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HUMAN IMPACTS IN A TOURIST KARSTIC GADIME CAVE (KOSOVA)

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ABSTRACT

Karst systems are extremely complex, and due to a number of geological and hydrological characteristics, they can be included among the most fragile and vulnerable environments in the world. Karst areas cover of about 10 percent of the land surface of the world, and there is widespread concern for the effects that human activities have upon the karst environment. The environmental sensitivity of karstic area is well known, and could be important because of environmental protection consideration. The natural processes of forming of the Gadime cave have continued during whole geological periods, since 200 million years.
This paper it is focused on the human and natural impact to Gadime cave. The human activities can negatively impact karst areas, including deforestation, agricultural practices, urbanization, tourism, water exploitation, mining and quarrying. Natural hazards associated with flooding of major cave from groundwater flows to the streets of karst tectonic faults and by flooding from increasing water level in the Klysyr River and from the building the water reservoir on the top of cave area. Amongst the geological and hydrogeological data, here there are included, shortly, the results of the study about the hazards of the cave on the basis of internal structural construction of the carbonate massif, and by the degree of development of karst processes.

Keywords: Gadime Cave, groundwater, water reservoir, impact

INTRODUCTION

There are more people visiting caves now than at any time in history, and the trend is for further increases. In recent years, interest in the underground karst environment has grown not only from a speleological or scientific viewpoint, but also from an economic perspective (Serjani, 2011). The profits derived directly and indirectly from the tourist exploitation of caves can acquire substantial importance at the local level.

However, in some instances, the lack of regulation the visits, or of an adequate maintenance infrastructure can result in a serious threat to the underground environment (Cigna, 1993). From the standpoint of the cave itself, the oldest and the most common methodological approach is based on the concept of a speleological network, which treats caves only as the mechanism of transference between the endokarst and the exterior (Torbe, 1952; Erason, 1969). Other authors consider a cave to be a closed system (Heaton, 1986), using models based on physics to predict environmental variations induced by human presence (Villar et al., 1984; Villar et al., 1986; Cigna, 1987). Mangin and D'Hulst (1995) treated the problem from a larger perspective, conceiving caves within their hydrogeological context and considering them as a system in dynamic equilibrium, in which the energy inputs are equal to the outputs.

Excessive human pressure upsets the balance, producing a progressive environmental degradation. The underground extent of caves is usually not apparent from the surface, and this sometimes leads to damage being done

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unwittingly. As wahlen mentioned, since caves form a part of karst aquifers the possibility of such damage is influenced by the hydrogeological characteristics of karst environments that are especially vulnerable to contamination (Zwahlen, 2004). An example is given by Slovenia, a country with a long tradition of karst conservation, where the first measure for cave protection dates from 1908 (Badiura et al., 1908) and in which approximately 20% of the 7405 caves recorded in the 2001 (Cave Survey) have been contaminated as a consequence of human activity (Kepa, 2001).

Gadime cave, with a total area of 56.25 ha in 1969 was declared a protected area and is listed by IUCN in the third category. Total length of all channels, corridors and halls in the Gadime cave is 1.260 m. In the upper galleries, which have so far been discovered, and other channels of assumed length of all rooms in the Gadime cave should be about 3 km. Ornaments inside the Gadime Cave, there are so much and so aesthetic giving to this geosite the international importance. This study it is done for determination of the impact to Gadime Cave, by the water reservoir, which is building on the top of carbonate massif above the cave (Avdullahi and Serjani 2012). For this reason the study was focused on two main issues:

1. Effect of the weight of the water reservoirs on Gadima Cave on the stability of the ground where the reservoir is located;
2. Effect of the water reservoirs on the inside structure of Gadime Cave.

During this study; geology, hydrogeology, tectonically construction of carbonate massif and surrounding metamorphic rocks were done new observations. Detailed observation and documentation were done on litho logical content of the rocks and on the karst processes in carbonate rocks. Below there are presented data about regional geological position of the Gadime Cave, geological construction of carbonate massif around the Cave, morphology of Gadime Cave and impacts to this cave.

2. GEOLOGICAL SETTING

2.1. Study area

The cave known as Gadima cave it is located in the district of Gadima, in Lipjan, Kosova. Gadima Cave is placed in Lower Gadima village, which is located to the east of Kosova Basin. This cave it is formed in the Gllavica carbonate massif, at level 656m, on the west slope of Gadime (758m), which sinks deeper in the northwest direction in the flat valley. On the right side of the Klysyr River appear three natural cave entrances in 6-10m height above the riverbed, respectively in 576 m, 582 m and 584 m above the sea level. On the left side of the Klysyr River, there is another entrance in the Cave, but with smaller dimensions (Figure 1). The slope of Gllavica it is in a shape form as an isolated cone, towards the northwest is more extended, which in all three directions is surrounded by the molasses of Neogen. Gllavica is separated from the hills of Gadima with a short strait of the Klysyr River with a maximum depth at 200 m.

