White Paper on Responsible Speleology

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THE PURPOSE OF THE DOCUMENT

This document sets goals that are reflected within the context of geoethical activities in speleology (speleoethics). This includes highlighting of scientific and educational factors, technical considerations, characteristics and values of subterranean georesources. Bearing in mind the significant vulnerability of subterranean karst environments. It is necessary to have an up to date, complete, and comprehensive understanding of potential anthropogenic impacts that can occur to geological, sedimentological, climatological, hydrological and biological components of caves and host karst systems. Within scientific peer-reviewed publications, there is little available on this topic. For this reason, this document proposes guidelines on how individuals should behave within caves. Which regulations and standards should be respected, as well as what measures should be taken in order to achieve maximum protection of caves. Furthermore, the pursuit of networking across speleological associations and the modernisation of multidisciplinary cooperation that should adhere to set geoethical strategies for speleoethics, is an important goal of this document. Mostly, because of geoethics, speleoethics can ensure objectivity and the improvement of ethically-responsible behavior towards caves and host karst. Also creating a unique approach for all individuals and interested communities to geoethical codes in speleology, is a crucial value to further gain and understand knowledge about caves and karst. Providing enhanced conservation management and protection of nature’s subterranean accessible environments is the goal.

Note – ***This White Paper by no means dictates who should, or who should not enter caves, including frequency of visitation. This document should be seen as enhancing educational behaviours within caves, to further highlight the importance of this sensitive habitat and its supporting karst biosphere.***

1. Introduction

1.1. Brief History of Speleology

The etymological origin of the word ‘speleology’ comes from the Greek ‘spélaion’ (‘cave’) and ‘logos’ (in the meaning of ‘study’).

The use of the term ‘Speleology’ came about during the Age of Enlightenment, from 17th to the early 19th century. This was perceived as the turning point of human reason. Philosophers like John Locke, Denis Diderot, linked reason with the maintenance of virtue and its ability to check potentially destructive human passions (White 2018).

Towards the late 19th and beginning of the 20th centuries, key proponents of cave exploration cemented the term speleology, to gain credibility and parity with institutionalised academia.

The first recorded, documented publication on the history of speleology was written by Franz Kraus (1879) in Vienna - “The history of caves still lies idle, because nobody has yet tried to arrange a systematic assorted and academic composed tableau of the results from different research. The Speleological Club in Vienna will have an honourable position if cave exploration in Austria can be considered as complete and somebody who tries to write a history about it” (Kraus 1879).

Édouard-Alfred Martel, used the words spéléologie and spélæologie on several occasions in the 1890's. Martel credits its coinage to the physician and paleoanthropologist Émile Rivière (Merriam-Webster 2010).

Speleology can cover diverse sub-specialities including geology, mineralogy, hydrology, limnology, ecology, climatology, zoology, botany, sedimentology, palaeontology, palaeoanthropology, archaeology, surveying and cartography. Cave diving and technical SRT rope work (Single-Rope Technique) are frequently needed to gain access in complex cases. An extension to speleological sciences, brings speleology to the all-encompassing word karstology. Karstology is a branch of knowledge devoted to all karst specialities and phenomena.

Karstology studies current and ancient phenomena of catchment wide processes that are inherent in soluble, weathered sedimentary geology, by natural meteoric waters as well as the formation, development, extent, and practical importance of karst and the host karst aquifer.

Speleologists, cavers and scientists study caves. Speleologists should understand the overall impact that humans can induce accessing the subterranean realm. Human access provides diverse harmful impactors to cave habitats. Several sensitivities, risks and threats to the subterranean environment are known, some of which can be irreversible. The most significant of these, is a lack of co-ordinated management that allows uncontrolled human activities to cause on-going degradation of this environment.

Speleologists globally have yet to be introduced to the concept of geoethics. The idea of geoethics has historically been one of personal preference, interpretation and understanding. Little in the way of peer reviewed publications is available on the topic. The role of geodiversity, speleogenesis and associated complex geology, hydrology and biospeleology requires more understanding and education dissemination.

