# ASPECTS CONCERNING ŞUGĂU CAVE TOPOCLIMATE

*M. CIGHER[1], L. MOLDOVAN[1], M. MIHALACHE[1]*

**Abstract. Aspects concerning Şugău Cave topoclimate**. The work presents a preliminary report on the diurnal topoclimatic characteristics specific to Şugău Cave, located in the southwest part of Giurgeu Mountains (Suseni, Harghita, Romania), in terms of the main topoclimatic parameters - temperature and relative humidity. The frequency of data for this study is hourly and covers the period May 15 - June 24, 2017, with high tourist flows. The main topoclimatic alignment represented by the Gemini Datalogger sensors follows the touristic gallery from the Entrance (Intrare) to the Music Hall (Sala Muzicii). In opposition, the sensors in the Great Hall (Sala Mare) and the Wonderful Hall (Sala Minunată) are meant to capture the topoclimatic features unaltered by mass tourism. Following the preliminary observation it is noted that the diminution of the diurnal thermal amplitudes occurs, on the tourist section, between 60-80 m away from the entrance, in G04 and G05 points, the average diurnal thermal amplitude is 0.2ºC. The average daily temperature on this alignment reaches the minimum value in the Music Hall (7.26 ºC), a value with 0.26ºC higher than that measured in the Grand Hall and 0.25ºC higher than that recorded in the Wonderful Room – Chandelier (Sala Minunată - Candelabru). The influences of the underground watercourse are strongly felt in the Active Gallery (Galeria Activă) with regard to temperature, stations G07 and G08 recording average daily temperatures of 5.71°C and 5.92°C respectively. The great topoclimatic stability in this gallery is also underlined by the extremely low diurnal average amplitude: 0.03ºC in station G07 and 0.06ºC in station G08. Stability meroclimate in this case is reached less than 10 m away from the entrance. Regarding relative humidity, except for the surface reporting station of the G02 and G03 sensors, all other sensors do not exhibit oscillations of the values. Starting with G03, the relative humidity values are over 97.5%.

**Key-words**:topoclimat,parameters, cave, Şugău

## 1. INTRODUCTION

Şugău Cave is classified under Romanian law (OM No. 604/2005) in protection class B, which allows, under certain conditions, the development of tourism activities according to a management plan. The discovery of the fossil top level of the cave in the 1960s led to its transformation into a tourist cave through

[1] Universitatea „Dimitrie Cantemir”, Facultatea de Geografie, Târgu-Mureş, e-mail: cighermarius@yahoo.com; m_2006_marius@yahoo.com; moldovanlucian@yahoo.com.

the dismantling, silting and layout of stairs with staircases, balustrades, etc. Physical changes to a cave may cause changes in topoclimate - temperature, relative humidity, ventilation (Russel and MacLean, 2008). Continuous monitoring for a period of at least one year can help to understand the variation of topoclimatic parameters for an assessment of the effects of tourism with applications in the management and protection of tourist caves (Lario and Soler, 2010).

The advantage of a study in Şugău Cave is the fact that it offers the possibility of comparing the microclimatic conditions in the gallery subject to tourist flows with those from the galleries with natural topoclimatic regime, as is the Dry Branch No. 1 (Ramura nr.1 Uscată), after the Superabundance Arm (Braţul Preaplin) or the Great Hall, makes the junction with the other levels of the cave. The argument of the existence of natural topoclimatic conditions too little altered on the Superabundance Arm is of a morphological nature, the topography - slopes, severe straits - being inhibitors of any anthropic climatic disturbances that could be propagated by convection. Numerous similar studies have highlighted precisely the need for prior monitoring of unmodified topoclimate by human presence, which would require that tourist activities be suspended for at least one year (Michie, 2005). However, this is not the case of Şugău Cave where, as mentioned above, there is a natural topoclimatic reporting basis.

Air temperature is a topoclimatic parameter that is relevant to understanding the thermodynamics of this system. Depending on this element, each cavity can be topoclimatically structured in the so-called meroclimatic subunits (Racovita, 1975). Given the topographic complexity of the underground network of Şugău Cave - a multi-floors system, rectangular network, three openings at different elevations, topoclimatic monitoring must continue for at least a year to have a complete climate cycle. Thus, the seasonal regime of the topoclimatic parameters can be surprised, edifications regarding the ventilation regime can be surpassed and the effect of mass tourism on the topoclimatic parameters may be more surprising.

