

## **CAVES: THE MOST IMPORTANT GEOTOURISTIC FEATURE IN THE WORLD**

### **CAVERNAS: RECURSOS GEOTURÍSTICOS MAIS IMPORTANTES NO MUNDO**

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#### **Abstract**

Natural caves started to be opened to tourism over 400 years ago and presently quite all the Countries of the world hosts at least one, but often dozens, of show caves. Some 500 major show caves with over 50.000 visitor/year exist in the world and over 250 million visitors pay yearly a ticket to visit them. If all the activities related to the existence of a show cave (transportation, lodging, etc.) are considered, some 100 million peoples take, directly or indirectly, their income from show caves: these figures may be at least doubled taking into consideration surficial and deep karst within geoparks. It is therefore evident that show caves are presently the most important geotouristic target all over the world and they represent an important economic resource for many of the still developing Countries. But caves have also an exceptional scientific value due to the fact that they represent the best archive for all the Quaternary and allow for extremely accurate paleo-environmental and paleo-climatic reconstructions. Moreover they are truly fragile environments, which may be easily destroyed when the cave is transformed into a touristic object. It is possible to maintain the aesthetic and scientific values of a cave when transforming it into a show cave; but to reach this goal it is important to follow strict rules before, during and after their tourist development. Guidelines aiming to supply a recommendation to be endorsed for the development of show caves were drafted in the last years and received strong recommendations from the UIS Department of Protection and Management at both the 14th International Congress of Speleology held in Kalamos, Greece, in August 2005 and the 15th International Congress of Speleology held in Kerrville, Texas, in July 2009.

**Key-Words:** Show caves; Geotourism; New materials and frontiers.

#### **Resumo**

*Cavidades naturais começaram a ser abertas para o turismo mais de 400 anos atrás e atualmente quase todos os países do mundo abrigam pelo menos uma, mas muitas vezes, dezenas de cavernas turísticas. Cerca de 500 grandes cavernas turísticas com mais de 50.000 visitantes/ano existem no mundo e mais de 250 milhões de visitantes anualmente pagam um ingresso para visitá-las. Se todas as atividades relacionadas com a existência de uma caverna turística (transporte, hospedagem etc.) fossem consideradas, os resultados seriam de cerca de 100 milhões de pessoas cuja renda depende, direta ou indiretamente, de cavernas turísticas. Estes valores podem ser pelo menos o dobro, levando em consideração áreas cársticas dentro de geoparques. Portanto, é evidente que as cavernas turísticas são, atualmente, o atrativo geoturístico mais importante em todo o mundo e representam um importante recurso econômico para muitos dos países ainda em desenvolvimento. Mas cavernas têm também um valor científico excepcional, devido ao fato de que eles representam o melhor arquivo para todo o Quaternário e permitem a precisa reconstrução paleoambiental e paleoclimática. Além disso, elas são ambientes verdadeiramente frágeis, que podem ser facilmente destruídos quando a caverna é transformada em um atrativo turístico. É possível manter os valores estéticos e científicos de uma caverna quando esta é transformada em uma caverna turística, mas para alcançar este objetivo, é importante seguir regras e premissas adequadas, antes, durante e após o seu desenvolvimento turístico. Orientações com o objetivo de fornecer uma recomendação a ser aprovada para o desenvolvimento de cavernas turísticas foram elaboradas nos últimos anos e receberam fortes recomendações do Departamento de Proteção e Gestão da União Internacional de Espeleologia (UIS), tanto no 14º Congresso Internacional de Espeleologia realizada em Kalamos, Grécia, em agosto de 2005 e do 15º Congresso Internacional de Espeleologia realizada em Kerrville, Texas, em julho de 2009.*

**Palavras-Chave:** Cavernas turísticas; Geoturismo; Novos materiais e fronteiras.

## 1. INTRODUCTION

Our ancestors often visited caves since the far prehistory, but at that time their interest was mainly quite practical: they searched for a shelter, or a burial place or also looking for minerals impossible to be found outside. There is no evidence at all of an early “touristic” interest toward caves, which arose fairly later.

Even if seldom touristic visits of a cave are documented since over 3000 yr BP, natural cavities started to be opened to tourism over 400 years ago and presently quite all the Countries of the world host at least one, but often dozens, of show caves. Actually some 500 major show caves with over 50.000 visitor/year exist in the world and over 250 million visitors pay yearly a ticket to visit them. If all the activities related to the existence of a show cave (transportation, lodging, etc.) are considered, some 100 million peoples take, directly or indirectly, their income from show caves: these figures may be at least doubled taking into consideration surficial and deep karst within geo-parks. Another considerable implement in cave economy comes from religious and health care tourism.

Beside their economic importance show caves are fundamental tools for the protection of peculiar cave environments (e.g. archaeological and paleontological remains, peculiar biocoenosis etc.) and privileged places where to perform research in many different fields.

But caves are extremely fragile environments and transforming them into a touristic object may strongly affect their pristine state. Therefore it is important to follow strict rules before, during and after their tourist development.

After a short outline of the development of cave tourism in the last three thousand years, the present paper is focused on the best way to plan, implement and manage a show cave.

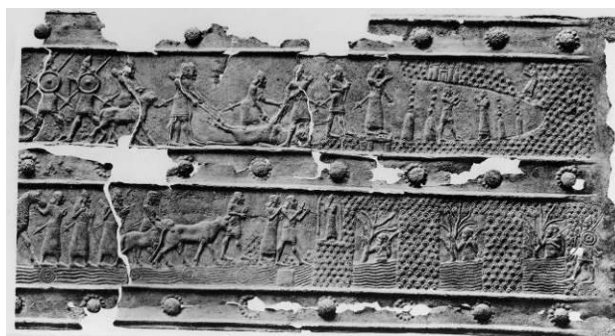
At the end the UIS (International Union of Speleology) Guidelines for the development of show caves are also attached.

## 2. A SHORT HISTORY OF THE CAVE TOURISM

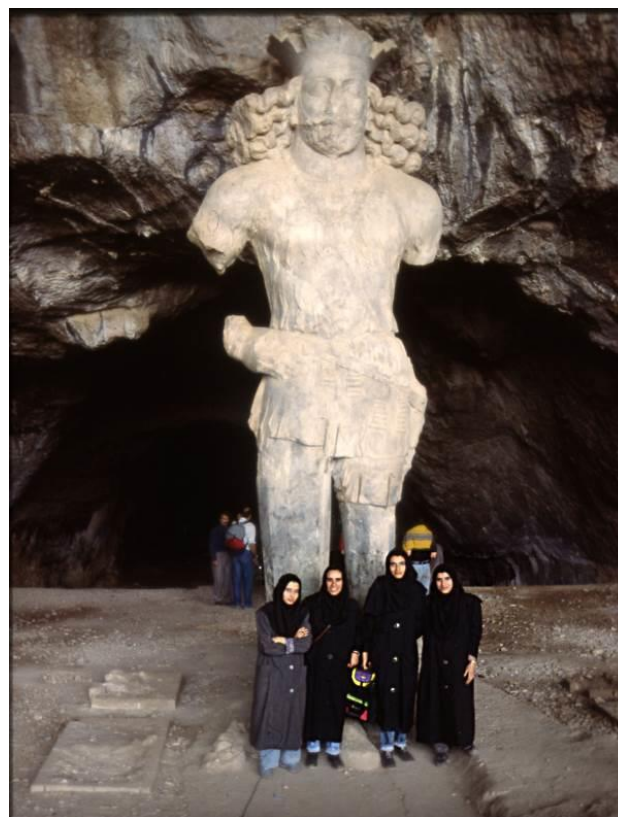
Caves always attracted the attention of humans since the prehistory, but at that time the interest was mainly quite practical, i.e. to have a shelter, a sanctuary or a burial place therefore these human activities cannot be considered touristic.

