (caves)

Cave	Scientific	Aesthetic	Historical-Cultural	Economic	Total average
Topolnița	0.91	0.8	1	0.35	0.76
Epuran	0.91	0.55	0.4	0.35	0.55
Gramei	0.45	0.25	0.1	0.6	0.35
Balta Cave	0.75	0.4	0.65	0.45	0.56
Criva	0.66	0.6	0.15	0.45	0.47
Sfodea	0.20	0.4	0.15	0.45	0.3
“PodulNatural” Cave	0.5	0.50	0.25	0.55	0.42
Bulba	0.79	0.55	0.2	0.5	0.51
GTV					0.49

Source: personal processing.

The highest values were recorded for the most popular caves - Topolnița and Balta caves (Figure 3). They are different in physiognomy, but are often integrated into local and regional events. These get a high Global Touristic Value due to the scientific value (Topolnița Cave) and, respectively, to the cultural value (Balta Cave).

Topolnița Cave has over 20,000 km in length, five entrances and consists of a huge system of passages, developed on 6 levels (3 hydrologically inactive, 2 temporarily active and the other active).

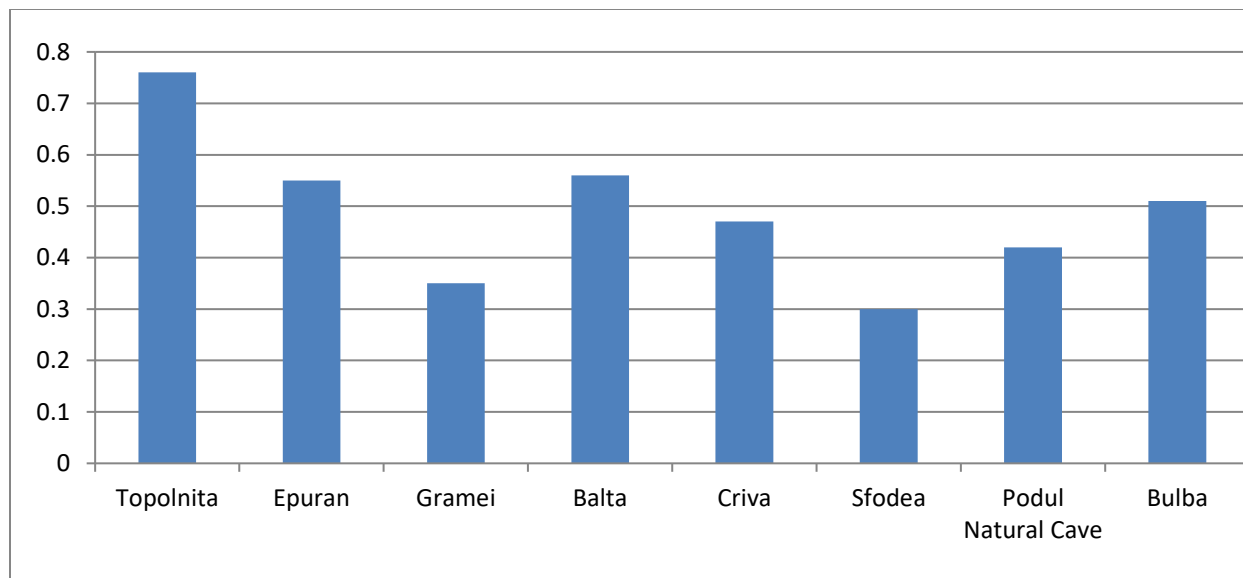


Figure 3. Global Touristic Value (GTV) for the main geomorphosites from the Mesozoic calcareous bar of the Mehedinți Plateau.

Source: personal processing.

Speleothems and size of halls, the ecosystems and the active sector make Topolnița one of the most impressive cave systems in Romania (Figure 4, 5). It is classified on A level of protection, being partially closed for mass tourism. Topolnița Cave („Peștera Femeii”/Woman’s Cave entrance) is open only one or two days per year for mass tourism.



Figure 4, 5. Topolnița Cave - speleothems, karst lake („Lacul de Cleștar”).

Source: personal archive, 2017.

Balta Cave is one of the most known caves from Mehedinți Plateau due to numerous events which are held annually in its passages and on the plateau nearby. It’s about Balta village feast and a classical music concert.

