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PRELIMINARY INVENTORY AND CONSERVATION CONDITIONS OF SPELEOTEMS FROM GRUTA DA SERRA DAS COBRAS, SANTA QUITÉRIA, CEARÁ, BRAZIL

INVENTÁRIO PRELIMINAR E CONDIÇÕES DE CONSERVAÇÃO DOS ESPELEOTEMAS DA GRUTA DA SERRA DAS COBRAS, SANTA QUITÉRIA, CEARÁ, BRASIL

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ABSTRACT
Natural underground cavities are environments composed of unique characteristics that house a great complexity of geological formations and lush scenery. The underground environment is considered a true treasure for science and humanity. The main objective of this research is to identify and classify the different types of speleothems found in Gruta das Cobras located in the municipality of Santa Quitéria/CE, also highlighting the risks that these structures face in terms of conservation. The materials and methods consisted of bibliographical research, fieldwork, photographic records and analysis and interpretation of information obtained at all stages. In general, the most common speleothem formation present in the study area is of the stalactite and stalagmite type. Speleothems of the column type, Bridal cake and Boxwork type were recorded inside the cave, complex formations that take millions of years to form and which are currently being impacted by the tourism sector, with no regulation or inspection. Impacts on structures, graffiti and breakage of speleothems were identified. In this way, it is concluded that further studies on the site are essential, as well as a preservation intervention by the competent public bodies.
Keywords: Caves; Crystalline formations; Speleothems.

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RESUMO
As cavidades naturais subterrâneas, são ambientes compostos por características únicas que abrigam uma grande complexidade de formações geológicas e cenários exuberantes. O ambiente subterrâneo é considerado verdadeiros tesouros para a ciência e humanidade. A presente pesquisa possui como objetivo central identificar e classificar os diferentes tipos de espeleotemas encontrados na Gruta das Cobras, localizada no município de Santa Quitéria/Ce, destacando também os riscos que essas estruturas enfrentam em termos de conservação. Os materiais e métodos consistiram em levantamento bibliográfico, trabalhos de campo, registros fotográficos e análise e interpretação das informações obtidas em todas as etapas. De maneira geral, a formação mais comum de espeleotema presente na área de estudo é do tipo estalactite e estalagmite. Foram registrados no interior da caverna Espeleotema do tipo coluna, bolo de noiva e do tipo *Boxwork*, formações complexas que levam milhões de anos para serem formadas e que atualmente estão sendo impactadas pelo setor de turismo, não havendo regulamentação e nem fiscalização. Foram identificados impactos nas estruturas, pichações e quebra dos espeleotemas. Desta forma conclui-se que seja imprescindível mais estudos sobre o local bem como uma intervenção de preservação pelos órgãos públicos competentes.
Palavras chaves: Cavernas; Formações cristalinas; Espeleotemas.

INTRODUCTION

Knowledge about the "underground world" presents a rich diversity of formations. Natural underground cavities are environments composed of unique characteristics that house a great complexity of geological formations and stunning scenery. Due to these characteristics, caves attract economic interest and the attention of many people, companies, mining enterprises, scientists, environmentalists, tourists, religious groups, athletes, adventurers, and especially speleologists (Monteiro, 2014).

Caves are increasingly threatened. This is due to the high degree of degradation observed in the country, mainly due to unplanned occupation, lack of planning, and disorganization among various segments of society (Theulen; Sessegolo, 2001).

In this context, this paper presents the Gruta da Serra das Cobras, in the municipality of Santa Quitéria, in the northwestern part of the State of Ceará. This cavity was completely unknown to the Brazilian speleological community until recently, with no detailed studies available in the scientific literature or even its registration in the technical records of public agencies responsible for managing Brazil's speleological heritage. The only reference to the existence of this cavity was made by Menezes (1889), who gives a brief physical description of its interior. Therefore, we have a speleological rediscovery in the territory of Ceará.

It is important to emphasize that nature has always been one of the attractions throughout humanities research (Falcão Sobrinho; Costa Falcão, in Falcão Sobrinho et al. 2023). This fact justifies our exploration in the less known areas of the municipality of Santa Quitéria, in the state of Ceará.