The very first documented tourist visit of a cave took place in Mesopotamia where, not far from

its source, the river Tigris flows through a natural rock tunnel. Tiglath Pileser, King of Assyria had his portrait carved at the entrance together with an inscription in 3100 BP (Optiz D., 1929). A subsequent Assyrian King, Shalmaneser, in 853 or 852 BC had his men exploring three caves near by the stream cave. The event is also reproduced in a bronze band of the gate of his royal palace in Balawat, now exhibited in the British Museum (Fig. 1). Anyway the best monument of an Assyrian king visiting a cave (Fig. 2) is just at the entrance of Shapur Cave not far from Persepolis in Iran (Forti, 1993).



**Fig. 1** – The bronze band of the gate of the royal palace in Balawat, now exhibited in the British Museum in which the visit to a cave (note the dripping over stalagmites) is represented



**Fig. 2** – The entrance of Shapur Cave not far from Persepolis (Iran) in which a giant statue of the Assyrian king was carved



Later, about 2000 year ago Plinius (77), a Roman writer, described the "Dog's Cave" near Naples, Italy, being visited by several peoples because of the peculiar release of carbon dioxide close to the floor, which killed small animals (hence its name) while standing people was not affected (Fig. 3).



**Fig. 3** – The “Dog cave” in a copper engraving of the XVII Century

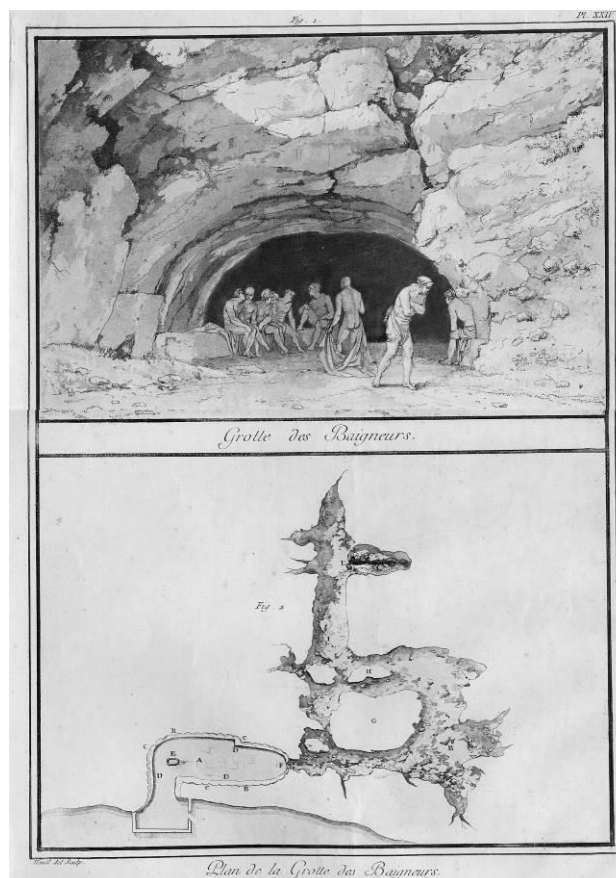
In the same period, several hot caves were transformed into *Thermal baths*, like the Sclacca cave in Sicily (Fig. 4), moreover in many country of the world, caves were visited for religious purposes. Later, until the Middle Age, caves were often associated with the devil or hell in general, and people avoided getting into for fear.

Even if cave tourism started with King Tiglath Pileser in 1100 BC and a few other visits to caves are variously reported since that time up to the X Century, only a few centuries later a true cave tourism started to develop.

In Postojna Cave (Slovenia), on the walls of the so called "Passage of the Ancient Names" on account of the old signatures left by occasional visitors, the most ancient ones date back to 1213, 1323 and 1393 according some authors of the 19th Century (Fig. 5). Around 1920 such signatures were scarcely visible on account of the seepage; presently the oldest signature, which can be read easily, dates 1412 and from the 16th Century onward they became rather abundant. This means that from the 16th Century many persons attracted by the underground world visited the cave more frequently.

Anyway, if a show cave is defined as a cave where a fee is paid in order to have access and visit it, then the oldest one is the Vilenica Cave in Slovenia, where an entrance fee was paid since the beginning of 17<sup>th</sup> Century. The cave is close to the village of Sežana, just a few kilometers from the Italian border. At the beginning of the 17<sup>th</sup> Century

the Count of Petač began to invite the people of Trieste and some noble friends to visit the cave. On certain holidays, at a hundred meters from the entrance, an area for the orchestra and a dance floor were set up and the entire dripstone passage was illuminated with torches and candles. Probably already in 1633 the Count Benvenut Petač charged the admission to visit the cave. Part of the money was donated to the local church of Lokev where masses were dedicated to "greater safety" of the people in the cave (Puc, 2000)



**Fig. 4** – The Sclacca Thermal Bath in a copper engraving of the XVIII Century

*Leschae Inschriften an den Wänden der alten Grotte nach genauer Vervielfältigung in Schlangen geordnet.*

12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
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**Fig. 5** – Table reproducing the signatures of the ancient visitors of Postojna cave from Hohenwart (1830)



In reality, only during the 18<sup>th</sup> Century cave tourism became popular in Europe: several caves become world renown and visited by hundreds persons/year and therefore a tourist organization grew around them: most of these early show caves are still important nowadays being visited by several hundred thousand visitors per year.

