DATING OF PROCESSES IN KARST AND CAVES: IMPLICATION FOR SHOW CAVES PRESENTATION

Pavel Bosák[1,2]

[1] Institute of Geology AS CR, v. v. i., Academy of Sciences of the Czech Republic, Rozvojová 269, 165 00 Praha 6 – Lysolaje, Czech Republic; bosak@gli.cas.cz
[2] Karst Research Institute, Scientific Research Center, Slovenian Academy of Sciences and Arts, Titov trg 2, 6230 Postojna, Slovenia

Abstract: Karst evolution depends particularly on the time available for process evolution and on the geographical and geological conditions of the exposure of the rock. The longer the time, the higher the hydraulic gradient and the larger the amount of solvent water entering the karst system, the more evolved is the karst. Unconformities influence the stratigraphy of the karst through the time-span that is available for subaerial processes. The end of karstification can also be viewed from various perspectives. The definite end occurs at the moment when the host rock, together with its karst phenomena, has completely been eroded/denuded. Karst forms of individual evolution stages (cycles) can also be destroyed by erosion, denudation and abrasion without the necessity of the destruction of the whole succession of karst rocks. Temporary and/or final interruption of the karstification process can be caused by the "fossilisation" of the existing karst phenomena due to loss of hydrological activity. The shorter the time available for karstification, the greater is the likelihood that karst phenomena are preserved in the stratigraphic record. The longer the duration of subaerial exposure, the more complex geomorphological agents are. Karst and cave fills are relatively special kinds of geologic materials. The karst environment favours both the preservation of paleontological remains and their destruction. On one hand, karst is well known for its richness of paleontological sites, on the other hand most cave fills are complete sterile, which is true especially for the interior cave facies. Another problematic feature of karst records is the reactivation of processes, which can degrade a record by mixing karst fills of different ages. Owing to the fact that unmetamorphosed or only slightly metamorphosed karst rocks containing karst and caves have occurred since Archean, we can apply a wide range of geochronologic methods. Most established dating methods can be utilised for direct and/or indirect dating of karst and paleokarst. The karst/paleokarst fills are very varied in composition, including a wide range of clastic and chemogenic sediments, products of surface and subsurface volcanism (lava, volcaniclastic materials, tephra), and deep-seated processes (hydrothermal activity, etc). Stages of evolution can also be based on dating correlated sediments that do not fill karst voids directly. The application of individual dating methods depends on their time ranges: the older the subject of study, the more limited is the choice of method.

Keywords: karst, speleogenesis, karst sediments, dating methods, geochronology, show caves

Show cave managers have to try to improve education of visitors (public) not only by stressing conservation and protection issues on karst in general (e.g., karst landscape, caves, speleothems), but also to attract people in scientific themes. One of the most attractive, for cave visitors, seems to be archaeological and paleontological finds in caves. Nevertheless, those issues are only a small part of very broad discipline of dating of processes in karst and caves. Lot of caves have been evolving for very long time, even from the geological point of view, i.e. millions of years; on the other hand others represent relicts of old evolutionary phases (relict karst *sensu* Bosák, Ford and Głazek 1989). Such cave can be nearly completely cut from active hydrogeological system and therefore represent real paleokarst (*sensu* Bosák, Ford and Głazek 1989). The selected examples are presented in Tab. 1. This kind of information could be interesting for public, as well.

The ancient caves recently accessible represent unique feature in karst due to the steady process of chemical denudation – lowering of the karst surface by dissolution, which acts,

Table 1. Examples of ancient caves, their origin and opening of connection to surface

Location		Estimated age		Origin	References
Cave	Region	of cave	open to surface		
Koněpruské Caves show cave	Czech Karst (CZ)	Oligocene – Lower Miocene	Lower Miocene	ascending waters, meteoric, phreatic and vadose	Bosák *et al.* 1989 Bosák 1996, 1998, 2000
Kůlna Cave show cave	Moravian Karst (CZ)	Oligocene	(1) Oligocene (2) post-Middle Miocene	water-table	Bosák *et al.* 1989
Amatérská Cave System	Moravian Karst (CZ)	Lower Miocene	(1) Middle Miocene (2) Pliocene (3) Quaternary	water-table multi-story	Panoš 1964 Bosák *et al.* 1989 Bosák *et al.* 1999
Javoříčské Caves show cave	Central-northern Moravia, Javoříčko Karst (CZ)	Oligocene – Lower Miocene	(1) Middle Miocene (2) Pliocene	water-table multi-story, ascending waters	Bosák *et al.* 1989 Pučálka *et al.* 2001
Králova Cave	Central Moravia, Tišnov Karst (CZ)	Upper Carboniferous – Lower Permian	Post-Badenian (?)	hypogene (mineralized), phreatic and vadose	Bosák 1983 Bosák *et al.* 1989
Javorka Cave	Czech Karst (CZ)	Permian to ?Middle Jurassic	Oligocene or Lower Miocene	hypogene, meteoric	Žák 2006
Únorová Chasm	Czech Karst (CZ)	Early to Middle Triassic	(1) Early to Middle Triassic (2) Cenozoic	meteoric	Žák *et al.* 2007
Špička Cave	Northern Moravia (CZ)	Lower Cretaceous (Hauterivian to Aptian)	(1) Lower Cretaceous (2) Quaternary?	mixing water	Bosák *et al.* 1989
Bližná Cave	Southern Moravia (CZ)	Upper Eocene to Lower Miocene	(1) Lower Miocene (2) Recent	meteoric, deep phreatic	Bosák 1991, 1997
Belianska Cave show cave	Belianske Tatry (SK)	Miocene	topmost Miocene to basal Pliocene	ascending waters, deep phreatic, probably hypogene low thermal sulphuric acid-enriched waters	Bella *et al.* 2010
Domica-Barada Cave System show caves	Slovak-Aggtelek Karst (SK-H)	pre-Pliocene	(1) pre-Pliocene (2) Pleistocene	water-table single level	Bosák *et al.* unpubl.