Water, climate, and weather tend to dictate local speleological activities. As a result of variables within geographic juxtapositions, it is important to understand that caves residing within high energy or high flow environments have a lower ecological contribution due to higher groundwater flows. Such environments rehabilitate faster post-anthropic visitation, than do those with a history of low energy or older, higher-sensitivity habitats. For example, high energy caves are those located within geographic regions with high rainfall, therefore high energy speleogenesis and relatively young geology. However, most caves are low energy systems, so anthropic visitation has a high impact even for short visits.

Until recently, many individuals, including speleologists and scientists, have had a cavalier attitude towards taking samples from caves. There is recent evidence of intrusive behaviour on the part of some academics. Information yield is not a satisfactory excuse for unnecessarily destructive sampling procedures and processes (Buchanan & Maguire 2002). A South African cave of note has seen groups of international paleoanthropologists repeatedly deploying excavation teams of researchers into one cave system, for up to three weeks. Movile Cave, Romania has an anthropogenically modified environment as a result of over visitation by scientific researchers. This behaviour will have a lasting detrimental impact on these caves.

1.2. Geological Settings

A majority of caves form within carbonate geologic karst systems. The ideal setting for speleogenesis is within limestone ($CaCO_3$) host geology; dolomites ($CaMg(CO_3)_2$), gypsum ($CaSO_4 \cdot 2H_2O$) facies are also common. Speleogenesis is further evident within anhydrite ($CaSO_4$), sandstones, quartzites (SiO_2) and ferruginous sedimentary banded ironstone formations (FeO or Fe_2O_3), geologic settings. Where a vast water column is typically the driver behind speleogenesis. All the latter are found within confined or unconfined speleogenetic, continental, hydrologic settings.

Lava tube caves typically differ and are found within basaltic environments. Where volcanic lava flows were present during formation (lava tubes; we opt to use the term cave).

1.3. Energy Levels, Hypogene, Epigene Speleogenesis

Any cave system can present with low, moderate or high energy-fluidic, climatologic environments. These are categorised by the volume of water present before, during and latent to the process of speleogenesis.

Heaton (1986) classified caves into three categories of high, moderate, and low energy. High-energy caves are those that experience important inputs of energy on a regular basis, such as periodic flooding or seasonal climatic events. Moderate-energy caves would normally undergo regular changes about one order of magnitude lower than the high-energy caves (e.g., caves with permanent streams or air current). Low-energy caves are those where the microclimate is extremely stable and often the highest energy event may be related to something as trivial as the falling of a single water drop (Cigna 2011).

1.3.1. Hypogene Speleogenisis

“Hypogene speleogenesis is the formation of solution-enlarged permeability structures by water that recharges the cavernous zone from below, independent of recharge from the overlying or immediately adjacent surface. (Klimchouk 2013)”

Hypogene speleogenesis could be defined as the cyclic rising and falling, pumping action or thermal injection of groundwater. As host aquifers recharge and discharge via seasonal, other episodic cycles or mechanisms. This allows for a number of other dissolution mechanisms and occurs in most cases where the vadose zone could shift downwards time dependent on the hydrogeologic flow regime due to continued enlargement of conduits and voids by dissolution. Typically, high energy cave environments can be followed by moderate or low energy settings as speleogenesis evolves over time.

“To date, discrimination between epigene and hypogene speleogenetic pathways is made using cave morphology criteria, exotic mineral assemblages, and the predominantly negative ‘delta four S’ values for the cave sulfates. This presentation highlights the role sulfur and oxygen stable isotope analyses have in discriminating between epigene and hypogene caves (Onac, 2014)”.

1.3.2 Epigene Speleogenesis

Epigene speleogenesis is defined as classically taught by academicians. Mildly acidic rainwater (H_2CO_3) permeation through soluble rock forms cavities and conduits within fault lines. This can be witnessed as a process continuum within some older caves formed initially by hypogene speleogenesis evolution.