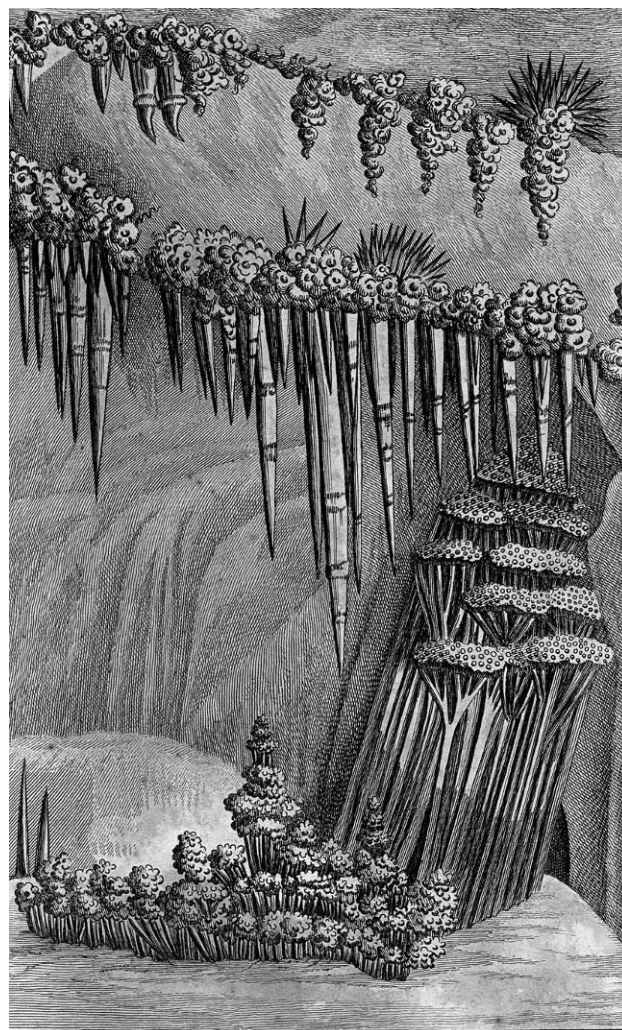
The Cave of Antiparos in Cyclades, Greece, became a great attraction as results by the many prints reproducing the cave (Fig. 6). Also at the same time in the Ural Mountains some 100 km SE of Perm, the Kungur Cave, a gypsum cave filled by ice speleothems, was normally inserted in the “Big Tour of Russia” by rich and noble persons (Fig. 7). On 13<sup>th</sup> August 1772 the scientist Joseph Banks landed on Staffa Island and in November he wrote in the “Scots Magazine”: *...there is a cave in this island which the natives call the Cave of Fingal*. Since that time this cave became one of the best-known caves of the world, inspiring poets and musicians. Its fame was so great that it became the natural cave most represented in paintings and engravings all over the world (Fig. 8).

At the end of the 18<sup>th</sup> century cave tourism starts developing also outside Europe: the Congo Cave (Oudtshoorn, South Africa) was discovered around 1780 and the first recorded visit was made in 1806 (Craven, 1987; Faure 1824). A few years later a farmer bought the land around the cave with the exclusion of the entrance. The Governor included into the deeds the condition that the farmer was obliged to leave perfectly free and undisturbed the entrance of the cave, to be considered as public property, with a road in his land to reach the cave. This document has a historical importance because it is probably the first attempt in the world to legislate for cave protection (Craven 1999; 2004).

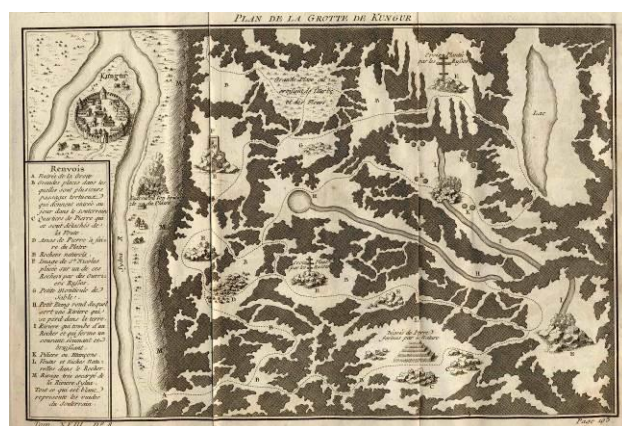
The Mammoth Cave (Kentucky) was already known in prehistory and in the late 18<sup>th</sup> Century the cave was mined for saltpeter to make gunpowder. Officially opened to tourism in 1816, it has been shown as a tourist attraction some tens of years before (Gurnee, 1990;1993).

The success of cave tourism was also testified by the fact that at the end of the XVIII and at the beginning of the XIX Century rather popular caving books became the tourist guides of the most world renown caves (Lang 1806, Hohenwart 1830, Bullit 1845) (Fig. 8).

At the beginning of the XX Century hundreds of show caves already existed, even if they were mainly located in Europe, where they were each year visited by a constantly growing number of tourists.



**Fig. 6** – Speleothems in the main chamber of Antiparos Cave in an engraving of the XVIII Century



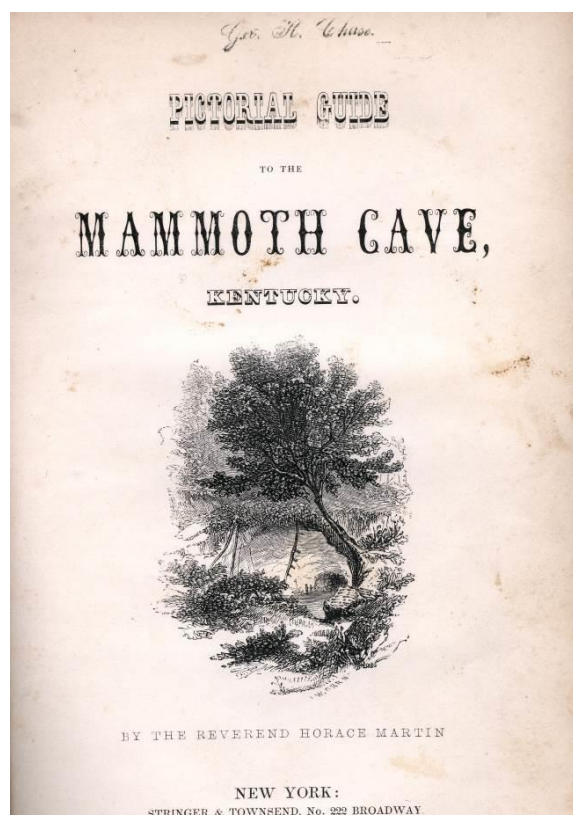
**Fig. 7** – Tourist map of the Kungur Ice Cave printed in the XVIII century

But the real explosion of the cave tourism started after the Second World War when the possibility of travel became cheaper and easier even in the middle class and the so-called mass-tourism became a matter of fact.

At the end of XX Century and at the beginning of the third millennium the importance of



cave tourism grew rapidly mainly in the still developing Countries, where hundreds of new show caves are developed each year: presently practically each Country in the world has at least one, but often dozens of show caves.



**Fig. 8** – Frontispiece of an tourist book (1851) on Mammoth cave, Kentucky

It is rather impossible to exactly define the cumulative economic budget of the whole show caves of the world due to lack of available and reliable data of their visitors and even fewer data on the business automatically induced by the presence of a tourist cave (transportation, lodging, feeding, etc). A rough evaluation was made in the past (Cigna & Burri 2000, Cigna e Forti 2004, Cigna et al. 2000). On that basis it is realistic to state that today several thousand show caves are active in the world and over 500 of them are visited by more than 50.000 visitor/year. As a consequence over 250 million visitors pay yearly an average ticket of 5 U.S. \$ to visit them, scoring a total of 1.25 billion/year. But much higher is the budget of all the activities strictly related to the existence of a show cave (transportation, lodging, feeding, etc.): if they are taken into account, the result is that some 100 million peoples take, directly or indirectly, their income from show caves.