The cave is located in the Harghita County, Suseni commune, the south-western slope of the Sipos Massif, a massive mountain ridge of the Giurgeu Mountains - 1568 m. The cave is positioned in a lentil of crystalline and dolomitic limestone, oriented northwest - southeast, 1400 m long and 390 m wide (Zsolt, 2016) (Fig. 1).

The geology of the studied area is determined by the crystalline-Mesozoic foundation of the stratigraphic ensemble consisting of two petrographic units: pre-permian crystalline schists and sedimentary Mesozoic layers deposited on the crystalline schist - carbonate rocks such as limestone, dolomite limestones, dolomite (Zsolt, 2016).

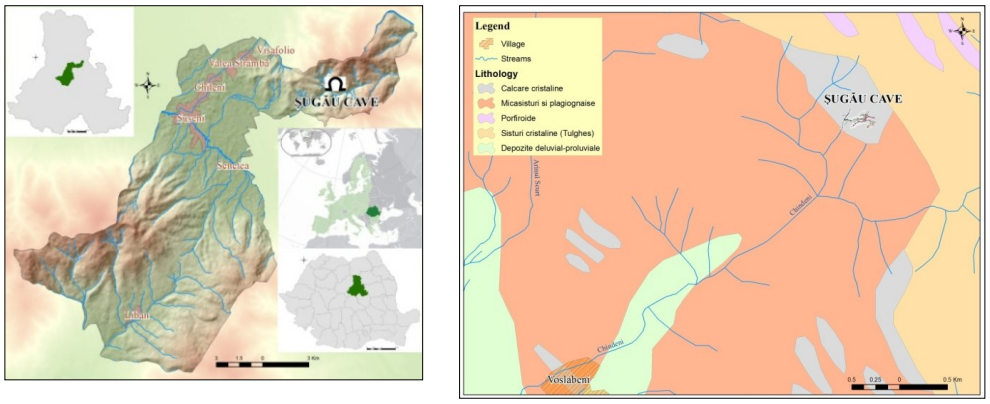



**Fig. 1** Localisation of Şugău Cave (a) and the lithology specific to the studied area (b), geological data after "Harta geologică a R.S. România, sc. 1:200000", Geological Institute, Bucureşti, 1967

The crystalline and dolomitic limestone lens in which the cave was formed is delimited in the northwest by a fault, being the most drastic geological limit. In the other cardinal directions, the lens gradually decreases, losing itself in the mass of graphite schists. Regarding the hydrogeological system, the water losses are of the areolar type, the water from precipitation and melting snow infiltrated on the south-western slopes of Şipoş Massif. There is no organized surface loss. Percolation water infiltrates underground on the cave fracture system and drains to the surface through current exertion. The cave system is a result of the correlation between the periodic oscillations of the local base level, the geological characteristics of the substrate and the meteorological processes. There are four distinct levels of karstification: Level 1 represented by Dry Branch No. 1, level 2 materialized by Dry Branch No. 2, Level 3 of the Link Gallery (Galeria de Legătură) and Level 4 marked by Active Gallery (Zsolt, 2016).

## 2. DATA AND METHOD

For the location of the topoclimatic sensors, it was necessary to make a topographic analysis of the underground holes network, the traverse and the radiation being the two topographic methods used. In order to accomplish these processes, a 50 m metallic roulette with 1 mm graduations was used, a Bosch PLR50C laser meter, a Suunto tandem with a clinometer and a compass with 1 degree scale. Thus, due to these tools, we obtained the 5th degree of precision from 7 in speleological topographical measurements. The collected data were recorded in a table. Data processing was done in AutoCAD 2013.

For the topoclimatic study, preliminary measurements were made with a Minolta Cyclops 300AF thermal imaging camera on the substrate temperature represented by the walls of the underground voids, ceiling and floor.

These observations helped place climatic sensors in order to capture fluctuations of the horizontal thermal gradient and the meroclimatic delimitation of the cavity, knowing the interdependence between the temperature of the underground void and the temperature of the substrate. The reporting station from the exterior was located in the immediate vicinity of the entrance, in a tree, 2 m high from the litter, on the shaded side. The main topoclimatic profile is designated by the sensors G01, G02, G03, G04 and G05, on the main caves mapping level, recorded on the map in 1985 as Dry Branch No. 1 (Fig. 2).