Epuran Cave, included in Topolnița-Epuran karst system, is totally closed for tourism, but locally it is well-known because of legends about a treasure that had been discovered at the entrance. Also, the calcareous walls above the entrance attract numerous lovers of mountain climbing. However, the main value of the cave is the scientific one. It has 2 levels, one hydrological inactive and the other active, linked by a system of sinkholes. It is also classified on A level of protection, as a natural protected area with a fragile ecosystem and hardly explored even by the most trained speleologists.

On the same time, Bulba Cave, an important component of the karst system Zaton Lake - „Podul Natural” Cave - Bulba Cave (Figure 6), is one of the most beautiful caves from Mehedinți Plateau, but it is difficult to access and explore. It is a strenuous cave because of a fast-flowing stream plus a hydrologically inactive level, extremely difficult to deal with (Figure 7).

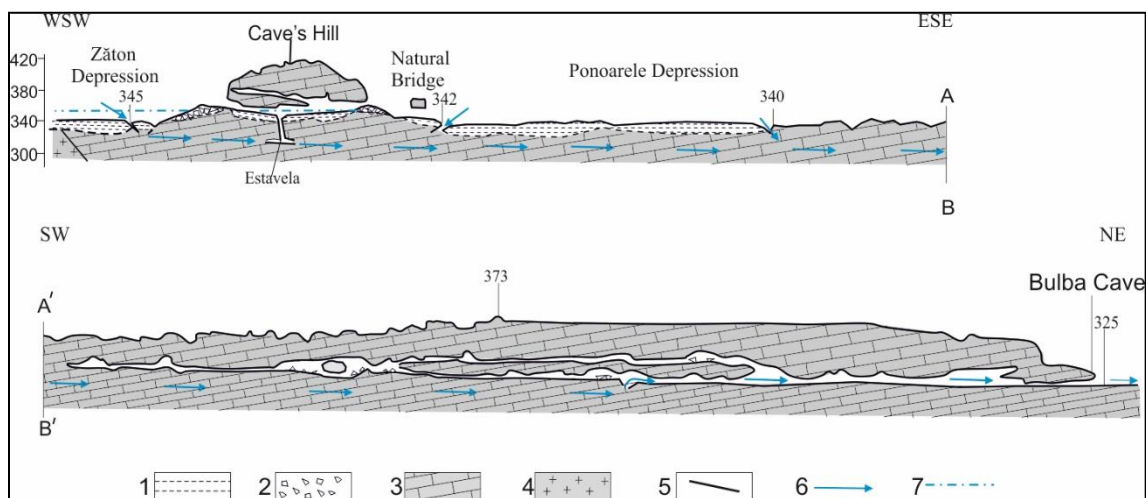


Figure 6. Morphological and hydrogeological cross-section between the Zaton endorheic basin and the Bulba Cave outlet (Povara & Lascu, 2018): 1. quaternary alluvia; 2. collapsed blocks; 3. J2-K1 limestones; 4. precambrian granites and granodiorites; 5. fault; 6. ground water flow path; 7. the highest water level of the Zaton Lake.

Source: Povara & Lascu, 2018.

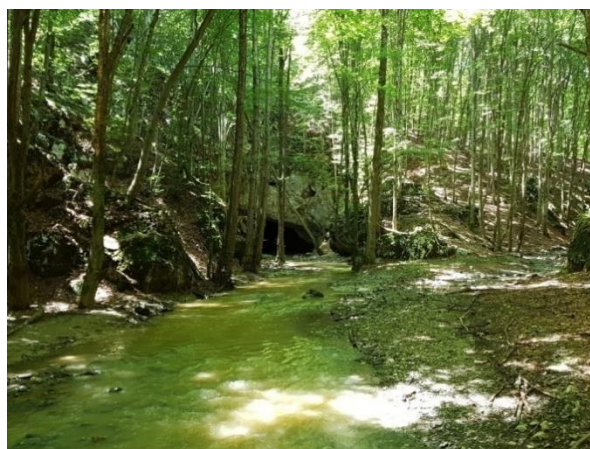


Figure 7. The entrance of the Bulba Cave.

Source: personal archive, 2018.