### 3. FROM SHOW CAVES TO KARST-GEOPARKS

For centuries caves were the single geologic objects interested by huge touristic flow. But in the last tens of years the idea of enlarging the content of a touristic attraction in order to take into account any possible aspects of the area considered took gradually more attention. This change of view was also due to economical reasons leading to a better integration among the different tourist targets.

Therefore in the last 20-30 years geoparks started to be implemented all over the world, and several of them include karst features and/or show caves. The “Geo-mining park of Sardinia” (Pani, 2005) with the world renown Santa Barbara Cave (Fig. 9) and the “Geopark of Hong Kong” with huge basaltic sea caves (Fig. 10) are typical examples of geoparks hosting important show caves inside them.



**Fig. 9** – General view of the Santa Barbara Cave (Sardinia, Italy)



**Fig. 10** – One of the largest basalt caves of Hong Kong



In the third millennium geopark tourism grew in exponential manner and nowadays several millions of tourists visit at least one geopark each year.

Taking into consideration that at least 1/3 of the existing geopark host karst features, the touristic budget related not only to show caves but also to karst geoparks should be probably doubled in respect to that restricted to show caves.

#### 4. OTHER REASONS MAKING CAVES A TARGET FOR HUMAN FREQUENTATION

Presently two other human uses of caves generate huge touristic flows: the first related to religion and the second to health care.

Probably the first time in which men started to consider caves as a peculiar place was only some tens of thousands years ago (30,000-10,000 years BP) (Shaw, 1992), and the first reason to go caving was to perform religious rites, as testified by scores of caves spread in France, Italy, Spain etc. (Fig. 11). Anyway a deep interest into caves was maintained in all the different religions developed later, as testified by sacred caves spread all over the world. Among them the Induist and Buddhist caves from India Nepal, Myanmar etc. (Fig. 12) and the Maya caves from Mexico (Fig. 13) are here worth of mention.



**Fig. 11** – Paintings in the Cervi Cave (Puglia, Italy)

Even today the three largest monotheistic religions (Jewish, Christian and Muslim) are deeply involved in caves and some of these sacred caves are visited by millions of pilgrims every year (Fig. 14).

Thus it is reasonable to evaluate that presently the cumulative budget of the sacred tourism in caves may correspond to 15-20% of that of the normal show caves and the total employed peoples should be increased by the same amount.

The second activity for economic importance, actually performed in caves is that related to health care: in the antiquity thermal caves have been used

as *Thermae* (Verde, 2000), but it is was from the first half of the XX century onwards that thermal caves started to become important from the economic point of view. In the second half of the last century the cold caves also started to be widely utilized for speleotherapy, mainly in the Countries of Eastern Europe (Sandri, 1997). Actually speleotherapy is normally used against several diseases like allergenic asthma, arthrosis etc. (AA.VV., 1997).



**Fig. 12** – Thousands of Golden Buddha fill the Pindaya cave in Myanmar



**Fig. 13** – Votive potteries in Lol Tun cave (Mexico)

The number of Countries, in which health care in caves is active, is still scarce, being practically restricted to Europe. Thus the number of persons actually involved in such a kind of health-tourism are of course much less than those involved in the sacred or normal cave tourism: in fact they maybe a few millions yearly all over the world; anyway their number is growing fast and this activity stats spreading outside Europe.

But even if the health care in cave represents no more than 3-5% of the total cave tourism, its economic importance is by far higher due to its high costs. Thus the budget of the Spas and speleotherapeutic caves may be evaluated up to 10-15% of that of the normal show caves, while in this

case the employed persons should be considered no more than 2-3% of the total.



**Fig. 14** – A ivory reproduction of the Amarnat cave in the Himalaya; this cavity is a sacred shrine to the Hindu’ because just there inside the God Shiva explained to his wife Parvati the problems related to immortality and metempsychosis

In conclusion the two types of peculiar cave tourism, just outlined, contribute up to 35-40% to the total budget of the show caves of the world (see Tab. 1).

**Tab. 1** – Different worldwide uses of show caves

Use of show caves	Visitors (%)	Economy (%)
Tourism	77-83	40-50
Religious	15-20	15-20
Health	2-3	35-40
<b>Total</b>	<b>100</b>	<b>100</b>

## 5. THE SCIENTIFIC IMPORTANCE OF SHOW CAVES

At the end of the second millennium it was already clear that caves are perhaps the best place of the world to perform research in many different scientific fields (Forti, 2002; 2009). This is because caves are low to very low energy sites, with scarce

“noise” coming into from the outside, thus allowing extremely accurate experiments impossible to perform outside. Moreover, cave environment acts as perfect accumulation traps over extremely long span of time (Fig. 15): most of the knowledge we actually have about our ancestors will never be available to us without caves. Their physical and chemical deposits proved to record practically any event occurring in the cave area during their growth, thus allowing accurate palaeo-climatological, palaeo-environmental and palaeo-seismical reconstructions (Fig. 16).



**Fig. 15** – The Men of Altamura is the best preserved old skeleton in Europe dating back to over 100.000 yr BP



**Fig. 16** – Deflection form verticality of the stalagmite axis may record strong earthquakes of the past



All these characteristics make caves perfect experimental laboratory in fields like physics, biology, geology, engineering, medicine etc.

Even if, theoretically, all natural cavities are suitable for research, in practice only few if them may be transformed into laboratories: in fact scientists require that a cave meets a few of common characteristics, which can be summarized as:

- To be in a condition as pristine as possible
- To be easily accessible
- To be safe
- To have power supply

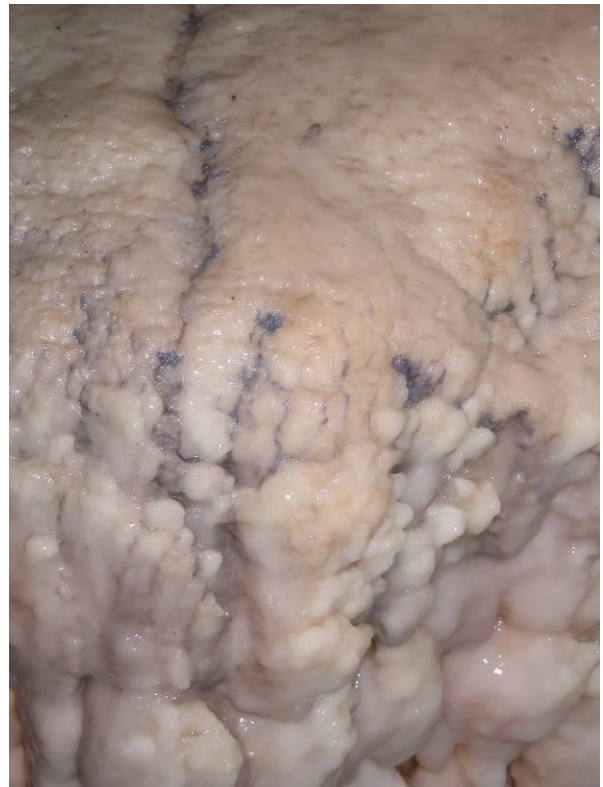
The request of the scientists perfectly fit the common characteristics of any show cave, which are always the best site where perform any kind of research: this is the reason why several experimental laboratories have been located just within them.