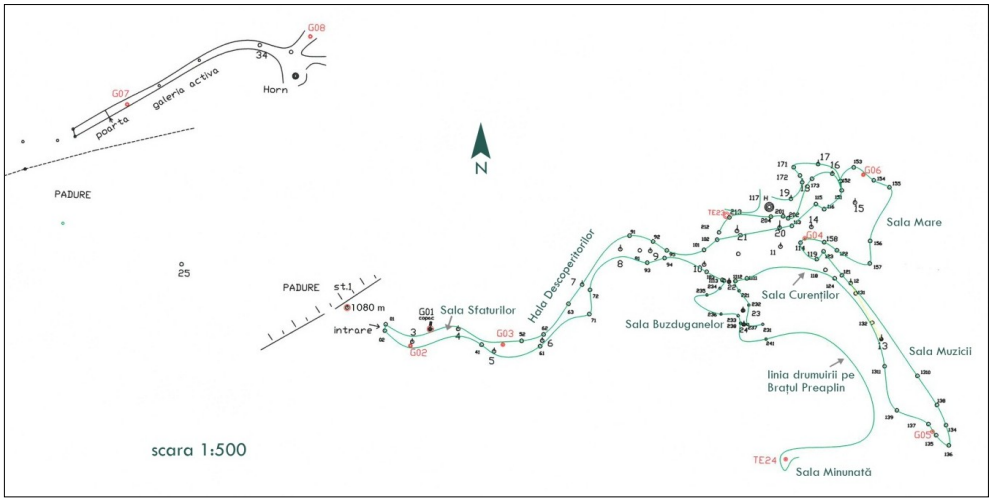



**Fig. 2.** Placement of climatic sensors (G01-G08; TE23 and TE24) in Şugău Cave – plan representation

The TE24 sensor was positioned near the Chandelier, the most spectacular speleothem of the cave, in the protected sector of the Dry Branch No.1, in order to surprise the natural thermal regime in the deep cave sector, compared to the one influenced by the mass tourism in Music Hall (including symphonic concerts). The positioning of the G06 sensor is of dual relevance - both as a point of connection to the Active Gallery via Dry Branch No. 2 and the Link Gallery, and similar to that of the TE24 sensor (Fig. 3).

**Fig. 3.** Installation of Gemini Tinytag TGP 4500 sensors in Şugău Cave

From a meroclimatic point of view, the TE24, G05 and G06 sensors are meant to capture the stability meroclimate, with the note that the G05 station in the Music Hall can record non-periodic, short-term fluctuations due to the large groups of visitors.

The sensors used in the study come from the UK's Gemini Data Loggers and are designed for relative humidity and air temperature measurements. Tinytag TGP 4500 sensors were used, with a moisture, dust and condensation resistant housing, for temperatures of -25 ... + 85°C; 0-100% UR.

They were set to measure the two parameters within one hour for one year. For the present study, the data was exhausted for a period of one month from May 15 to June 24, 2017. The data was processed in Microsoft Office Excel 2007.

## 3. RESULTS AND DISCUTIONS

The morphological characteristics were defining in the design of the Şugău Cave touristic route, which overlaps to a large extent the Dry Branch No.1 - the main level of karstification - on the alignment: the Locker (Vestiar), the Hall of Advices (Sala Sfaturilor), the Hall of the Discoverers (Sala Descoperitorilor), the Currents Hall (Sala Curenților), the Ödön Hall (Sala Ödön) and the Music Hall. The pronounced declivity of the Great Hall and the extremely narrow passages of the Superabundance Arm are the reasons why these sectors remained outside the touristic circuit, offering instead the possibility of comparing topoclimate with a natural regime specific to them and the one exposed to anthropogenic influences, with the specification that the occasional visits of speologists on these protected

routes cannot bring significant changes to short-term climatic parameters with less cumulative effects.

The main topoclimatic profile is represented by the alignment of the sensors G01 - G02 - G03 - G04 - G05, which seeks to capture the horizontal thermal gradient, the downward variation curve of the average daily temperatures, the variation curve of the average daily temperature amplitude for the main level of karstification, overlapping the tourist galleries. Regarding the distribution of the average daily temperatures, there is a pronounced progressive decrease in the first 20 m, after which the temperature drops after a much lower thermal gradient and the minimum temperature is reached in the station G05 (7.26ºC) at 115.56 m from the entrance.