Thus, the general objective of this study is to identify and classify the different types of speleothems found in the Gruta da Serra das Cobras, also highlighting the risks these structures face in terms of conservation. The specific objectives include identifying and analyzing the different forms of damaging impacts suffered by these structures, which includes documenting the impact of activities such as vandalism, graffiti, and inappropriate visitation that affect the integrity of these vulnerable structures. Additionally, conservation measures will be proposed aiming not only at preserving the cave structure but also the cave environment as a whole. The purpose of these measures is to protect the natural resources and unique underground ecosystems, reducing existing damage and preventing future adverse effects. In light of this, the

present work will contribute to the knowledge of the area, which is an important point in terms of planning areas to be protected. It is impossible to establish conservation strategies without considering this item as paramount.

STUDY AREA

The Gruta da Serra das Cobras is a cave located in the homonymous mountain range, in the municipality of Santa Quitéria, in the northwest of the state of Ceará, at coordinates 4° 19' 55" S latitude and 40° 09' 24" W longitude, with an altitude of approximately 363 meters (Figure 1). It is bordered to the north by Sobral, Forquilha, Groaíras, and Cariré; to the south by Catunda, Monsenhor Tabosa, Boa Viagem, Madalena, and Itatira; to the east by Itatira, Canindé, and Sobral; and to the west by Cariré, Varjota, Pires Ferreira, and Hidrolândia (IPECE, 2017).

The study area is part of the geomorphological compartmentalization of the Sertaneja surface. According to Souza (2006), these are surfaces embedded between sedimentary or crystalline plateau levels, with altitudes below 400 meters and a significant lithological diversity broadly subjected to hot semi-arid conditions. These surfaces also exhibit the following characteristics:

> Strong rainfall irregularity; dense, weak and moderately notched fluviometric network on the surface and with river channels with seasonal intermittence; mosaic of soils with a wide variety of associations, with the existence of shallow soils, rocky outcrops and stony floors being common, extensively covered by caatingas that display a wide variety of physiognomic and floristic patterns and different levels of degradation. (Souza, 2006, p. 25).

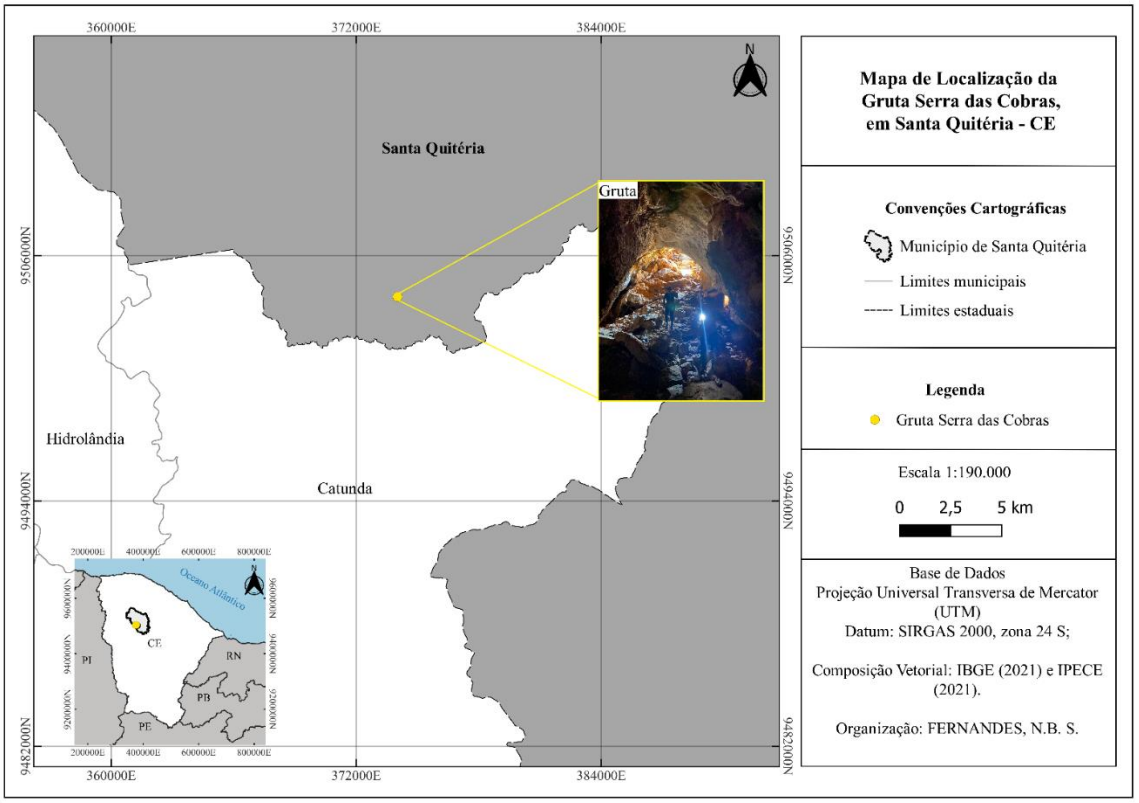
The Serra das Cobras constitutes a granite relief (inselberg) that stands out in altitude within the semi-arid landscape of Santa Quitéria. These formations are more resistant to erosive processes that lower the relief. The Sertaneja surface is frequently dotted with inselbergs and clusters of inselbergs, many of which are supported by resistant granite rocks. These features invariably stand out in the monotonous landscape of flattened surfaces. In some cases, these residual landforms are arranged in long alignments of hills or hillocks that extend for hundreds of kilometers, controlled by more resistant rocks of ancient mylonitic belts (Brasil, 2014).