Anyway, until now, sometimes the show cave managers may have scarce interest or, even worse, they totally disagree in having in their cave a scientific laboratory because they consider the research only as a waste of their money and a hinder to the normal tourist activity.

Of course they are right when saying that scientific research need space, time and money, but they do not consider the fact that scientists may greatly help the management of a show cave in two fundamental fields: the conservation of the cave equilibrium and the increase of its touristic appeal.

It is well known that tourism may induce negative changes in the cave environment: dust, lint (Fig. 17) and lampenflora degrading the cave formations and cave heating being the most frequent ones. It is evident that the presence of a laboratory, where cave parameters are constantly monitored, may help to prevent these undesirable consequences of the tourist activity.

Even more important is the second effect of the presence of scientific activities (Fig. 18) within a show cave: in fact researchers may easily supply suggestions and materials for the environmental education of the visitors, satisfying also their request of clear answers about scientific questions related to the show cave itself, or karst and caves in general. Hopefully scientists may also train the tourist guides in order to improve their knowledge and ability to explain the cave to the visitors.



**Fig. 17** – Dust and lint cemented inside a stalagmite close to the tourist paths inside the Frasassi show cave (Italy)



**Fig. 18** – Scientists performing research inside a cave

## **6. THE WAYS TO PLAN, IMPLEMENT, AND MANAGE A SHOW CAVE**

The fundamental criteria to be adopted are the protection of the cave environment, the safety of the



visitors and a correct profit from the cave management. All such criteria must be taken into account otherwise the development would have very negative effects. As Summers (2012) stated, the worst fate that can befall a cave is for it to be developed as a show cave, then for it to fail as a business entity, and be closed. The cave becomes very vulnerable to misuse. Therefore the show cave must not be profitable for the short term, but perpetually.

The view that a show cave is a golden goose laying golden eggs implies that the goose must be properly fed and protected. This means that is necessary to having all of the knowledge and awareness regarding the physical needs of the cave to ensure that its environment is preserved and conserved.

Hundreds of wild caves are yearly transformed into show caves sometimes resulting only in a waste of money and wilderness. To avoid this possibility, before to start the development a new show cave, the following questions must be positively answered:

1. Is there a real request of cave tourism in the region?
2. The cave and the karst environment may host the supposed tourism without major problems?

In fact if even only one of this two questions has a negative answer, it is practically sure that the show cave will be unsuccessful and in few years it will be closed with noticeable loss of money and its pristine state.

Thus, in order to be sure that a wild cave may become a good show cave it is necessary to perform a multidisciplinary study to highlight not only all the cave characteristics but also those of the country in which the cave is developed and the social and economic problems which will arise during and after its transformation into a tourist object.

Therefore a good Environmental Impact Assessment for the Development and the Management of a Show Cave must be subdivided in three different steps, where specific studies and analyses must be performed (Fig. 19):

1. Before starting
2. During Transformation
3. During management

Due to the extreme differences existing from cave to cave it is impossible to list all the studies to be performed when a new show cave will be developed. In fact they will change time-by-time

depending on the specific characteristics of the cave itself and/or of its environment.

Anyway some of the most important points related to the three steps of the Environmental Impact Assessment of a Tourist cave will be shortly outlined.

## 6.1. BEFORE STARTING

In this period all the positive possible points of interest for tourists (scenic points, speleothems and cave minerals, biologic inhabitants, archaeological remains etc.) should be described. In the same time also all the negative points (hazards, like boulders sliding or breakdown, flooding, or other problems limiting or avoiding the tourist fruition of the cavity, like cave climate and microclimate) must be clearly defined and studied. But the investigations must be extended also outside the cavity, taking into consideration not only the cave area, its problem of access and infrastructures etc., but also the whole region, analysing the already existing touristic flows and the possibility to drive tourists in a fast and easy manner to the show cave.

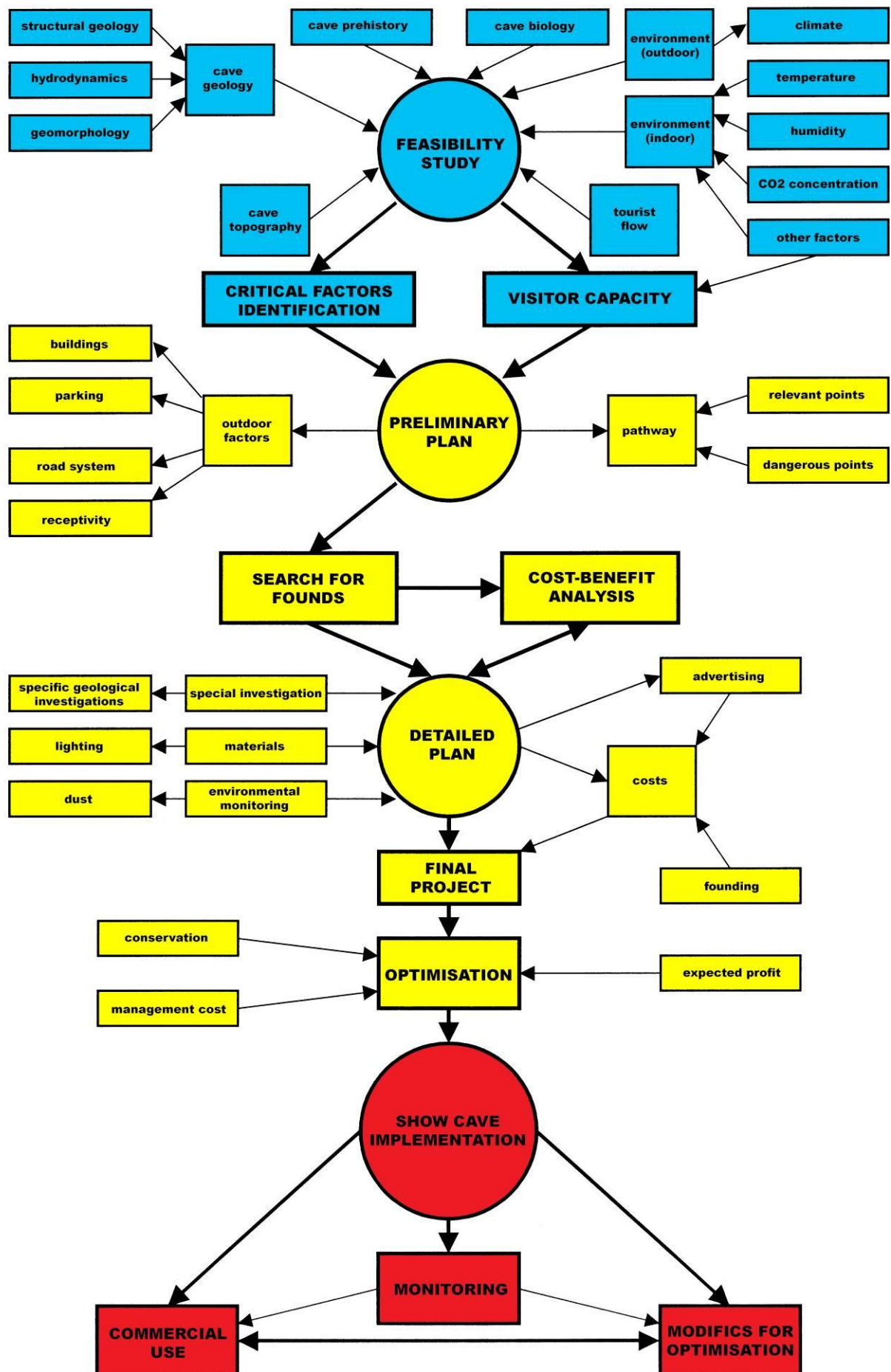
In any case the most important factor to decide if the show cave implementation is economically sustainable is the *visitor carrying capacity*, which define the maximum number of tourists that may enter the cave in a given time interval.