It should be noted that the average daily temperature for the mentioned interval recorded at the G06 station, in the Great Hall, was of 7,001ºC and 7,01ºC in the Wonderful Hall at the Chandelier. Comparing the sensor values placed in the stability meroclimate sector results in a difference of 0.25°C between the natural topoclimate and the one with anthropogenic influences. The thermal changes due to anthropogenic presence are more pronounced in the variation curve of the daily diurnal thermal values (Fig. 4, a).

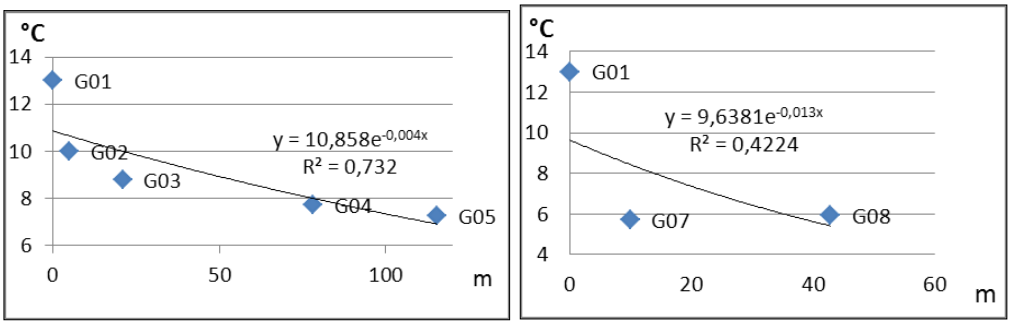
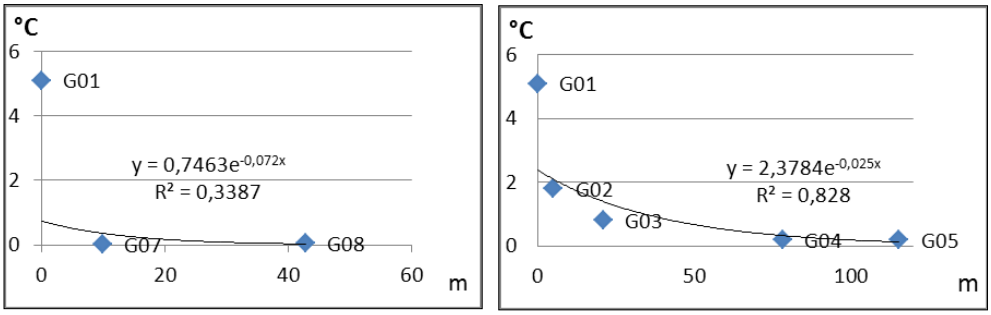



**Fig. 4.** Spatial distribution of diurnal average temperatures on Dry Branch No.1 (a) and the Active Gallery (b) during observation period

On the Active Gallery, the G07 and G08 sensors show close values of 5.715ºC and 5.923ºC respectively. The higher value in G08 can be explained by the fact that the sensor is located close to the Active Gallery's connection with the upper fossil galleries, the thermo circulation being very active, the air not reaching the thermodynamic equilibrium.

Lower temperatures from the Active Gallery are due to the presence of the underground water course, whose temperature, determined with the Minolta Cyclops 300AF, was 5.6ºC at the station G07 (Fig. 4, b).

As for the attenuation of the average daily thermal variations, the descending curve shows a sharp decrease in the first 20 m, the equilibrium being reached between 70 and 80 m, the sensors G04 and G05 recording the same value of the average daily amplitude: 0,2ºC (Fig. 5, a).




a b

**Fig. 5.** Attenuation of diurnal average thermic variations on Dry Branch No.1 (a) and Galeria Activă (b) during observation period

According to this thermal parameter, the meroclimatic delimitation of Dry Branch No. 1 could be plotted between stations G03 and G04, the perturbation meroclimate being specific to the vestibular space. The thermal amplitude of 0.2ºC for the points G04 and G05 indicates the presence of a stabilized meroclimate. However, the stability of the Active Gallery's climate is much bigger, with a thermal amplitude of 0.03°C for G07 and 0.06ºC respectively for G08. As such, in this sector of the gallery, the stability meroclimate is reached at most 9 m away from the entrance (Fig. 5, b). From the previous graph we can see that the value for $R^2$, of 0.3387 is very much below 1, suggesting the need for more measuring points on the first 10 m of the gallery, in order to capture a gradual translation of the thermal variations.