Speleogenesis can encompass a mixture of epigene and hypogene evolution. This can occur in many instances. Older hypogenic genesis and subsequent continued relatively recent epigenic genesis tend to be the norm. In all cases, the processes can take many hundreds of thousand years to evolve.

2. (Geo)ethical Speleology

2.1. Why Should a Heightened Level of Protection Be Exercised in Caves?

Due to the high level of vulnerability, age and fragility of karst systems, it is necessary that surface and underground karst landforms be adequately protected (Gillieson et al. 2022), so that their conservation is in accordance with geoethical principles and sustainable strategies for protecting the value of speleological geoheritage (speleoethics). Bearing in mind the complexity and uniqueness of underground karst formations; geomorphological structure, hydrological characteristics, biospeleology and speleoclimatic properties, protection, and application of ethically responsible anthropic behaviour implies a compound set of challenges to preserve the speleological ecosystem and subterranean fauna and flora (essential entrance zone habitats).

The origin and biological evolution of life in caves and other micro and macro karst cavities have undergone impressive changes (Lee et al. 2012). Studying such species allows us to step out of our perspective of understanding life on Earth, to have an insight into unique forms of biological adaptation, and to understand the evolution of ecological processes. Worldwide, caves and groundwater habitats comprise thousands of species which are adapted to subterranean karst environments (Gibert & Deharveng 2002) and are highly vulnerable to any external influence (Niemiller & Taylor 2019). Precisely due to these advantages and vulnerability of cave biodiversity, strict regulations and protection norms are necessary to reduce anthropogenic impacts. Therefore, the implementation of a minimal human footprint code to preserve the sustainability of cave life is a crucial priority to scientific communities as well as local management structures.

2.2. From Whom Should Caves Be Protected?

Throughout history, caves have often been the focus of human activity. Quarrying and the removal of karst pavement leads to irreversible damage to an entire karst catchment (Hamilton Smith and Eberhard 2000), including karst features like caves. Caves have served as shelters and abodes for hunter-gatherer societies, where spiritual rituals took place and where prehistoric art emerged and are still preserved. Today, in addition to active tourist affirmation, caves are often the nucleus of multidisciplinary research in which speleologists, geologists, geographers, archaeologists, anthropologists, and many other experts participate. Exploring and understanding the natural and anthropogenic values of caves is important, both for their practical use to improve the quality of life and for giving caves value through knowledge. However, every entry into a cave, regardless of whether it is for research activities, sports and recreational tours, or the entry of locals, will have certain consequences that can be catastrophic for the longevity and sustainability of the cave ecosystem, if not undertaken with speleoethical thinking. Caves are well known for their constant environments with high resilience when impacts are low, but with little resilience for prolonged or intensive continued impacts over a short period of time. The deterioration of a cave's functional integrity and subterranean ecosystem functionality are irreversible in tourist caves, e.g., floor substrate compaction. Very little in the way of restoration or biological remediation measures are possible. For that reason, it is necessary to point out the potential harm human presence within the subterranean can induce. As well as to present protection measures and sustainable practices that can reduce the negative consequences of human visits to caves. Furthermore, host karst systems can be contaminated by agricultural and industrial activities such as groundwater drawdown, contamination which will lead to terrestrial desertification, reduction of groundwater quality of the host karst system and impact its caves over time (Culver & Pipan 2009).

3. Recommendations for Responsible Cave Access

Responsible caving and speleology is the totality of decisions, actions, and measures to be taken by each individual or a group of individuals who enter a natural subterranean cavity for its protection as a whole and all its natural, cultural and archaeological elements (rocks, minerals, sediments, deposits, organisms, microorganisms, fossilised bones, engravings, etc.).