Figure 1. Sketch map of study area

The Klysyr River has a complex and composed valley, because after expansion in the upper Gadime entered in a narrow valley, in low and narrow Gadime, flows into the mud valley of Gadime. In the months with precipitation from the mud valley of Gadime leak large water and after 4 km discharged into the Nerodime River, near the bifurcation between the basin of Black Sea and Aegean Sea.

In the region of the Gadime cave hydrological characteristics are very different. In terrains that are built by marble rocks, as are the Gllavica and Gadime hills, there are neither springs nor surface flows. These are dry terrains. However, inside of these measures is characterized by large groundwater. In the wide region, in the terrains constituted by Palaeozoic and lake deposits of

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Neogen, water springs displaying often, with small outflow and temporary surface flow. Such is the largest Klysyr River which in the bottom dries.

There is no doubt that the waters of the Klysyr supply underground flow in the leaks and in a number of underground lakes in Gadime cave. The level varies depending on the amount of water in the river bed (Avdullahi, 2008). However, only part of water from Gadime cave flow in the surface, in the western part of the Gllavica and Gadime valley, others probably infiltrates into different horizons of Kosova Basin.

The coldest month is January with temperature of -1,11^{o}C, while the highest temperature is in July with 19.9^{o}C. High extreme temperatures there are in summer, beyond the 34.5^{o}C, while during the winter can fall below -23^{o}C. With annual rainfall average of 610 mm the Gadima region is classified into the areas with small amounts of rainfall. The snow falls in the Kosova Basin in November, until March, but the highest quantity it is in December and January months. During the winter with strong winds in the basin snow reaches the height 1.5m.

In Klysyr River basin snow has great significance for surface and ground waters, especially for underground flow and for the lake system in the Gadime cave. Because of very steep terrain, inadequate climatic conditions, primarily small precipitation and dismantled marbles Gllavica hill is covered with a thin layer of diluvium. At the top of the hill, there are outcrops of limestone rocks, while soil is placed only on the surfaces and into the cracks. At the end of the slope the thickness of the soil cover reaches up to 25cm. Klysyr River with a numerous cracks has built a dense system of river valleys. The largest numbers of these valleys are coming from the first expansion direction of the Nerodimka erosion. In difference from the part of source basin which is built in the old Palaeozoic rocks and volcanic rocks. Valley in the upper Gadime is filled by Neogene lake sediments. This means that it is created at the same time with Kosova Basin, respectively before Neogene.

2.2. Geology and hydrogeology of Gadima area

Geological construction of Gadime cave region it is constituted by different kind of rocks of different mineralogical-petrographical content, and of different ages. The oldest rocks belong to the oldest Palaeozoic Era. They are metamorphised, transformed in schist rocks, mica schist's, phyllites and as the most important there are marbles (Petrovic, 1972). The last coverage belongs to the Quaternary Era, which consists of Klysyr stream flows and other streams nearby the mountains that brings large quantities of clay, sand and gravel. The youngest sediments there are placed on the new alluvium and lake sediments. (Figure 2). Palaeozoic series in the eastern edge of the Kosova Basin, there are composed mainly by metamorphic rocks.

Gadime Cave it is placed inside the marble limestone rocks of the Mesozoic age. The age of metamorphosed limestone, respectively marbles is not completely defined yet. There are opinions of geologists that marble rocks, where is formed Gadime Cave, may be belong to the Late Palaeozoic age.

Metamorphised limestone represents massive and compact rocks, but they have secondary cracks and there are divided into blocks by tectonic faults. Secondary cracks are often very dense, forming a dense network. Limestones there are totally metamorphosed, what seems clear from the textures of the schist rocks and from the secondary colours ingredient of rocks. In most cases observed blocks of metamorphic and volcanic rocks have clear-cut contacts with limestone and marble rocks, with irregular contour, with mutual links, but compact.

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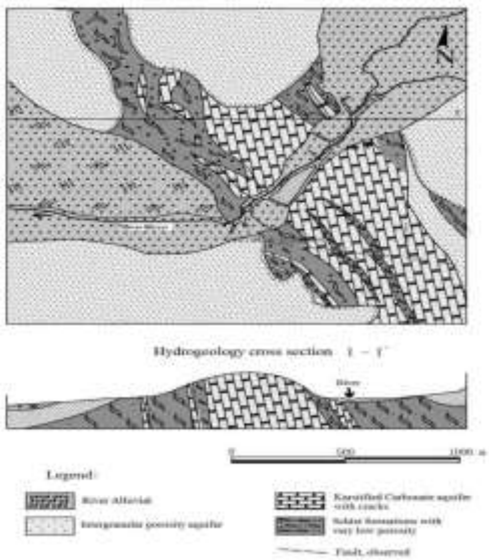

Figure 2. Map of the Gadime Region.

The karst processes there are mainly developed in primary system of cracks, and in fissures in the carbonate formations, while the water penetration and filtration is done through secondary fractures and through the contacts of schist rocks, especially through the disjunctive faults. The orientation of the branches in the cave in southeast-northwest direction correlates with the orientation of tectonic fracture, which are always served as a major route for infiltration of water from upper levels to depth.