The absolute thermal amplitude recorded by the Gemini sensors is between 17.3°C in the exterior station and 0.1 in the G06 and TE24 stations, the lowest value designating cave sectors with stability meroclimate. Moreover, G06 was taken as a benchmark for the cave's natural topoclimate, unaffected by mass tourism (Fig. 6).

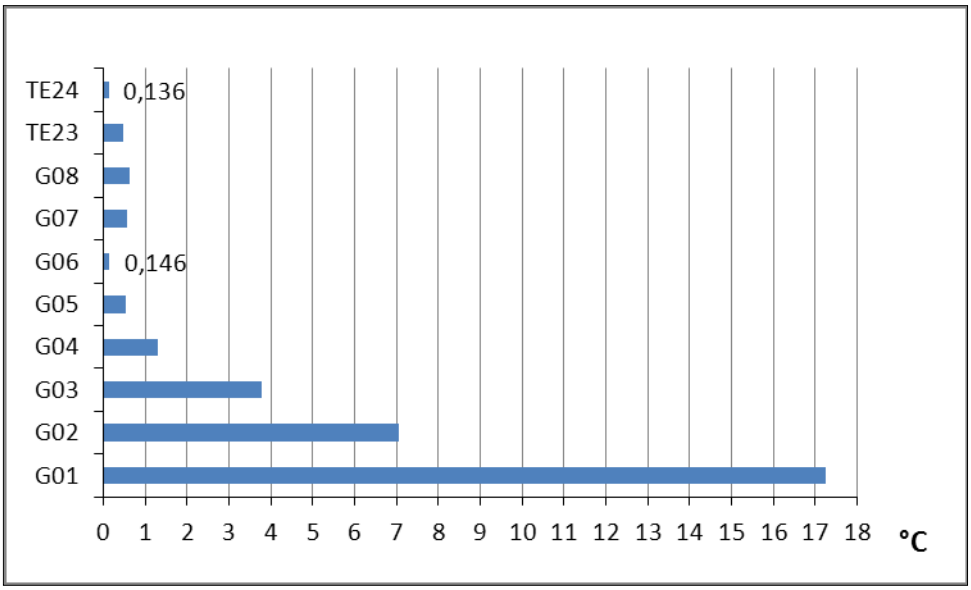



**Fig. 6.** Absolute thermic amplitude registered by the Gemini Datalogger sensors during the entire observation period

The absolute thermal amplitude of 0.623ºC, recorded by the G08 sensor on the Active Gallery, suggests the presence of the main convective flow that is evacuated through the opening at the lowest cavity of the cavern system. A fraction of this downward air current is drained by the opening of Dry Branch No. 2, located on the same slope, at an intermediate level, between the karst spring and the opening of Dry Branch No. 1.

The diversity of water sources in a cave and the non-periodic variations of relative humidity from exterior determine the irregular values of this parameter along the cave, consequently it is impossible to adapt a mathematical model (Caba, Gavruş, 1984).

The distribution of absolute relative humidity values shows important variations only in the vestibular sector of Şugău Cave, on Dry Branch No.1, the external influences propagating only on the first 20 m (Fig. 7).