according to climatic conditions and lithology of host rocks, in range of several meters up to 760 m per 1 million years (Ma), in average some 20 to 50 m per 1 Ma (for detail see e. g., Ford and Williams 1989, 2007). More diagenetically mature and metamorphosed carbonate rocks are more resistant to chemical denudation in average. Lowering of surface by the chemical denudation leads to the origin of so called unroofed caves (*sensu* Mihevc 1996, for details see Mihevc 2001). Caves are expected to persist for 10 Ma in a single erosive cycle as expected by Sasowsky (2007) in respect of the formation depth and chemical denudation rate. Nevertheless, the complex sequence of transgressions, connected with sediment deposition, and regressions, connected with sediment weathering, erosion and denudation, can halt the action of chemical denudation for a long time. Owing to such complicated geological history of both folded and platform regions, even Palaeozoic caves can be accessible recently (e.g., Bosák 1983; Osborne 2010). General frames of dating of karst processes and related problems were summarized by Bosák (2002, 2007, 2008); this compilation is based on those three papers principally.

Determining the beginning and the end of the life of a karst and cave system is a substantial problem. In contrast to most of living systems, the development of a karst system can be „frozen" and then rejuvenated several times, i. e. it can has polycyclic and polygenetic nature (*cf.* Bosák *et al.*, Eds. 1989) so that karst deposits represent a special kind of geological record (Bosák 2002). The principal problems may include precise definition of the beginning of karstification (e. g., legacy karst – Wright 1991; Wright and Smart 1994 or inception in speleogenesis – Lowe 1999) and the manner of preservation of the products of karstification. Karst evolution is particularly dependent upon the time available for process evolution and on the geographical and geological conditions of the exposure of the rock. The longer the time, the higher the hydraulic gradient and the larger the amount of solvent water entering the karst system, the more evolved is the karst (Bosák 2008).

Karstification of the host rocks *may start* during their formation phases – diagenesis – converting the soft sediment into consolidated material shortly after deposition itself. Such karstification is a consequence of the emergence of part of a depocenter (sedimentary basin) and the introduction of meteoric water into the diagenetic system. The formation of a fresh-water lens and a halocline zone related to the surface relief and sea-level changes is the result. The early stages of the origin of dissolutional (karst) porosity by meteoric diagenesis in carbonate rocks have been described in numerous sedimentological and paleokarst studies (a.o., Longman 1980; James and Choquette 1984; Tucker and Wright 1990; James and Choquette, Eds. 1988; Wright, Esteban and Smart, Eds. 1991; Wright and Smart 1994; Moore 1989, 2001; Mylroie and Carew 2000). Some authors suppose karst to be merely the facies of meteoric diagenesis (Esteban and Klappa 1983).

The *end* of karstification can be viewed also from various perspectives. The final end of karstification occurs at the moment when the host rock, together with its karst phenomena, is completely eroded/denuded, i.e. at the end of the karst cycle *sensu* Grund (1914; see also Cvijić 1918). In such a case, nothing is left to be studied. Karst forms of individual stages of evolution (cycles) can be destroyed also by other non-karst erosion processes or by the complete filling of epikarst and burial of karst surfaces by impermeable sediments, without the necessity of destroying the entire succession of karst rocks (the cycle of erosion of Davis 1899; see also Sawicki 1908, 1909). Temporary and/or final interruptions of karstification can be caused by fossilisation due to the loss of the hydrological function of the karst (Bosák 1989, p. 583) and it becomes paleokarst (Bosák 1981, 1989; Bosák, Ford and Głazek 1989; Ford and Williams 1989), independent of whether the karstification is halted definitely or only temporarily. Such fossilisation can be caused by metamorphism, mineralisation, marine transgressions, burial by continental deposits or volcanic products, tectonic movements, climatic change etc. (for a review, see Bosák 1989). The introduction of new energy (hydraulic head) to the system may cause reactivation of karstification reflected in the polycyclic and polygenetic nature of karst formation. The most common reasons for reactivation are regression, deglaciation and uplift (for a review, see Osborne 2002). Multiple reactivations are result in polycyclicity of karst formation, which is a characteristic feature (e.g., Panoš 1964; Ford and Williams 1989, 2007; Osborne 2002). The polygenetic nature of many karsts features that evolved during several different steps should be stressed, too (Ford andliams 1989); these may take the form of, for instance, an overprint of cold karst processes on earlier deep-seated/hydrothermal products, which themselves followed meteoric early diagenesis (e.g., Bosák 1997) or the succession of other processes (a.o., Osborne 2000, 2002; Osborne *et al.* 2006).