According to Falcão Sobrinho (2006; 2020), in the Sertaneja surface environment, high temperatures prevail, increasing mechanical weathering. This results in the exposure of fractured rock blocks, stony grounds, and shallow soils throughout the Sertaneja landscape, accompanied by the caatinga, which has a significant spatial extent among the elements that form the landscapes.

ENVIRONMENTAL CHARACTERISTICS

The study area has a Hot Semi-Arid Tropical climate, with an average annual rainfall of 799.8 mm and average temperatures ranging from 26°C to 28°C. The rainy season is concentrated from February to April, with rains being irregular in both time and space, resulting in a prolonged dry season. The predominant soils in the area are: Non-Calcic Brown, Litholic Soils, Solodic Planosol, Red-Yellow Podzolic, and Regosol. The vegetation consists of Open Shrub Caatinga, Deciduous Thorn Forest, and Tropical Semi-Deciduous Rainforest (IPECE, 2017).

Figura 1 – Mapa de localização da Gruta da Serra das Cobras.



Source: IBGE (2021), IPECE (2021). **Organized** by Fernandes (2023).

This cave harbors a diversity of geological formations known as speleothems, which have been affected by uncontrolled and unregulated human intervention, resulting in the deterioration and damage of the structures, as well as incidences of graffiti. The oldest bibliographic record about this cave, and the only one found so far, is provided by Menezes (1889), which can be considered the first and only information about the cave under study. During his expedition to the mentioned cave, this author observed the presence of various types of speleothems and other typical characteristics of the cave environment, leaving us with the following account:

> Right at the entrance, our attention was drawn to the presence of curious objects formed by stalactites and stalagmites; thrones, confessionals, pulpits, chastisements, tenants, columnatas, etc. but unfortunately without the magnificent scintillations of the limestone concretions in the reflection of the lights, due to the droppings of bats (vespertilio murinus) that yellow the whiteness of these beautiful stones, and take away their elegant shape and shine (Menezes, 1889, p. 240) .

The cave has two entrances: the main one (Figure 2-b) is large enough to allow multiple people to enter simultaneously, while the second entrance is quite narrow (Figure 2-c), but can also be used to access the cave. Figure 2-a provides a broader view of the formation of Serra das Cobras, a type of relief that is more resistant compared to the adjacent surface. Figure 2-b

shows the main entrance of the cave, immediately displaying the characteristics of this geological formation.