As it is well known, caves may be classified into widely different energetic categories. Heaton (1986) proposed three categories: high-energy, moderate-energy, and low-energy levels. In order to avoid any permanent change in the environmental equilibrium it is necessary to avoid the introduction of energy beyond the intrinsic cave capacity. Such a constraint implies a limitation of both electric power supply for the cave lighting and the visitors' flow, i.e. the visitors carrying capacity.

This limit may be evaluated according different methods and specialists only are entrusted to carry out the whole procedure according the best choice to be applied to each local situation (e.g.: Mangin & d'Huils, 1996; Lobo et al., 2013).

## 6.2. During Transformation

If the first step gave a positive support to the tourist implementation of the cave then the tourist project must be defined in detail on the basis of the data collected during the previous step.



**Fig. 19** – Flow chard for a correct planning implementing and managing a show cave



Of course the structure of the tourist pathways should be consistent with the visitor carrying capacity and must be designed to a safe approach of peoples as close as possible to the already defined scenic points, but avoiding the possibility to damage them.

Moreover the siting of the above ground facilities must be well planned by avoiding that these features be built over the cave itself, or relevant parts of it. In particular any intervention, such as the watertight surface of a parking area, must be avoided. Any change in the rainwater seepage into a cave, as well any change to the land above the cave, may have a negative influence on the cave and the growth of its formations.

Later, particular care has to be addressed to the techniques and materials utilized to transform the wild cave into a show cave in order to optimize costs and scenic effects while keeping the loss of its pristine state to a minimum. Recently an astonishing improvement and renovation occurred in the materials to be used in a show cave implementation (Cigna, 2013). Here are shortly described only the most important ones, those related to pathways and lighting.

### 6.2.1. Pathways

In the last tens of years new material were develop incredible advantages with respect to the past. In particular the pathways can be built entirely with plastics.

The material used for the pathways, including the handrails and kickplates, are manufactured by a pultrusion process. It is a continuous molding process whereby reinforcing fibers are saturated with a liquid polymer resin and then carefully formed and pulled through a heated die to form a part. Pultrusion results in straight constant cross section parts of virtually any shippable length, where continuous fiberglass roving and mat is covered by resin. The resin used for handrails is, isophthalic polyester and the resin used for other components is vinyl ester. Both have a low flame spread rating of 25 or less. These materials are delivered in various colors, avoiding, e.g., the brightness of the stainless steel that is not aesthetically agreeable.

These components have about one-third the weight of steel allowing easy an installation using standard hand saws. Stainless steel bolts connect the different parts. Such pathways may be easily repaired or modified to adapt to new layout, if necessary. Since the mechanical properties of this materials are very close to steel's properties it is

evident the advantage because also long sections can be easily transported inside a cave, while the different parts can be easily worked out with simple instruments.

The design of fiberglass pathways needs a detailed survey of the strip where the pathway itself will be installed, because each element can be prepared in advance according the design. During the assembly of the pathway the legs require only small adjustment that can be easily obtained with sliding feet.

### 6.2.2. Lighting

Nowadays very efficient light sources have been developed (see Tab. 2). The most useful in caves are the LEDs and the cold cathode lamps (CCL). Both are characterized by a very long life of 50,000 hours and longer. The LEDs cost from 20% to 100% more than CCLs for the same results.

**Tab. 2** – Indicative comparison of the overall luminous efficiency per input power for different lamps (lm/W).

Lamp	lm/W
Incandescent (IL)	15
Light emitting diodes (LED)	45
Cold Cathode Lamps (CCL)	67

In Table 2 a comparison among the overall luminous efficiency per input power (as lumen/watt) for incandescent lamps (ILs), LEDs and CCLs is reported.

The advantage of the new light sources is evident both for the cost of lighting and the long life of the lamps. But these new sources have specific qualities of their own: LEDs are point sources while CCLs are linear. LEDs may be chosen with different temperature color, i.e. warm (with a red component) or cold (more white). CCLs may be produced with a negligible contribution of their emission spectrum in the regions (around 430-490 nm and 640-900 nm), which mostly contribute to the chlorophyllian process. In this way the proliferation of lampenflora is reduced.

The emergency lighting can be obtained at a very low cost with the "rope light" i.e. a flexible plastic polymer rope with lights inside that can be cut at a convenient length and placed along the pathways (Fig. 20). In particular such emergency lights can be divided into two sections distributed alternatively and connected to two different power lines in order that, in case of a failure of one section, there will always be another one in operation.

Such a kind of lighting can also supply enough light to the pathways in normal conditions, and special scenic features only, must have additional light sources.

The power supply must comply with both the country rules, which at present are in general rather severe, and the aesthetic requirements. The plastic pathways may host below the platform and along the legs, pipes with the cables of the power supply (Fig. 21). The cable network may be somewhat more complex than in the past because in general only the parts of the cave occupied by visitors should be switched on. The power supply of the emergency light should be split into at least two independent sections as reported above.



**Fig. 20** – The emergency lights placed along the edge of the pathway in the Grutas de Bustamante, Mexico



**Fig. 21** – The pathway in the Grutas de Bustamante, Mexico, with visitors. The cables of lighting and monitoring are placed under the walkway

### 6.3. During management

Surely, the “health” care of a show cave during its tourist exploitation is the most important of the three steps, but still now is normally the neglected one by cave managers. This because they wrongly think that a well-planned show cave will

experience non-problem and they do not want to “waste money” in activities they consider not connected to the direct cave management. As already outlined in a previous paragraph, the tourism may affect the cave environment in a strongly negative manner both in the short and long period of operation.

Therefore it is really a necessity to control constantly at least the most sensitive cave parameters in order to correct immediately the cave management as soon as the very first bad effects could appear, avoiding the possibility to seriously damage the show cave itself

It is evident that the presence instruments constantly monitoring cave parameters, may help to prevent such undesirable consequences. But any data collection might be of little or no use at all in the absence of persons who have the capacity to take advantage of the data themselves. Probably a good Scientific Committee abreast of the management is the most important tool to assure a good development of a show cave. In any case the members of such a committee must obviously have not only a deep competence in their specific fields of interest but also a good knowledge of the cave environment.