Karst sediments are a special kind of geologic materials. The development of karst and/or part of the karst system can be „frozen" and rejuvenated for a multiplicity of times (Bosák 1989, 2002, 2003), and the dynamic nature of karst can lead to re-deposition and reworking of classical stratigraphic order. Those processes can make the karst record unreadable and problematic for interpretation (see Osborne 1984). Temporary (e.g., filling by cave sediments) and/or final interruption of karstification (fossilization *s.s.*) is due to the loss of the hydrological function of the karst (Bosák 1989, p. 583). The introduction of new energy (hydraulic head) to the system may cause reactivation of karstification reflected in the polycyclic and polygenetic nature of karst formation.

The karst environment favours both the preservation of palaeontological remains and their destruction. On one hand, karst is well known for its wealth of palaeontological sites (e. g., Horáček and Kordos 1989), but most cave fills are completely sterile on the other hand. The role of preservation is very important because karstlands function as traps or preservers of the geologic and environmental past, especially of terrestrial (continental) history where correlative sediments are mostly missing, but they carry also marine records (Horáček and Bosák 1989).

The methodology applied to obtain dating results depends on the nature of the geologic material filling the karst. The fills of exokarst landforms (especially some epikarst forms) offer more possibilities for the preservation of fossil fauna and flora than do cave interiors. The cave environment can be divided from the sedimentological point of view into an entrance facies and an interior facies (Kukla and Ložek 1958). The *entrance facies* includes fine-grained sediments transported from the vicinity of the cave by wind and water and coarser clasts transported into the cave by slope processes. The entrance facies represents the most valuable section of the cave from a stratigraphic point of view. The cave entrance contains pollen as well as datable archaeological and palaeontological remains that are protected from surface erosion, weathering and biochemical alteration (Ford and Williams 1989, 2007). The *interior facies* develops in those parts of the cave that are more remote from the surface. Sedimentary sequences here can be extensive, consisting of fluvial gravels and sands overlain by flood or injecta deposits of laminar silts and clays often intercalated by speleothems. They can also contain dejecta, colluvial material and outer clastic sediments (including marine ones) often redeposited and/or injected for longer distances within the cave (*cf.* Ford and Williams 1989, 2007). They form in vadose conditions. Due to the dynamic environment of cave interiors and periodicity of events, sedimentary sequences often represent a series of depositional and erosional events (sedimentary cycles). They are separated by unconformities (breaks in deposition), in which substantial time-spans can be hidden (Bosák *et al.* 2000b; Pruner and Bosák 2001; Bosák 2002, 2003; Bosák, Pruner and Kadlec 2003). The erosional phases can be much longer that depositional events. Troglobitic fauna and flora are usually much too small in number and volume to be significant (Ford and Williams 1989, 2007). Therefore, fossil remains within a cave, that come from the surface (carried in by sinking rivers) or from trogloxenes (e. g., cave-using bats, some birds and mammals), are more important. Airborne grains (pollen, volcanic ash) can only be important when favourable air-circulation patterns are developed within a cave. Nevertheless, cave sediments, especially far from the ponor or other entrance, tend to be highly depleted in fossil fauna (Bosák, Pruner and Zupan Hajna

1998) and/or the preservation of the fossils is too poor for precise determinations (Bosák *et al.* 2000a). Relics of phreatic silts and clays are relatively rare and they typically contain no fossils.

The stratigraphic order in sedimentary sequences is usually governed by the law of superposition, according to which the overlying bed is younger than the underlying one under normal tectonic settings. The law is valid for the majority of sedimentary sequences. However, river terraces and karst environment may present exceptions. The succession of processes connected with entrenchment of river systems cause higher levels of sediments to be older than lower ones. Karst, owing to its dynamic nature, polycyclic and polygenetic character carries some other thresholds – the karst records can be damaged by the simple process of erosion and re-deposition. The reactivation of karst processes often mixes karst fill of different ages (collapses, vertical re-depositions in both directions, etc., e.g., Horáček and Bosák 1989). Contamination of younger deposits by re-deposited fossil-bearing sediments has been known elsewhere in caves (Bosák, Pruner and Kadlec 2003). Well-known are also sandwich structures, described by Osborne (1984): younger beds are inserted into voids in older ones. Those processes degrade the record in karst archives (Horáček and Bosák 1989).

The final accumulation phase has been dated in caves in most cases, i.e. when the cave is in a quasi-stationary state because the input of energy (water) has been interrupted, detaching the cave from the local hydrological regime for different reasons and for highly differing time-spans; the cave becomes fossilised, at least temporarily. The temporary fossilisation of the cave (i.e. fill by cave sediments) and rejuvenation (excavation of sediments) mostly reflect changes in the resurgence area, especially vertical change (in both directions) of base level at the karst springs. The rejuvenation of the karst process can excavate the previous cave fill/fills completely, which is the most common case resulting from the polycyclic nature and dynamics of cave environments (e.g., Panoš 1964; Kadlec *et al.* 2001). Under favourable settings, fills belonging to more infill phases (cycles) separated by distinct hiatuses (unconformities) can occur in one sedimentary profile. Such amalgamation is typical especially in ponor (sinkhole) parts of the cave (e.g., Kadlec *et al.* 2001).