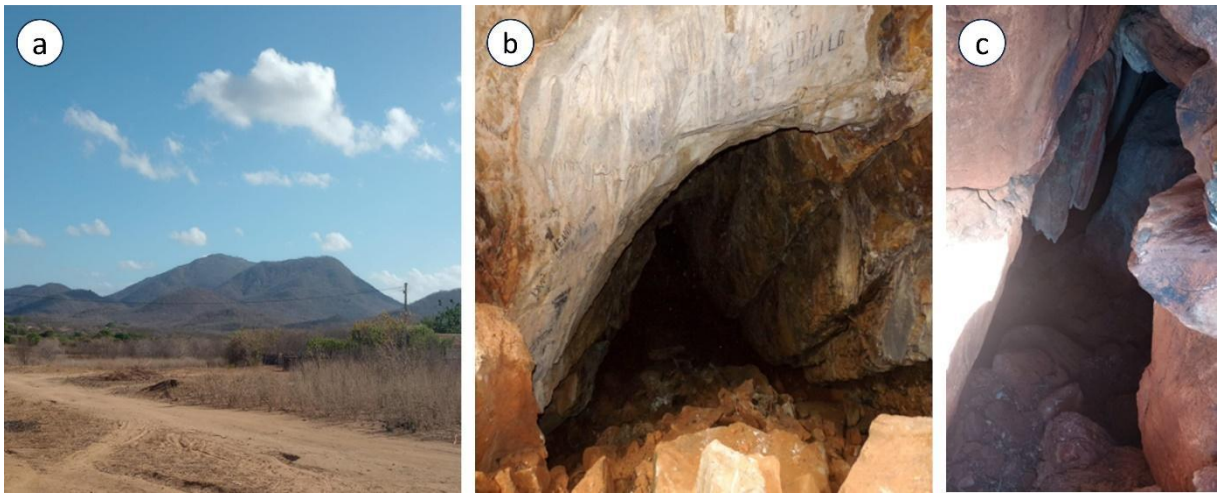


Figure 2 – Physical aspects of the study area. a) View of Serra das Cobras (facing south); b) Main and largest entrance to Gruta das Cobras; c) Secondary and minor entry.
Source: Victor Paiva (2023).

MATERIALS AND METHODS

The procedures used in the research consisted of three stages:

Literature Review: The purpose was to understand the theoretical concepts related to speleology, obtain data about the physical environment of the region, and gather historical information about the studied cave. A systemic approach was used to understand the geodiversity of Serra das Cobras, integrating both physical and anthropogenic factors present in the area. Topics related to the theme were developed based on a literature review to support the proposal of the work. Through the literature review, the researcher seeks relevant published works to understand and analyze the research problem, aiding from the beginning to the completion of the work (Carvalho et al., 2024).

The General Systems Theory (GST) is one of several methodological approaches used in Geography, a synthetic discipline, applied through the systematization of a specific space, environment, or landscape (Falcão Sobrinho, Carvalho, 2023).

Preliminary Field Recognition: This involved visiting the cave site to collect speleological data, information on the use and conservation of the underground environment, and photographic documentation of the cave, its structures, and the anthropogenic impacts on the speleothems.

Final Office Work: This phase included processing the collected data, identifying and analyzing the structures present in the cave through the obtained photographs, and correlating the findings with the theoretical review to propose conservation measures for these structures.

RESULTS AND DISCUSSIONS

In general, the most common types of speleothems present in the cave are stalactites and stalagmites. According to Cruz and Piló (2019), the dripping process from the ceiling gives rise to stalactites, which have a central duct through which water circulates. When the dripping

frequency is higher than usual, there is not enough time for deposition on the stalactite, and the drop reaches the ground, forming another type of speleothem, the stalagmite.

The following images show the presence of both types of formations, with colors ranging from white to characteristically yellowish tones, as mentioned by Menezes (1889). It is also noticeable that parts of these structures are missing (Figure 3-a), due to breakage caused by visitors who lack awareness of the importance of preservation. In Figure 3-b, a well-developed stalagmite can be observed on the cave floor. However, when analyzing the stalactite that led to the formation of the stalagmite below, it is evident that the structure is much smaller than the normal corresponding stalagmite. This discrepancy is due to the breakage of structures that were in the process of formation and would have eventually become a column-type speleothem, which will be further discussed in the next section.