2.3. Morphology of Gadima cave

The today's entry into the cave consists of two horizons. The lower horizon is very complex and consists of two parallel corridors, in the south-north direction, three transverse channels and curved corridors, in the west-east direction.

The upper horizon consists of two linked corridors, located above 12m in the west-east direction (Muratagic, 1973). Total length of all channels, corridors and halls in the Gadime cave is 1.260m (Figure 3).

Figure 3. Entries in the Gadime cave

Western gallery - with SE-NW direction, represents the essence of the discovery of parts of the Gadime Cave. It is built right along the contact between marbles and Palaeozoic schist. This gallery is consisted by main channel and several small and large rooms.

North galleries - have a big number of corridors, channels and linked halls. Three main channels which begin from the western gallery have SW-NE direction.

East gallery - in difference to the above mentioned galleries, which consist by many channels and corridors, eastern gallery is simpler. This gallery consists of two channels: the long channel and blue channel. With a length of about 95m long, this channel extends in NE-SW direction.

Exit corridor - this corridor is about 30m long and begins at deep lake and ends in one of the oldest natural exit. This corridor have direction SW-NE and is connected with the entry gallery through a support channel.

3. METHODOLOGY AND THE IMPACTS

This study was intended to determine the impact of water reservoir in Gadima Cave, which is building on the top of the limestone massif, above the Cave. For this reason the study was focused on two main issues:

1. The effect of the weight of the water reservoirs on Gadima Cave, on the stability of the ground where the reservoir is located;

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2. Effect of the water reservoir inside structure of Gadime Cave.

The complex of the hydro geological studies is based in the geological documentation of the field data of this region with complex geological construction. During the field study following observations and documentations were made: geomorphologic, geological, hydrological and hydro geological observation of the region and Klysur River Valley.

The geodetic measurements are performed in the place (x, y, z), where it was planned to build water reservoir. Also are measured a geodetic points at the entrance of the Gadime cave in order to set absolute quotas of these two objects. At the beginning we have measured the reference point in Lipjan. From this point then we measured the position of reservoir in four points and we have determined the coordinates. We have also measured a point at the entrance of the Gadime cave (Figure 4).

Figure 4. The position of the reservoir and the cave galleries plan

The field measurements show that the distance from where ends all galleries of Gadima Cave to the first point from where water reservoir began to be constructed is 205.50 m. The height difference between the reservoir and cave is 58.9m.

Samples of rocks have been taken in the place of construction of the water reservoir (Figure 5). For these types of objects is important defining the general condition of the geological-engineering and determination of physical-mechanical features of rocks, involved in the active area.
The carbonate massif of Gadime forms the nearly closed aquifer, limited by the formation from metamorphic schist of Palaeozoic on the east side and west side, while on the northwest side and the north is covered by clay-sandstone and molasses, which closes the water basin in the north, not so far.

Figure 5. Sampling place

Figure 6. Samples during testing

The total loads of water reservoir filled with water and covered with soil is 83.72kN/m2. To determine the sustainability of marbled limestone's during this field survey we took a sample. The sample was sent to the laboratory for analysis. At the beginning the samples were cut into cube shape with dimensions 5x5x5cm. The prepared sample is set in equipment to determine the pressure resistance (Figure 6). Test resulted that the pressure resistance of the marbled limestones is 81310kN/m^2.

Technical conditions of construction of the water reservoir and it's operation without leaking water on carbonate rocks of the hill above the cave, guarantees a lack of communication with the massif carbonates where is constructed and therefore there is no direct connection or influence in the cave structure. Based on field observations, geodetics measurements and analysis of rocks samples we conclude that based on the large size of the carbonate massif north of the river, the high hardness and compressive

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resistance of the rock, we are of the opinion that the reservoir has no effect on the rocks where was built neither in the Gadime cave.

Natural hazards of Gadime Cave are connected by the floods from Klysyr River as has hapened in 1969 year, and by the water clay muds, which came down through tectonical faults into different levels of the Cave. While the human impacts can be happened as result of demage of ornaments by visitors, and by quarries on the surface of carbonate massif, especially north of Klisur River, and along with the bottom of the River.

4. CONCLUSIONS

The Gadime cave with large size and rare natural ornaments is formed in Gadime marble carbonates rocks. The marbled limestones are massive and with schist-layer textures that are separated into blocks by tectonic faults, fractures and cracks. Karst processes there are intensively on the surface of carbonate rocks and in depth.

Based on field observations, geodetics measurements and analysis of rock's samples we can conclude that the large size of the carbonate massif north of the river, the high hardness and compressive resistance of the rock, we believe that total loads of water reservoir has no effect on the rocks where the water reservoir was built neither in the Gadime cave.

Technical conditions of construction of the water reservoir and its operation without leaking water on carbonate rocks of the hill above the cave, guarantees a lack of communication with the carbonate massif, where it is constructed and therefore there is no direct connection or influence in the cave structure. The risks for the northern part of the massif, where the main stretch of the cave is, can come from interventions in the river bed raising barrier, excavations and construction in the slope and the whole north part of the river.

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