The proper and exact dating of karst processes, including filling of cave/karst voids, is most often the only means of reconstructing the evolution of individual karst features, extensive karst regions, speleogenetical or fossilization processes. The application of a number of dating methods in past decades enabled also the more exact dating of processes in the karst (Ford and Williams 1989, 2007; Bosák 2002). Owing to the fact that unmetamorphosed or only slightly metamorphosed karst rocks have existed since the Archean, we are facing the wide range of application of geochronologic methods. Most of the methods outlined below can be utilised for direct and/or indirect dating of karst and paleokarst processes. Karst/paleokarst fills are highly variable in origin and composition, including a wide range of clastic and chemogenic sediments, products of surface and subsurface volcanism (lava, volcaniclastic materials, tephra), and deep-seated processes (hydrothermal activity, etc). During burial, paleokarst forms can be cut or penetrated by products of younger deep-seated processes (volcanic or hydrothermal – ore – veins). Evolutionary karst stages can be based also on dating of correlative sediments, which do not fill karst voids directly, i.e. glacial deposits, river terraces, eolian and lacustrine sediments, marine deposits and fossils. Certain dating methods cannot be used for karst events at all, especially those requiring magmatic and/or metamorphic lithologies as suitable materials.

Colman and Pierce (2000) reviewed the range of geochronologic methods for the Quaternary period. Their conclusions can be adapted also for older chronologic units. The methods are grouped into six categories: (1) *sidereal* (calendar or annual) methods, which determine calendar dates or count annual events; (2) *isotopic* methods, which measure changes in isotopic composition due to radioactive decay and/or growth; (3) *radiogenic* methods, which measure cumulative effects of radioactive decay, such as crystal damage and electron energy traps; (4) *chemical and biological* methods, which measure the results of time-dependent chemical or biological processes; (5) *geomorphic* methods, which measure the cumulative results of complex, interrelated, physical, chemical, and biologic processes on the landscape; and (6) *correlation* methods, which establish age equivalence using time-independent properties. Results of dating can be classified into four groups as follows: *numerical-age*, *calibrated-age*, *relative-age*, and *correlated-age* (Colman and Pierce 2000, p. 3). They also proposed to abandon the term *absolute date* in favour of *numerical date*.

The application of individual dating methods depends on their time-spans. In general, we can state that the older is the subject of our study, the more limited are the methods of dating available. The nature of geologic materials to be dated represents another threshold. Not all geologic materials are suitable for numerical dating. On the other hand, most of materials are suitable to attempt correlated-age (see detailed review in Bosák 2002, 2007, 2008). (AV0Z30130516)

References

Bella P., Bosák P., Pruner P., Głazek J. (2010): Vývoj doliny Bielej vo východnej časti Belianskych Tatier: implikácie z morfológie a veku sedimentov v Belianskej jaskyni. – Zborník abstraktov z 15. kongresu Slovenskej geografickej spoločnosti a 6. vedeckej konferencie Asociácie slovenských gomorfológov pri SAV, Košice 8.–11. 9. 2010: 79–82. Košice.

Bosák P. (1981): Terminology and study of ancient karst phenomena. – Český kras, VI: 58-66. Beroun (in Czech).

Bosák P. (1983): Polycyclic development of karst phenomena in the Tišnov area (Western Moravia, Czechoslovakia). – Proceedings. European Regional Conference on Speleology, 2: 253–256. Sofia. Published in 1985.

Bosák P. (1989): Problems of the origin and fossilization of karst forms. – In: P. Bosák, D.C. Ford, J. Głazek & I. Horáček (Eds.): Paleokarst. A Systematic and Regional Review, Elsevier-Academia, Amsterdam-Praha: 577-598.

Bosák P. (1991): Phreatic cave system of the Bližná graphite deposit, South Bohemia, Czechoslovakia. – Studia carsologica, 5: 7–35. Brno.

Bosák P. (1993): Předběžné výsledky hodnocení zkrasovění v koněpruské oblasti. – Český kras (Beroun), XVIII: 14–20.

Bosák P. (1996): The evolution of karst and caves in the Koněprusy region (Bohemian Karst, Czech Republic) and paleohydrologic model. – Acta Carsologica, 25: 57-67. Ljubljana.

Bosák P. (1998): The evolution of karst and caves in the Koněprusy region (Bohemian Karst, Czech Republic), part II: hydrothermal paleokarst. – Acta carsologica, XXVII/2, 3: 41–61. Ljubljana.

Bosák P. (2000): The evolution of karst and caves in the Koněprusy region (Bohemian Karst, Czech Republic), part III: Collapse structures. – Acta carsologica, 29, 2, 2: 35–50. Ljubljana.

Bosák P. (1997): Paleokarst of the Bohemian Massif in the Czech Republic: an overview and synthesis. – International Journal of Speleology, 24, 1995, 1-2: 3-40, L´Aquila.