Responsible caving must be undertaken with the minimum impact on any cave, by considering each of its natural objects, elements, components as unique and irreplaceable resources. Walking through a cave must be done with maximum care for each of its elements. No matter the size, each object or element inside a cavity can be a unique natural, possibly endemic resource with importance for science or for human health. For instance, unique and rare bacteria in the soils under foot, can be of use in developing new medicines or in biotechnological applications to produce food, etc. Archaea found in caves are considered to be the oldest species on Earth. Archaea perform aerobic oxidation of ammonia, the only biological process converting reduced ammonia to oxidised inorganic nitrogen (ESA Blog 2014).

Any action, movement, use of rope technique, visit, research, archaeological work etc. must be done with minimal impact on the whole cave, its natural, cultural, or archaeological elements, and its natural functioning. Known for its constant climate, any cave is a geode, with a natural or artificial entrance and is unique independent of its size. Decluttering, removal of its elements (fossil bone, living fauna, speleothem, etc) or installing ropes are decisions that should be done only if all the elements of a cave are taken into consideration including possible change of climate, uniqueness of elements, the rational between necessity and protection of these unique elements in installing a rope for example, or the irreplaceable removal of formations or speleothem, etc. could cause a change in a cave's habitat (i.e. use of unwashed ropes or speleo kit).

Recommendation - Another aspect that could be considered is the "order" in which studies should be carried out in any caves. As an example, an archaeological study that requires excavation in the entrance zone can severely impact the ecotonal communities that are extremely important, as biological filters at cave entrances (Rodrigo Ferreira, Brazil 2022).

Useful information on cave zonation can be found here - https://science.howstuffworks.com/life/biology-fields/cave-biology2.htm

4. Best Practices for Responsible Speleology

4.1 Human Impact

Caves being part of the karstic biosphere are sensitive to the impact of human visits. Caution is required for both the cave explorer and the cave alike, the latter held as priority from a cave conservation and management perspective. The supposition that caves are there to be explored or exploited is an archaic one. Due to endemicity, both biologic and geologic uniqueness, a cautious approach should be adopted. Cave trips should be carefully planned prior to any visit with geoethical environmental conservation in mind (speleoethical thinking). “Caves do fine when left on their own to follow nature's intended path. But interference from people can produce irreparable alterations in cave systems (Hildreth-Werker and Werker 2006)”.

4.2 Cave Ownership

In most countries, cave ownership tends to be two-fold, from a legal or statutory perspective. A property owner is responsible for terrestrial stewardship of the land within which the cave is located. The respected government, owns rights below ground in most cases:

a) Landowner permission, for access to the land up to the entrance of the cave.
b) Statutory management permission below ground by governmental conservation authorities.

In some cases, water or heritage departments have authority. Possibly by the issuing of permits (desirable). Cave access is not a right. It is dependent on landowner relationships and permissions and may be subject to permitting requirements. Groups should be moderated to limit impact. Any more than six people for a day underground should be questioned due to induced soil compaction or liquification, carbon dioxide elevation, clothing pill or lint, skin sloughing. Most of the latter provide abnormal nutrition sources or habitat destruction of the in-balance cave ecosystems. Repetitive daily visits to the same cave must be avoided, and considered carefully with a preferential, valid scientific purpose. Whether this be conducting an ongoing survey, project or scuba diving within a large cave system. Leaders, owners, and statutory authorities must contemplate the geoethics, and speleoethics of impacts on cave habitat recovery times when planning trips. Geoethical best practice should be to allow the cave to recover over a +/− six-to-twelve-month period before any further access is contemplated (Hildreth-Werker and Werker 2006). This is not an absolute, due to variables in hydrologic energy levels, geologic type, and biospeleological content (in most cases unpredictable). The justification of a six – twelve-month period becomes relevant where caves are used, or erratically used as bat hibernacula or maternity roosts. More so, rare troglobitic species can take years to reproduce. Group leaders need to further contemplate past trips, impacts by non-associated caving clubs, organisations or academic institutions. Should the site be popular, it is advisable that statutory trip organisation be considered by the booking for formal appointments to said sites under the management of a permitting authority. Specifically, those which have attractive or interesting biospeleological, geologic, crystallographic, hydrologic, sedimentological, climatologic, archaeological, or paleontological contents.