In the past a complete network to supply environmental data to a central computer was considered the best solution to be achieved. But it was experienced that such a network might be convenient for larger caves only. The main problems being a relatively high cost (installation and maintenance) and the danger of damages due to lightning, which may discharge high tension peaks on the line connecting the sensors with the main computer.

A less expensive solution, which is also more robust, is obtained with a number of stations whose data are download, e.g. once a month, and the elaboration is carried out in a computer outside the cave without any hardware connection.

Recently, in addition to the usual parameters (temperature, relative humidity, etc.) radon became a relevant issue due to the regulation in some countries requiring a monitoring of its concentration in air on a yearly basis. The scope is the evaluation of the yearly average dose to cave guides to be kept below a given value, otherwise this personnel would be classified as professionally exposed and implying a number of constraints for the cave managers (Cigna, 2005).

The most suitable detector is the etched track detector because it is unaffected by humidity, may be kept to record the average concentration up to one



year and its cost is very low. Other detectors do not comply with such characteristics and, in general, should be avoided.

Finally to improve visitors' safety, a special network enabling a guide to talk with the outside office from any point of the cave would be strongly advisable.

## 7. FINAL REMARKS

Caves were the first and, for a long period, the single geologic item for tourism. In the last few tens of years, with the creation of "Geo-Parks", new geomorphological items started to become touristic targets. Anyway show caves are still now by far the most important geologic tourist attraction from the economic point of view and, in the last 20 years, their interest grew very rapidly and actually show caves and karst tourism supply, directly or indirectly, the income for over 100 million peoples, many of them living in the still developing Countries.

Often show caves are the best or even the single way to protect delicate speleothems and rare minerals, to avoid spoliation of archaeological and/or paleontological deposits, and to protect rare biocoenosis.

Thanks to their facilities, show caves may result a powerful tool for scientific research and environmental protection, which in turn may enhance the touristic appeal of the show cave itself.

Therefore the transformation of a wild cave into a show cave should be regarded, at least in theory, a good thing for caves and karst in general. But it must be clear that, if not well planned and implemented, such a transformation will result the most efficient and the fastest method to destroy a wild cave and its treasures.

Planning, implementing and managing a show cave is very complex and needs interdisciplinary studies during the whole process, which can be performed only by a specific "scientific committee", which should always be present in any show cave of the world.

The International Union of Speleology (UIS) is aware of the fundamental importance of a correct process to open a new show cave, thus worked hardly in order to produce a generally accepted guidelines aiming to supply a recommendation to be endorsed for the development of show caves.

The UIS Management Guidelines for Show Caves (see Annex) are very useful recommendations, if not a list of the least requirements, for a good development and management of a show cave. But such guidelines do not include the principle that it is imperative to keep oneself always up-to-date with the advancement of technology.

The UIS Guidelines are the result of wide cooperation between the International Show Caves Association (ISCA), the Union Internationale de Spéléologie (UIS) and the International Union for Conservation of Nature and Natural Resources (IUCN). The intention was to create commonly accepted guidelines that all show cave managers can work toward, taking into account both the protection of the environment and socio-economical constraints. Many recommendations and suggestions have been received in the course of nearly twenty years, and therefore the document reported here can be considered as the result of an active cooperation among many specialists involved in this matter. At present an agreement among such interested organizations was found aiming to rewrite a new text to assure anyway the best possible protection of the cave environment.

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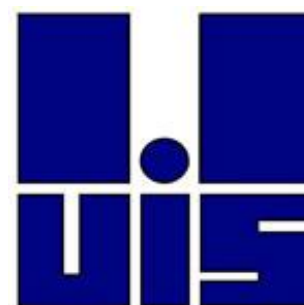
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## ANNEX

### UIS Management Guidelines for Show Caves

Those guidelines received strong recommendations from the UIS Department of Protection and Management at both the 14<sup>th</sup> International Congress of Speleology held in Kalamos, Greece, in August 2005 and the 15<sup>th</sup> International Congress of Speleology held in Kerrville, Texas, in July 2009. Such guidelines are here reported.



#### 1 DEVELOPMENT OF A WILD CAVE INTO A SHOW CAVE

*The development of a show cave can be seen as a positive financial benefit to not only itself, but also the area surrounding the cave. The pursuit of these anticipated benefits can sometimes cause pressure to be applied to hasten the development of the cave.*

*Before a proposal to develop a wild cave into a show cave becomes a physical project, it is necessary to carry out a careful and detailed study to evaluate the benefits and risks, by taking into account all pertinent factors such as the access, the synergy and possible conflict with other tourism related activities in the surrounding area, the availability of funds and many other related factors. The conversion should only take place if the results of the studies are positive. A wild cave that is developed into a show cave, and is subsequently abandoned, will inevitably become unprotected and be subject to vandalism in a very short time. A well managed show cave assures the protection of the cave itself, is a source of income for the local economy and also may contribute to a number of scientific researches.*

**A careful study of the suitability of the cave for development, taking into account all factors influencing it, must be carried out, and must be carefully evaluated, before physical development work commences.**

#### 2 ACCESS AND PATHWAYS WITHIN THE CAVE

*In many caves it has been found to be desirable to provide an easier access into the cave for visitors through a tunnel, or a new entrance, excavated into the cave. Such an artificial entrance could change the air circulation in the cave causing a disruption of the ecosystem. To avoid this, an air lock should be installed in any new entrance into a cave. On the other hand it must be mentioned that in some very exceptional cases a change in the air circulation could revitalize the growth of formations. A decision not to install an air lock must be only taken after a special study.*

**2-1 Any new access into a cave must be fitted with an efficient air lock system, such as a double set of doors, to avoid creating changes in the air circulation within the cave.**

*Caves are natural databases, wherein an incredible amount of information about the characteristics of the environment, and the climate of the cave, are stored. Therefore any intervention in the cave must be carried out with great care to avoid the destruction of these natural databases.*

**2-2 Any development work carried out inside the cave should avoid disturbing the structure, the deposits and the formations of the cave, as much as possible.**

*When a wild cave is developed into a show cave, pathways and other features must be installed. This invariably requires materials to be brought into the cave. These materials should have the least possible impact on both the aesthetics of the cave and its underground environment. Concrete is generally the closest substance to the rock that the cave is formed in, but once concrete is cast it is extremely expensive and difficult to modify or decommission. Stainless steel has the distinct advantage that it lasts for a long time and requires little, to no, maintenance but it is expensive and requires special techniques to assemble and install. Some recently developed plastic materials have the advantage of a very long life, are easy to install and are relatively easy to modify.*

**2-3 Only materials that are compatible with the cave, and have the least impact on the cave, should be used in a cave. Cement, concrete, stainless steel and environmentally friendly plastics are examples of such materials.**

*The environment of a cave is usually isolated from the outside and therefore the introduction of energy from the outside will change the equilibrium balance of the cave. Such changes can be caused by the release of heat from the lighting system and the visitors and also by the decay of organic material brought into the cave, which introduces other substances into the food chain of the cave ecosystem. In ice caves, the environmental characteristics are compatible with wood, which is frequently used for the construction of pathways, as it is not slippery.*

**2-4 Organic material, such as wood, should never be used in a cave unless it is an ice cave where, if necessary, it can be used for pathways.**

### **3 LIGHTING**

The energy balance of a cave should not be modified beyond its natural variations. Electric lighting releases both light and heat inside the cave. Therefore high efficiency lamps are preferred. Discharge lamps are efficient, as most of the energy is transformed into light, but only cold cathode lamps can be frequently switched on and off without inconvenience. Light-emitting diode (LED) lighting is also very promising. As far as possible, the electric network of a cave should be divided into zones to enable only the parts that visitors are in to be lit. Where possible a non-interruptible power supply should be provided to avoid problems for the visitors in the event of a failure of an external power supply. Local code requirements may be applicable and these may permit battery lamps or a network of LEDs or similar devices.