Bosák P. (2002): Karst processes from the beginning to the end: how can they be dated? – In: F. Gabrovšek (Ed.): Evolution of Karst: From Prekarst to Cessation, Carsologica, Založba ZRC, Postojna-Ljubljana: 191-223.

Bosák P. (2003): Karst processes from the beginning to the end: how can they be dated? – Speleogenesis and Evolution of Karst Aquifers, 1, 3: 24 pp.

Bosák P. (2007): Time and karst: some considerations. – Acta carsologica, 36, 1: 207–208. Postojna.

Bosák P. (2008): Karst processes and time. – Geologos, 14: 15–24. Poznań.

Bosák P., Ford D.C., Głazek J. (1989): Terminology. – In: P. Bosák, D.C. Ford, J. Głazek, I. Horáček (Eds.): Paleokarst. A Systematic and Regional Review, Elsevier-Academia, Amsterdam-Praha:

25-32.
Bosák P., Ford D.C., Głazek J., Horáček I. (Eds., 1989): Paleokarst. A Systematic and Regional Review. – Elsevier-Academia, Amsterdam-Praha, 728 pp.
Bosák P., Horáček I., Panoš V. (1989): Paleokarst of Czechoslovakia. – in P. Bosák, D.C. Ford, J. Głazek, I. Horáček (Eds.): Paleokarst. A Systematic and Regional Review: 107–135. Elsevier–Academia. Amsterdam–Praha.
Bosák P., Kadlec J., Otava J., Polák P., Vít J. (1999): Exkurzní průvodce, Moravský kras, Česká republika. Excursion Guide, Moravian Karst, Czech Republic. – Čes. speleol. spol: 1–55+1–55. Praha.
Bosák P., Knez M., Otrubová D., Pruner P., Slabe T., Venhodová D. (2000a): Palaeomagnetic Research of Fossil Cave in the Highway Construction at Kozina, SW Slovenia. – Acta Carsologica, 29, 2, 1: 15-33, Ljubljana.
Bosák P., Pruner P., Mihevc A., Zupan Hajna N. (2000b): Magnetostratigraphy and unconformities in cave sediments: case study from the Classical Karst, SW Slovenia. – Geologos, 5: 13–30. Poznań.
Bosák P., Pruner P., Kadlec J. (2003): Magnetostratigraphy of cave sediments: application and limits. – Studia Geophysica et Geodaetica, 47, 2: 301–330. Praha.
Bosák P., Pruner P., Zupan Hajna N. (1998): Paleomagnetic research of cave sediments in SW Slovenia. – Acta Carsologica, XXVII/2, 3: 151-179, Ljubljana.
Colman, S.M., Pierce, K.L. (2000): Classification of Quaternary geochronologic methods. – In: J.S. Noller, J.M. Sowers, W.R. Lettis (Eds.): Quaternary Geochronology. Methods and Applications, American Geophysical Union: 2-5, Washington.
Cvijić J. (1918): Hydrographie souterraine et évolution morphologique du Karst. – Rec. Trav. Inst. Géogr. Alpine, 6, 4: 376-420.
Davis W.M. (1899): The geographical cycle. – Geogr. J., 14: 481-504.
Esteban M., Klappa C.I. (1983): Subaerial exposure environments. – In: P.A. Scholle, D.G. Bebout, C.H. Moore (Eds.): Carbonate depositional environments, Amer. Assoc. Petroleum Geol., Tulsa: 1-54.
Ford D.C., Williams P.W. (1989): Karst Geomorphology and Hydrology. – Unwin Hyman, London, 601 pp.
Ford D.C., Williams P.W. (2007): Karst Hydrology and Geomorphology. – Wiley, 562 pp., Chichester.
Grund A. (1914): Der geographische Zyklus im Karst. – Ges. Erdkunde, 52: 621-640.
Horáček I., Bosák P., 1989: Special characteristics of paleokarst studies. – In: P. Bosák, D.C. Ford, J. Głazek, I. Horáček (Eds.): Paleokarst. A Systematic and Regional Review, Elsevier-Academia, Amsterdam-Praha: 565-568.
Horáček I., Kordos L. (1989): Biostratigraphic investigations in paleokarst. – In: P. Bosák, D.C. Ford, J. Głazek, I. Horáček (Eds.): Paleokarst. A Systematic and Regional Review, Elsevier-Academia, Amsterdam-Praha: 599-612.
James N.V., Choquette P.W. (1984): Diagenesis 9. Limestones – the meteoric diagenetic environment. – Geoscience Canada, 11: 161-194.
James N.V., Choquette P.W. (Eds., 1988): Paleokarst. – Springer, New York: 416 pp.
Kadlec J., Hercman H., Beneš V., Šroubek P., Diehl J.F., Granger D. (2001): Cenozoic history of the Moravian Karst (northern segment): cave sediments and karst morphology. – Acta Musei Moraviae, Sci. geol., LXXXV: 111-161. Brno.
Kukla J., Ložek V. (1958): K problematice výzkumu jeskynních výplní. – Československý kras, 11: 19–83. Praha.
Longman M.W. (1980): Carbonate diagenetic textures from near-surface diagenetic environments. – Amererican Association of Petroleum Geologists Bulletin, 63, 4: 461-487, Tulsa.
Lowe, D.J., 1999: Why and how are caves „organized“: does the past offer a key to present. – Acta Carsologica, 28/2, 7: 121-144, Ljubljana.
Mihevc A., 1996: Unroofed cave at Povir. – Naše jame, 38: 92-101. Ljubljana. (in Slovenian)