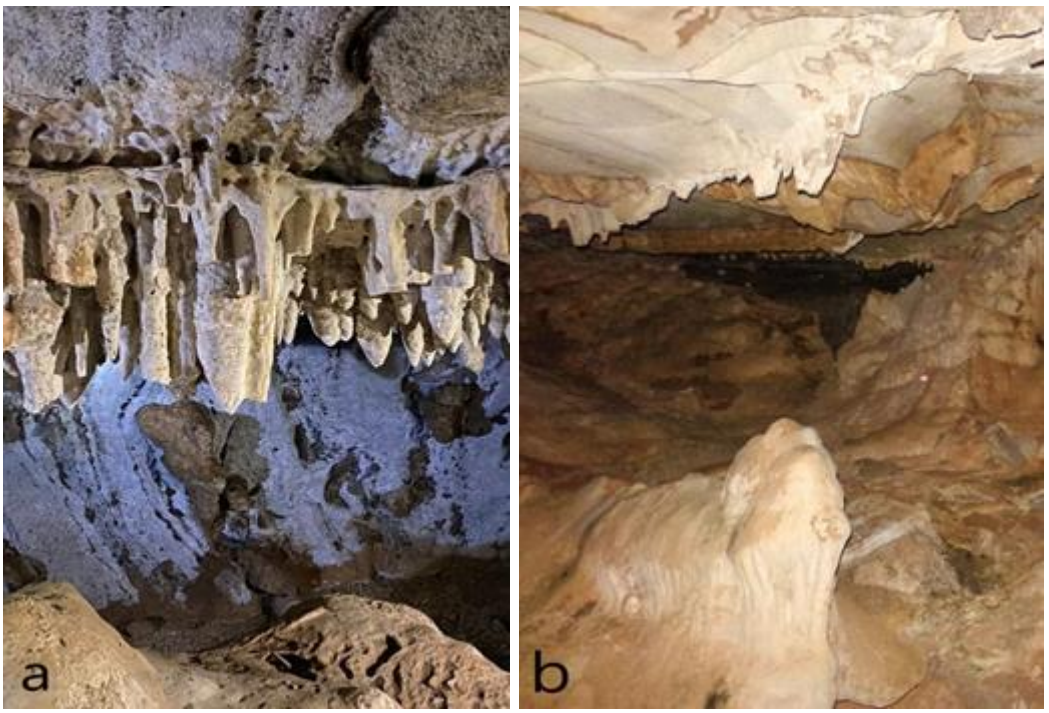


Figure 3 - a) Stalactites with complex shapes associated with straws and small curtains; b) Stalagmite-type speleothem originating from the deposit of sediments in the soil.

Source: Victor Paiva (2023).

Another formation found in the Gruta da Serra das Cobras is the so-called "Column." According to Bittencourt et al. (2020, p. 5), "a column is a type of speleothem that develops by connecting the ceiling and the floor of a cave. This phenomenon occurs when a stalagmite and a stalactite unite or when one of them grows enough to reach the substrate opposite to its origin."

Column-type speleothems play a fundamental role in maintaining the cave environment, as these structures ensure the cave's structural support. In Figure 4-a, we observe the presence of both fully developed and incomplete columns. Once again, the interruption in the formation of columns is due to anthropogenic actions, which in seconds can

destroy a formation that took thousands of years to develop, thereby jeopardizing the cave's structure.

In Figure 4-b, we can see a meeting of a stalactite and a stalagmite that have already formed a column. However, there are more stalactites under the forming column, which will further develop the column through the union of speleothem structures such as stalactites, stalagmites, and columns. This can eventually lead to the development of a bridal cake-type speleothem.

Figure 4 - Column-type speleothem: a) formation of already developed columns; b) meeting of the stalactite and stalagmite.

Source: Victor Paiva (2023).

Bolo de noiva: is the process of overlapping and joining structures, creating a kind of deposit with a white coloration. Several formations of this structure were observed in the study area, indicating an intense stage of limestone dissolution process. Therefore, it is possible to deduce that the cave has speleothems at different stages of development, ranging from simpler and basic levels of formations to more complex and detailed characteristics. Figure 5 shows the set of structures in the shape of a "Bolo de noiva."

Figure 5 - Wedding cake-type speleothem.

Source: Victor Paiva (2023).

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Boxwork: is a speleothem formed by the intersection of mineral plates. They can fill fractures or result from the residual dissolution of more soluble material (Bittencourt, 2020, p.14). A significant occurrence of this formation structure at various stages of development was observed, indicating the presence of several residual fractures in the cave ceiling. In other words, these structures emerge from the diverse mineral interaction, filling the fractures with different types of minerals, and their coloration is due to the presence of iron oxides. Figure 6 shows the Boxwork-type speleothems.

Figure 6 - Boxwork-type speleothem.

Source: Victor Paiva (2023).

Curtain: According to Cruz and Piló (2019), when the cave ceiling is not flat, the dripping process tends to flow laterally, resulting in the deposition of a layer of calcite that can grow and form a tortuous sheet known as a "curtain." Therefore, as shown in Figure 7, the existence of this type of speleothem can be observed on the upper part of the ceiling in both images. Additionally, dark tones are noticeable on the walls of the location in the first image. This occurs due to the presence of bats in the environment, which deposit their excrement, guano, responsible for the dark coloration on the cave ceiling. During the cave reconnaissance, no human aggression to this structure was noticeable due to its height and often being mistaken for the cave ceiling.

Figure 7 – Curtain-type speleothems.

Source: Victor Paiva (2023)

DETERIORATION OF CAVE STRUCTURES AND ENVIRONMENT

In addition to the damage caused by the breaking of speleothems in the cave, various other signs of harmful human intervention in the cave environment were observed. This includes the presence of waste such as garbage, ash remnants, and wood used for fires inside the cave, graffiti, PET plastic bottles, and even sewing threads.