4.3 Harm to Humans - Pathogens

If there is a doubt about the suitability of a site for group exploration, there is no doubt that the precautionary principle should apply by staying out. Furthermore, caves within the tropics are mostly mild to severe pathogenic harbouring environments. This includes, Histoplasma capsulatum (caves disease), Sporotrichosis, Marburg, Corona and Ebola viruses, etc. The subterranean is, in retrospect, the incubator for many diverse, harmful to humans, subterranean borne diseases. Any person visiting caves should do so, being fully informed of possible consequences of cave access, regardless of nationality, culture of participants, or country the cave in question resides within.

4.4 International Codes of Conduct

Many notable speleological organisations, caving clubs, should have well thought through codes of conduct that should be used as guidelines for cave access. Many of these can be found on the internet. It is important for all those that intend to participate in cave access to acquire first-hand knowledge of caving and the dangers within, prior to embarking on a caving, speleological or research trip underground. If in doubt, contact your local speleological organisation, including the overarching governmental department, for guidance on anticipated access. In some countries, foreign speleologists are only allowed to enter caves “guided” by native speleologists, as is the case in Brazil.

Please find a few recommended codes of conduct links below:

- https://uis-speleo.org/wp-content/uploads/2020/03/Code-of-Ethics-of-the-UIS-English-Language.pdf
- https://caves.org/NSS_Code_of_Conduct_2020_Updated.pdf
- https://caves.org/brochure/Guide_to_Resp_Caving.pdf
- https://caves.org/conservation/cavingcode.shtml
- http://www.cancaver.ca/bcsf/cavethic.htm
- https://cncc.org.uk/conservation/downloads/BCA-Caving-Guidelines.pdf
- https://www.caves.org.au/administration/codes-and-standards/send/8-codes-and-standards/55-asf-minimal-impact-caving-code
- http://speleoukraine.org/index.php/en/publications/code-of-ethics-caver

5. Conclusion

Considering sedimentary caves occur within highly vulnerable karstic carbonate groundwater bearing sensitive catchments, it is crucial to establish and share applicable geoethical rules of conduct for Speleology. Due to the unique approach and the importance of geoethical principles, it is necessary to include speleology (speleoethics) in the world of geoethics, and to unequivocally present the sustainability of cave protection that can be achieved. Furthermore, all karst features should be equally protected and treated with the same respect and anthropic sensitivity as the host karst system.

Speleologists should understand the disparities that exist between low, moderate, and high hydrologic or climatologic energy levels within caves. Therefore, they should have garnered a deep understanding of geoethical, speleoethical behaviours and conduct required within caves, and their host karst catchments. It has become imperative that this understanding is articulated to all those who wish to enter caves, whether their ambitions be exploration, research, or education. All caves should be treated as biologically important habitat regardless of anthropic visibility of said biospeleology and the history of the site in question. In some cases, this could manifest as vulnerable molecular life only, of which the visitor needs to be acutely aware. Cave impacts, whether they be mechanical (compaction or liquification), gaseous (CO_2), waste products (lint, pill, skin slough or hair), flagrant research or unintentional speleothem damage, will play out with consequences to a cave’s chronic, in balance living inhabitants, and their habitat. The adoption of geoethics by speleologists, karstologists, cavers and academia must be placed at the forefront of cave exploration. This applies both here on Earth and that of extraplanetary subterranean resources.

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British Columbia Speleological Society - Minimal Impact Caving Guidelines: https://cncc.org.uk/conservation/downloads/BCA-Caving-Guidelines.pdf

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National Speleological Society - Minimum-Impact Caving Guidelines: https://caves.org/conservation/cavingcode.shtml

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