Mihevc A., 2001b Speleogeneza Divaškega krasa. – Zbirka ZRC, 27: 180 pp. Ljubljana.
Moore C.H. (1989): Carbonate Diagenesis and Porosity. – Developments in Sedimentology, 46, Elsevier, New York: 338 pp.
Moore C.H. (2001): Carbonate Reservoirs. Porosity Evolution and Diagenesis in a Sequence Stratigraphic Framework. – Developments in Sedimentology, 55, Elsevier, Amsterdam: 444 pp.
Mylroie J.E., Carew J.L. (2000): Speleogenesis in Coastal and Oceanic Settings. – In: A.A. Klimchouk, D.C. Ford, A.N. Palmer, W. Dreybrodt (Eds.): Speleogenesis. Evolution of karst aquifers, Nat. Speleol. Soc., Huntsville: 226-233.
Osborne R.A.L. (1984): Lateral facies changes, unconformities and stratigraphic reversals: their significance for cave sediments stratigraphy. – Cave Science, 11, 3: 175-184.
Osborne R.A.L. (2000): Paleokarst and its Signinficance for Speleogenesis. – In: A.A. Klimchouk, D.C. Ford, A.N. Palmer & W. Dreybrodt (Eds.): Speleogenesis. Evolution of karst aquifers, Nat. Speleol. Soc., Huntsville: 113-123.
Osborne R.A.L. (2002): Paleokarst: Cessation and Rebirth? – In: F. Gabrovšek (Ed.): Evolution of Karst: From Prekarst to Cessation, Carsologica, Založba ZRC, Postojna-Ljubljana: 97-114.
Osborne R.A.L. (2010): Rethinking eastern Australian caves. – Geological Society, London, Special Publication, 346: 289-308.
Osborne R.A.L., Zwingmann H., Pogson R.E., Colchester D.M. (2006): Carboniferous clay deposits from Jenolan Caves, New South Wales: implication for timing of speleogenesis and regional geology. – Australian Journal of Earth Sciences, 53: 377-405.
Panoš V. (1964): Der Urkarst in Ostflügel der Böhmishen Masse. – Zeitschrift für Geomorphologie, N.F., 8, 2: 105-162.
Pruner P., Bosák P. (2001): Palaeomagnetic and magnetostratigraphic research of cave sediments: theoretical approach, and examples from Slovenia and Slovakia. – Proceedings, 13th International Speleological Congress, 4th Speleological Congress of Latin America and the Carribean, 26th Brazilian Congress of Speleology, Brasilia, July 15–22, 2001, Vol. 1: 94–97 + CD ROM.
Pučálka R., Panoš V., Buček A., Čížek O., Holzer M., Vašátko J. (2001): Krajinné charakteristtiky javoříčského a mladečského krasu. – In: Jirka Z. (Red.): Speleoterapie. Principy a zkušenosti: 156-254. Univ. Palackého. Olomouc.
Sasowsky I.D. (2007): Clastic Sediments in Caves – Imperfekt Recorders of Processes in Karst. – Acta Carsologica, 37, 1: 143-149. Ljubljana.
Sawicki L. (1908): Skizze des slowakischen Karstes und der geographischen Zyklus im Karst überhaupt. Kosmos, 6-7, 395-444, Lwów. (in Polish)
Sawicki L. (1909): Ein Beitrag zum geographischen Zyklus im Karst. – Geogr. Zeitschrift, 15: 185–204. Wien.
Tucker M.E., Wright V.P. (1990): Carbonate Sedimentology. – Blackwell, Oxford: 482 pp.
Wright V.P. (1991): Palaeokarst types, recognition, controls and assocations. – In: V.P. Wright, M. Esteban, P.L. Smart (Eds.): Palaeokarsts and Palaeokarstic Reservoirs, P.R.I.S. Occas. Publ. Ser., 2, Reading: 56-88.
Wright V.P., Esteban M., Smart P.L. (Eds., 1991): Palaeokarsts and Palaeokarstic Reservoirs. P.R.I.S. Occas. Publ. Ser., 2, Reading: 158 pp.
Wright V.P., Smart P.L. (1994): Paleokarst (Dissolution Diageneis): Its Occurrence and Hydrocarbon Exploration Significance. – In: K.H. Wolf, G.V. Chilingarian (Eds.): Diagenesis, IV, Developments in Sedimentology, 51, Elsevier, Amsterdam: 489-502.
Žák K. (2006): Geologický a karsologický popis jeskyně Na Javorce. – Speleofórum, 25 (2006): 19-20. Česká speleologická společnost. Praha.
Žák K., Pruner P., Bosák P., Svobodová M., Šlechta S. (2007): New type of paleokarst sediments in the Bohemian Karst (Czech Republic), and their regional tectonic and geomorphological relationships. – Bulletin of Geosciences, 82, 3: 275–290. Praha.