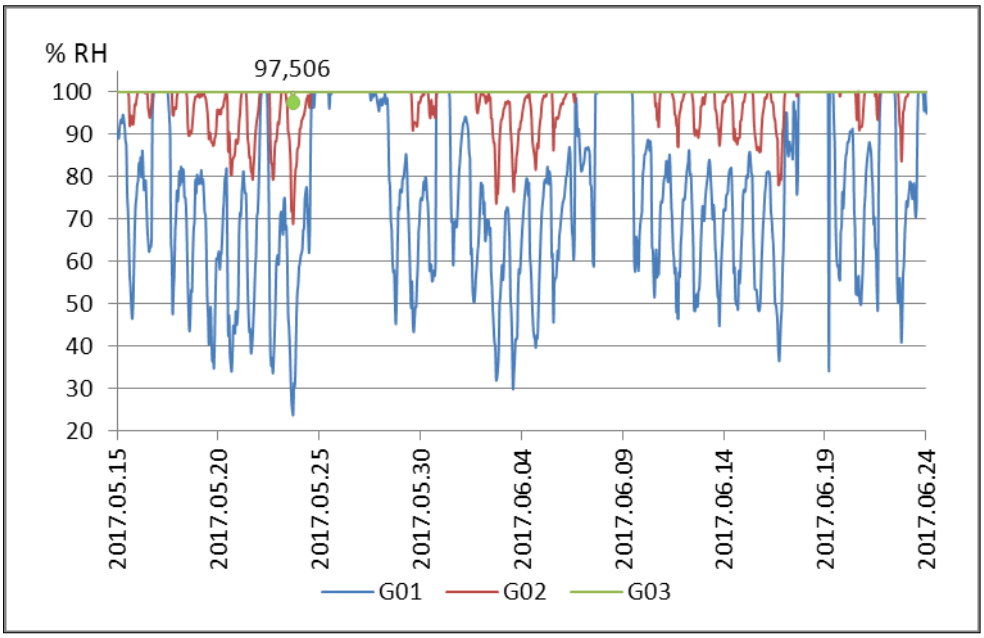



**Fig. 7.** Distribution of relative humidity absolute values (%) on the G01-G05 topoclimatic alignment, during observation period

The sensors G03, G04 and G05 show, with only one exception - 97.5% for the G03 sensor, absolute values of 100%, which may indicate a malfunction of the moisture sensor in the sense that the condensation formed on the receiving surface influences readings, contrary to technical specifications provided by Gemini Company. In fact, the same phenomenon is seen in all other sensors.

In the absence of specific data on the number of tourists who visited the cave during the considered period, any interpretations related to the interaction between tourism and cavern topoclimate are devoid of solid scientific support. This variable will be taken into account for a future study, the current custodian having among the set goals the one on the monitoring of tourist flows, which has been implemented since July 6, 2017. The following three variables are monitored: temperature, relative humidity and tourists' number - for one year and interpreting data on a complete climate cycle.

## 4. CONCLUSIONS

The distribution of diurnal air temperature values over the G01 - G05 topoclimatic alignment best captures the interdependence between exterior and inner cave temperatures, especially on the first 80 m, up to the G04 sensor (Fig. 8).

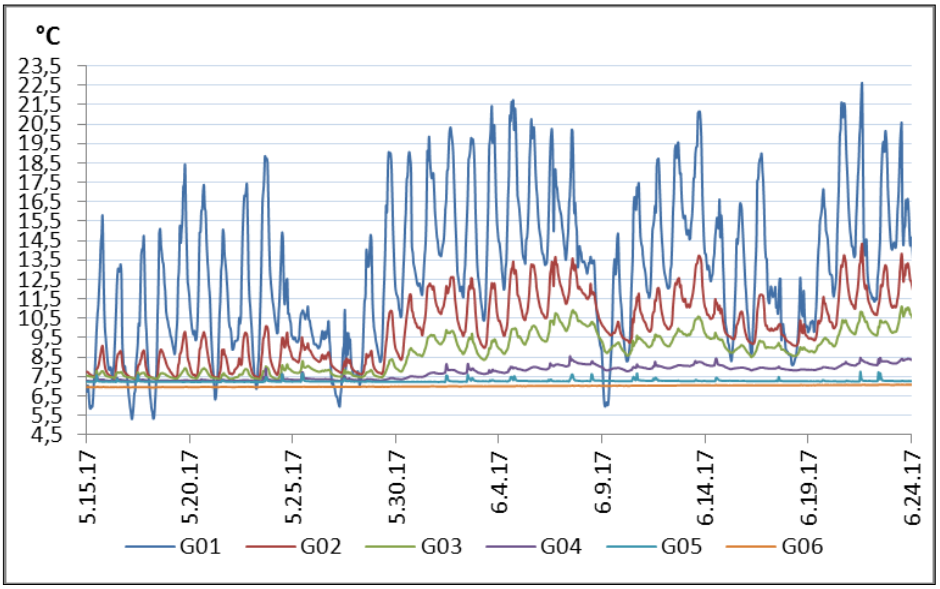



**Fig. 8.** Diurnal temperatures variation on the G01-G05 and G06 topoclimatic alignment

The amplitude of diurnal oscillations is progressively attenuated with the increase of the distance from the entrance, so that there are barely observed variations at the G05 sensor, with apexes registering increases of diurnal air temperature by 0.5°C compared to average (Fig. 9).