The graffiti appears to be left by visitors as a kind of record of their passage through the site. Regarding the fires, they were presumably made to illuminate the cave during visits where the absence of natural light was noticeable. The presence of sewing threads and fishing hooks seems to serve as guides so that visitors do not get lost, as the cave has multiple galleries and complex natural labyrinthine systems.

Figures 8-a, 8-b, and 8-c show the situation in terms of deterioration, respectively: a stalactite-type speleothem broken by the irregular and irresponsible actions of visitors to the cave; the presence of garbage, wood remnants, and plastic packaging; and graffiti with more broken speleothems. This occurs due to a lack of supervision and regulation by the authorities regarding visitation.

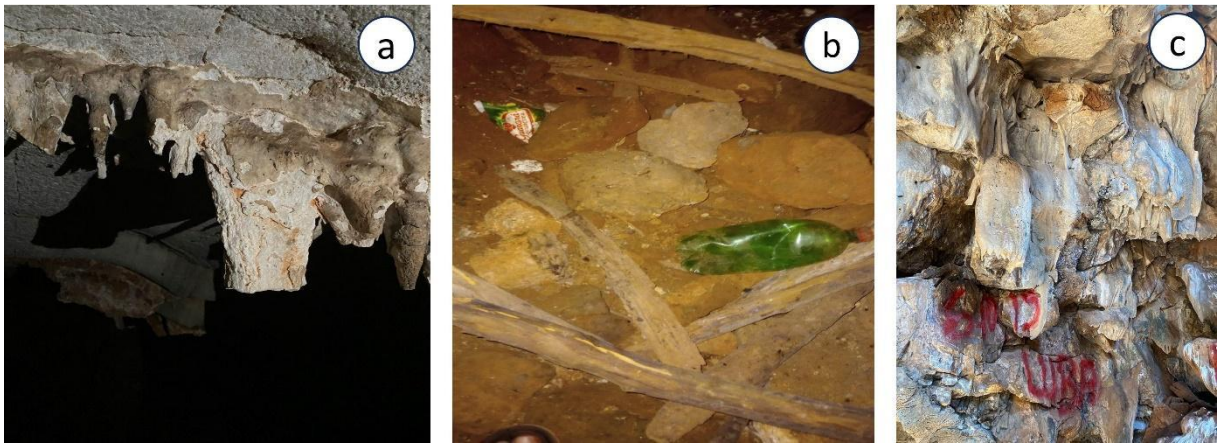

Figure 8 – Anthropogenic impacts observed in Gruta da Serra das Cobras: a) Stalactite in the process of broken formation; b) Presence of plastic waste; c) Set of broken speleothems and with graffiti.

Source: Victor Paiva (2023).

PROPOSAL FOR THE CONSERVATION OF GRUTA DA SERRA DAS COBRAS

To preserve the Gruta da Serra das Cobras, it is crucial to implement educational and awareness initiatives for the local community about the importance of caves, their delicate ecosystems, and the negative effects of human presence. Furthermore, establishing access control and rules for visitation can reduce the impacts of human activities in the cave. Continuous monitoring and scientific research on the state of the cave will allow for a more precise identification of impacts on its structure, enabling the suggestion of more effective conservation measures.

Despite the array of legal instruments for the preservation of cave environments, many of them remain unprotected. Theulen and Sessegolo (2001) highlight that an efficient way to conserve the Brazilian speleological heritage is through the creation and implementation of indirect use conservation units, especially those in the public domain. Private areas should also be concerned with preserving these environments, as they are often not known to public authorities.

It is worth noting that for the speleological heritage of the study area to be effectively preserved, it is necessary to have public policies aligned with scientific knowledge and actions that ensure the sustainable use and preservation of these natural cavities.

CONCLUSION

Therefore, cave ecosystems are understood as fragile and peculiar in their formation dynamics, composed of complex systems ranging from the formation of speleothems to the mineral composition of caves, according to general system theory. Furthermore, the various types of aggression that the Gruta da Serra das Cobras has been suffering in its environment as a whole are noticeable, from the breaking and disturbance of local structure and life, which puts the existence of the cave at risk, given that it has geological formations in different stages of development.

Thus, it is concluded that further studies on the site are essential, as well as intervention by the competent public authorities, tourism inspections, given the importance of these rare underground formations, located in the midst of the northeastern semi-arid region, witnessing

the rich geodiversity of the Ceará backlands. This research does not represent a final point, but only a starting point for the advancement of research on the Gruta da Serra das Cobras.

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