THE ESSENTIAL ROLE OF INTERPRETIVE GUIDING IN ENSURING UNDERSTANDING AND CONSERVATION OF CAVES AND KARST

Dan Cove

Manager Cave Operations, Jenolan Caves, NSW, Australia; dan.cove@jenolancaves.org.au

Abstract: An automatic love of the natural world and a desire to see it protected is not instinctive to the majority of individuals. The majority of the population do not desire to do harm to the environment, rather there is no instinctive appreciation of the fragility of one's surrounds and the ease with which they may be irrevocably altered and damaged. Such an appreciation may be reached and indeed it often proves very easy to cultivate. Recognising this need to educate and foster understanding and appreciation in individuals places an onus on the managers, custodians and guides of significant sites. Any commitment to conservation requires public support, and this support requires a public that feels a connection to the values of the environment in question. One extremely effective means of achieving this is through well planned and delivered interpretive guiding, and highly trained guides.
The importance of interpretive guiding is of special relevance to cave management, as geodiversity has a generally lower popular perception of potential fragility than does biodiversity. A geological site may be seen as a far less renewable natural resource that a biological site because of the time involved in its formation processes. Training of guides, and delivery of a coordinated and structured interpretive tour experience are of an importance once overlooked. It is inadequate to recruit a new guide, present them with the necessary facts and figures and expect them to translate these into a meaningful experience for visitors. The on-site experience can be the single greatest factor in establishing a long-term connection to both the site and the broader associated environment and therefore the quality of the guide and the guided experience are of enormous importance.

Keywords: caves, interpretation, guides, conservation, training

It is an unfortunate reality that an automatic love of the natural world and a desire to see it protected is not instinctive to the majority of individuals. This may seem like a harsh assessment but it is one that is all too often evidenced. It does not suggest that the majority of the population are malicious or desirous of causing harm to the environment, rather that there is no instinctive appreciation of the fragility of one's surrounds and the ease with which they may be irrevocably altered and damaged. Such an appreciation may be reached, indeed it often proves very easy to cultivate, but recognising a need to educate and foster understanding and appreciation in individuals does place an onus on the managers, custodians and guides of significant sites. Any commitment to conservation requires public support, and this support requires a public that feels a connection to the values of the environment in question. One extremely effective means of achieving this is through well planned and delivered interpretive guiding. The on-site experience can be the single greatest factor in establishing a long-term connection to both the site and the broader associated environment and therefore the quality of the guide and the guided experience are of enormous importance.

A great number of geosites world wide employ guides, and utilise the concept of the 'guided tour'. Yet the terms 'guide' and ‘guiding’ are relatively elastic. For some they may be virtually synonymous with tourism at its very worst, and it is certainly true that there are some very poor examples of guides in environmentally based tourist sites. Some guides appear utterly indifferent to their subject matter, others positively distasteful of it. Others deliver dry lectures. Many sound as if they are reciting a script, one which they have performed so often that it has become a chore. However, it is important to focus on the enormous potential inherent in on-site interpretive guiding rather than to focus on the percentage of practitioners who perpetuate these negative stereotypes, a percentage that happily appears to be in general decline. The positive experience that is achievable is far more true to the literal meaning of the term ‘guide’, as it involves genuinely providing guidance which is exactly what is required as a first stage in establishing a connection and, ultimately, creating an advocate – the goal of sound interpretive guiding.

‘Interpretation’ has also been, on occasion, a much maligned term, as again it raises the spectre of lecturing, and suggests that visitors will be subject to a very specific point of view, rather than being allowed to explore their own motivations regarding a site visit. However, this again is an entirely negative focus, and not at all the case when examining interpretive guiding in the truest sense. Interpretive guiding recognises that there are aspects of the experience or attraction that will be foreign and unknown, even unknowable, to visitors without some guidance. An interpretive guide will accept that every visitor and every group will be different and possess differing motivations, and as such will never guide exactly the same way twice, but will have an underlying framework to a tour consisting of a theme, or a series of themes, aimed at encouraging visitors to explore the many aspects of a site. This is not a one-way process, for genuine interpretive guiding is interactive and responsive, with a necessary skill being the adaptability of the guide and their ability to ‘read’ each individual and group. Interpretive guiding also aims to convey a message which will not easily be forgotten, and that will lead to the advocacy noted previously. Naturally, the best practitioners of interpretive guiding are frontline advocates themselves.

Guidance does not directly equate to education, although the latter is a component of the former. Science is one extremely important aspect of any geosite, but it is important to remember that it is only one of several aspects that may provide a sense of connection to the site, and that the best way to foster scientific interest is not always to directly attempt to teach science. The oft-cited argument that understanding is a prerequisite to appreciation is a dangerous one, as it runs the risk of alienation. It is not necessary to fully understand the set of geological processes that go into forming a limestone cave system for a visitor to appreciate the extraordinary beauty of the speleothems. What is important is that values overlap, and that appreciation for a local environment in one fashion, for example aesthetic values, can lead ultimately to acknowledgement of the existence of other values be they scientific, cultural or otherwise, and thus a desire to know more and to explore the site on other levels and, as knowledge and appreciation increase, to conserve and protect this environment.