„Podul Natural” Cave/Natural Bridge Cave is one of the most accessible and visited caves in northern Mehedinți Plateau, being favored by its location: just below the Natural Bridge from Ponoarele and near the spectacular Zaton karst lake - which occasionally dries, to be filled-up by water during other periods, having a depth of almost 20 m (Pișota *et al.*, 2010). Above the cave, one can see a huge karren field, near the cave another karst lake linked to the system, and an impressive chasm, where a „flying fox” device was set up for tourists (Figure 8). The tourists’ movement between Gorj and Caraș-Severin counties favors this touristic hub from Mehedinți County and capitalizes the karst objectives from the northern Mehedinți Plateau.



Figure 8. Natural Bridge (“God’s Bridge”) and Natural Bridge Cave from Ponoarele.
Source: personal archive.

Criva, Gramei and Sfodea caves are small caves, always open, but not very accessible.

Touristic flows are increasing in the analyzed area. As can be seen from Table 4, Topolnița Cave is representative for the number of visits in one of the temporary opened galleries for tourists during a short period (6-12 hours/two days/year). This pressure could be lowered by opening this passage all year round, but for a much smaller number of tourists/visit. This possibility is analyzed by researchers from „Emil Racovița” Institute of Speleology of the Romanian Academy, together with the representatives of the Mehedinți Plateau Geopark.

Table 4. Visits in the caves from the center of the Mehedinți Plateau (2018 vs. 2017)

No.	Cave	Type (open or partially open for tourism)	Visits/ 2017	Visits/2018 Until September	No. pers./ entrance	Visitors from	Time/ visit
1.	Topolnița	PO	<500	<1000	5-8	Romania, Spain, Germany, Poland, Turkey, France, Sweden	5-6 h
2.	Epuran	PO	<200	<100	3-5-8	Romania	4-5 h
3.	Gramei	O	<500	<500	2-10	Romania	2 h
4.	„Podul Natural” /Natural Bridge Cave	O	<1000	>1000	1-20	Romania, others	20-30 min
5.	„Peștera Mare de la Balta”/The Balta Cave	O	<1000	<500	1-200	Romania	1h
6.	Criva	O	<100	<100	1-10	Romania	1-4h
7.	Sfodea	O	<100	<100	1-10	Romania	2-3h
8.	Bulba	PO	<100	<100	2-6-8	Romania	5-6h

Source: based on Mehedinți Plateau Geopark data.

Open versus closed caves for tourism

It is about show caves versus non-touristic caves, dedicated only for researchers. The caves such as Topolnița, Epuran or Bulba must be preserved and protected against human impact. The natural conditions need to be continuously preserved by scientific programs. The preservation of the fragile ecosystems is one of the most important challenges in the high protected areas (Matei, 2011). Speleothems, fauna, historical relics still have to be protected, because all of these caves are part of a valuable national and international caving heritage.

The numbers presented in the Table 4 are estimated. Compared to 2017, in 2018 one can see an increasing number of visitors, especially in Topolnița Cave (partially open for tourism activities) and in Natural Bridge Cave from Ponoarele. This year, at Topolnița Cave, on the cave' feast, a part of a main passage of the cave was open for tourism, 6 hours on Saturday, 6 hours on Sunday, and this is the reason why the number of visitors has grown. At Natural Bridge Cave, multiple touristic facilities were installed - such as a „flying fox” device over the chasm from Natural Bridge. At the same time, the entire natural area from Ponoarele was more promoted.

On the other hand, at the Balta Cave, the number of visitors has decreased because of technical problems causing the cancellation of the traditional classical concert. However, in 2018, the popular feast of Balta village („Nedeia”) was organized near the entrance of the cave. Topolnița, Epuran and Bulba caves visitors are especially foreign researchers, invited by the

Romanian researchers from „Emil Racovița” Institute of Speleology of the Romanian Academy in sharing experience programmes.

Conclusions

In the central part of the Mehedinți Plateau there are numerous geomorphosites with high touristic potential, based on GTV value. All of these geomorphosites are generally exploited for tourism only partially and locally. The touristic development of Mehedinți Plateau need investments, especially in infrastructure and touristic facilities - hotels, boarding houses and other accommodation facilities, souvenir and homemade products shops. Even if this area will be open for tourism, that will be only for controlled tourism, ecotourism (Smaranda, 2006). The tourists access in high protection areas from Mehedinți Plateau must be made only with approval of the Mehedinți Plateau Geopark Administration. The tourist will be led by professional rangers and any rules violation will be severely sanctioned.

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