**3-1 Electric lighting should be provided in safe, well-balanced networks. The power supply should preferably be non-interruptible. Adequate emergency lighting should be available in the event of a power outage.**

Lampenflora is a fairly common consequence of the introduction of an artificial light supply into a cave. Many kinds of algae, and other superior plants, may develop as a result of the introduction of artificial light. An important method to avoid the growth of green plant life is to use lamps that do not release a light spectrum that can be absorbed by chlorophyll.

**3-2 Lighting should have an emission spectrum with the lowest contribution to the absorption spectrum of chlorophyll (around 440 nm and around 650 nm) to minimize lampenflora.**

Another way to prevent the growth of lampenflora is the reduction of the energy reaching any surface where the plants may live. The safe distance between the lamp and the cave surface depends on the intensity of the lamp. As a rough indication, a distance of one meter should be safe. Special care should also be paid to avoid heating the formations and any rock paintings that may exist.

**3-3 Lighting sources should be installed at a distance from any component of the cave to prevent the growth of lampenflora and damaging the formations and any rock paintings.**



The lighting system should be installed in such a way that only the portions of the cave occupied by visitors are switched on, leaving the lighting in the portions of the cave that are not occupied switched off. This is important from the aspects of reducing the heating of the cave environment and preventing the growth of lampenflora, as well as decreasing the amount of energy required and its financial cost.

**3-4 Lighting should be installed to illuminate only the portions of the cave that are occupied by visitors.**

#### **4 FREQUENCY OF VISITS AND NUMBER OF VISITORS**

*The energy balance of a cave environment can be modified by the release of heat by visitors. A human being, moving in a cave, releases about 150 watts – approximately the same as a good incandescent lamp. Consequently, there is also a limit on the number of visitors that can be brought into a cave without causing an irreversible effect on the climate of the cave.*

**4-1 A cave visitor capacity, per a defined time period, should be determined and this capacity should not be exceeded. Visitor capacity is defined as the number of visitors to a given cave over a given time period, which does not permanently change the environmental parameters beyond their natural fluctuation range. A continuous tour, utilizing an entrance and another exit, can reduce the time that visitors spend in a cave, compared to the use of a single entrance/exit.**

*In addition to the normal tours for visitors, many show caves have special activities, sometimes called “adventure tours”, where visitors are provided with speleological equipment for use in wild sections of the cave. If such a practice is not properly planned, it may cause serious damage to the cave.*

**4-2 When visits to wild parts of a cave are arranged, they must be carefully planned. In addition to providing the participants with the necessary speleological safety equipment, the visitors must always be guided by a guide with good experience in wild caves. The pathway, where visitors are to travel along, must be clearly defined, for example with red and white tape, and the visitors should not be allowed to walk beyond this pathway. Special care must be taken to avoid any damage to the cave environment, and the parts beyond the pathway must be maintained in a clean condition.**

#### **5 PRESERVATION OF THE SURFACE ECOSYSTEM WHEN DEVELOPING BUILDINGS, PARKING, REMOVAL OF SURFACE VEGETATION AND WASTE RECOVERY**

*It is important that the siting of the above ground facilities, such as the buildings, parking and waste recovery, be well planned. There is a natural tendency to try and place these development features as close as possible to the cave entrance. Sometimes these features are built over the cave itself, or relevant parts of it. The hydrogeology above the cave must not be modified by any intervention such as the watertight surface of a parking area. Any change in the rainwater seepage into a cave can have a negative influence on the cave and the growth of its formations. Care should be exercised also when making any change to the land above the cave, including the removal of the vegetation and disturbance of the soils above the bedrock.*

**5-1 Any siting of buildings, parking areas, and any other intervention directly above the cave, must be avoided in order to keep the natural seepage of rainwater from the surface in its original condition.**

#### **6 MONITORING**

*After the environmental impact evaluation of the development, including any other study of the cave environment, it is necessary to monitor the relevant parameters to ensure that there is no deviation outside acceptable limits. Show caves should maintain a monitoring network of the cave environment to ensure that it remains within acceptable limits.*

**6-1 Monitoring of the cave climate should be undertaken. The air temperature, carbon dioxide, humidity, radon (if its concentration is close to or above the level prescribed by the law) and water temperature (if applicable) should be monitored. Airflow in and out of the cave could also be monitored.**

*When selecting scientists to undertake studies in a cave, it is very important that only scientists who have good experience with cave environments be engaged for cave related matters. Many, otherwise competent scientists, may not be fully aware of cave environments. If incorrect advice is given to the cave management, then this could result in endangerment of the cave environment. Cave science is a highly specialized field.*

**6-2 Specialized cave scientists should be consulted when there is a situation that warrants research in a cave.**

## **7 CAVE MANAGERS**

*The managers of a show cave must never forget that the cave itself is “the golden goose” and that it must be preserved with great care. It is necessary that persons involved in the management of a show cave receive a suitable education, not only in the economic management of a show cave, but also about the environmental issues concerning the protection of the environment at large.*

**Cave managers should be competent in both the management of the economics of the show cave and its environmental protection.**

## **8 TRAINING OF THE GUIDES**

*The guides in a show cave have a very important role, as they are the “connection” between the cave and the visitor. Unfortunately, in many instances the guides have not been trained properly and, notwithstanding that they are doing their best, the overall result will not be very good. It is very important that the guides receive proper instructions about the environmental aspects of the cave as well as dealing with the public. It is important that guides are skilled in tactfully avoiding entering into discussions, which can have a detrimental effect on the overall tour. The guides are the guardians of the cave and they must be ready to stop any misbehaviour by the visitors, which could endanger the cave environment.*

**Cave guides should be trained to correctly inform the visitors about the cave and its environment.**

### **I. Information on show caves in the world**

There are many books published in different countries providing guides to the local caves. On one hand they report a rather large amount of information but, on the other hand, they are fully reliable for a short time only after their publications. In fact show caves have a certain turnover with changes of the visit details, etc. or, sometimes, on very existence of the show cave itself.

Recently a rather useful way to obtain up-to-date information became available. "Showcaves of the World" is a website, which can be found at <http://www.showcaves.com/>. This site changes and grows continually, so on the web the latest version may be always seen.

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**TOURISM AND KARST AREAS**

(formerly/formalmente: Pesquisas em Turismo e Paisagens Cársticas)

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