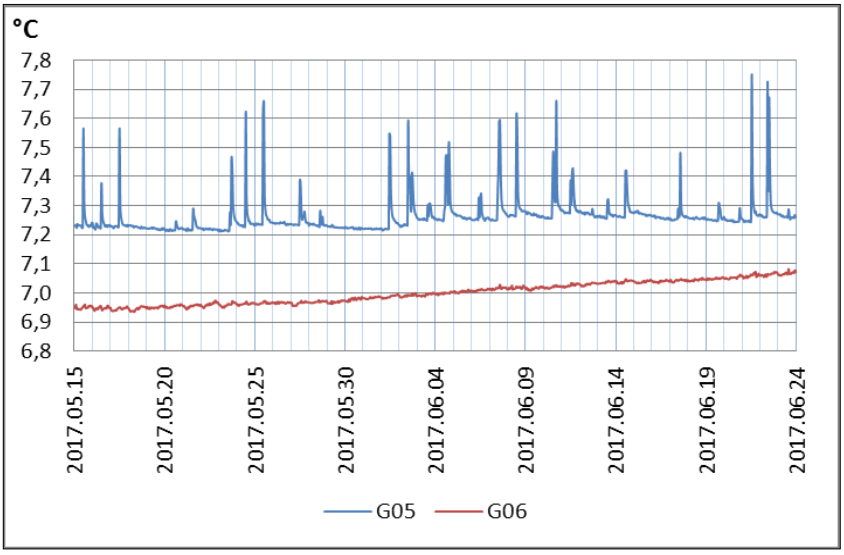



**Fig. 9.** Diurnal temperatures variation in a stability meroclimate (Music Hall and Grand Hall)

By comparing the temperature variation line recorded by the G05 sensor with that measured by the G06 sensor, no major disturbance is detected in the latter, being a typical diurnal run for stability meroclimate, with absolute maximum diurnal amplitudes of 0.15°C. In the absence of tourist activities during that period, the high oscillations in the Music Hall must be attributed to the propagation of the external thermal influences, with June 21 recording the highest diurnal exterior temperatures during the observation period. Surprisingly, these "echoes" are felt at 116 meters away from the entrance. After setting up the monitoring of the number of tourists visiting the cave, starting July 6, 2017, the influence of anthropogenic presence over this topoclimatic parameter could be quantified in a future study.

## REFERENCES

1. Caba, Elena, Gavruş, M., (1984), *Recherches topoclimatiques dans le grotte de Peretele Dârninii (Valeé d'Albac, Massif du Bihor)*, Theoretical and Applied Karstology, Vol. 1, Bucharest
2. Cigna, A., (1993), *Environmental management of tourist caves: the examples of Grotta di Castellana and Grotta Grande del Vento*, Italy: Environmental Geology, v. 21, p. 173–180.
3. Lario, J., Soler, V., (2010), *Microclimate monitoring of Pozalagua Cave (Vizcaya, Spain): Application to management and protection of show caves,* Journal of Cave and Karst Studies, v. 72, no. 3, p. 169–180,
4. Michie, N.A., (2005), *On the placing of objects in caves*, in *Cave management in Australasia 15:* Proceedings of the 15th Austra - lasian Conference on Cave and Karst Management, Chillagoe Caves and Undara Lave Tubes, North Queensland, Carlton South, Victoria, Australasian Cave and Karst Management Association
5. Racoviță, Gh., (1975), *La classification topoclimatique des cavites souterraines* - Trav. Inst. Speol., E. Racovitza", *XIV,* p. 197-216.
6. Russell, M.J., and MacLean, V.L., (2008), *Management issues in a Tasmanian tourist cave: Potential microclimatic impacts of cave modifications*, Journal of Environmental Management, v. 87, p. 474–483.
7. Ruşdea, Evelyn, (1985), *Etude topoclimatique de la Grotte Gheţarul de la Vârtop (Monts du Bihor)*, Theoretical and Applied Karstology, Vol. 2, Bucharest
8. Zsolt, A., (2016), *Peştera Şugău, 50 de ani,* Editura Mark House, Gheorgheni