Here again is the potential of the on-site guide. Just as there is not always the instinctual love and respect for nature that would exist in an ideal world, so to there may not always seem to be an automatic appreciation of science in many visitors. However, there is frequently an underlying curiosity particularly evident in children who are natural scientists in that they exhibit a great desire to understand the natural world. Unfortunately this desire is often suppressed by adults who scold their children for asking ‘silly’ questions (often the most thoughtful and hardest to adequately answer). A guide has the opportunity to encourage and nurture this natural tendency by making science fascinating, relevant, and even fun! When are Earth system processes ever as easy to captivate an audience with, than when one is quite literally surrounded by them? Site guides have an opportunity that is not so readily available in a classroom setting to build a scientific interest on the human inclination to be immediately involved with what can be seen directly in front of you.

From this it follows that one key to successful site interpretation is allowing visitors the opportunity to explore their own motivations rather than imposing a predetermined set of 'topics'. How many reminiscences of 'bad guiding' stem from the simple fact that the guide did not discuss a topic that was of interest of their audience? A good interpretive tour will certainly provide the visitor with a message to take home, and the tour may have central theme but this is a genuine storyline, rather than a 'topic', such as geology. There are a great many potential means of delivering the ultimate take-home message; "*This site is worth conserving*". One initially unlikely sounding example is the "Legends, Mysteries and Ghosts" tour, offered at Jenolan Caves, NSW. An extremely popular product, the name and theme of the tour attracts a large and generally diverse crowd. The storyline that the guide then runs through the two hour trip underground weaves the history of European exploration with the conservation efforts of the early guides and the enduring belief that visitors 'feel' or even see the ghosts of these early custodians still haunting the caves. However the ultimate message is that these custodians are a watchful presence and why not, as the caves are worth protecting. Hence a conservation message is at the heart of a tour that would initially seem removed from any such concept, and it is a message that has its basis in an emotional connection with visitors.

There is enormous advantage in emotional connection to a site. People may possibly stand up for a cause that they feel a general obligation towards. However they will fight tooth and nail for any cause in which they feel a genuine sense of personal ownership. As stated, this advocacy should be the objective of all good on-site interpretive guides; to turn passive visitors into passionate supporters who would fight should the natural resource be threatened. The very best science and scientific work lacks potency in the face of public apathy. In order to be effective, science requires popular support even if it is not support for the science itself but for a set of related values. Public understanding and support is vital to successful long term conservation efforts, and the scientific rationale that underlies these efforts may find its backing in the related aesthetic, historical, cultural or spiritual connection that visitors may have formed with the area to be protected.

The importance of interpretive guiding is of special relevance to cave and karst management, as geodiversity has a generally lower popular perception of potential fragility than does biodiversity. At the heart of this is the enduring belief that people, even in large numbers, do not harm geosites because you can't really hurt a rock. "As solid as a rock", "between a rock and a hard place", 'as immovable as a mountain": all our lives we are reminded that rocks are unchanging and unchangeable. This perception has led to, and continues to lead to, great harm. A geological site may be seen as a far less renewable natural resource that a biological site precisely because of the time involved in its formation processes. Early tourists souvenired crystal formations from caves confident that they were doing no real harm, yet it will be thousands of years before these areas will regrow. Structures and car-parks are built over catchment areas. Pollutants are allowed to enter aquifers which are out of sight and, therefore, mind. There are problems with perceptions of time and space – geosites are too large and too old, size and age conveys strength and endurance requiring less stewardship. Visitors to limestone caves are often genuinely surprised when asked to refrain from touching calcite formations, as the concept that a person touching a rock is damaging can be a very difficult one to grasp.

Yet again, this is an area where on-site interpretive guiding has the greatest potential for public education through experience. To be able to incorporate the message of the potential fragility of the site into a tour is a significant step in future conservation. If the message is that the site is worth conserving, then there is great weight behind demonstrating examples of past practices, either malicious or simply degradation as a consequence of ignorance. A skilled interpretive guide can reinforce this point several times in the course of a tour without 'preaching' a message. This will then become knowledge that is transferrable; and this is an important concept. If public understanding and support is vital to successful long term conservation efforts, then the support for one geotourist destination can be harnessed to provide a broader support base for geoconservation efforts. Well planned and delivered interpretive guiding of visitors is a critical element in gaining and maintaining this support.

If a visitor comes to appreciate that one geosite may be subject to human impact, then it is a relatively small leap to apply this to similar sites, and from here to a broader general environmental ethic. This leads to the 'flagship' concept. Just as in biodiversity conservation, flagship species such as the Panda or Humpback Whale are used to generate interest and support for conservation efforts that extend far beyond the original flagship species, so too cave systems require their flagship sites. The value of these sites is that they are relatively well known to a general audience and may already have an emotional resonance in the popular consciousness. Once again it should be a function of all on-site interpretive guides at these flagship areas to ensure that visitors are aware that the issues that confront their site are not necessarily site-specific, but extend widely to other geosites. This has the dual benefits of raising environmental awareness as well as promoting wider knowledge of less well known sites with the potential trickle-on effect of increased geotourist visitation and consequent appreciation. Of course there is also a commercial element to this equation, as geotourism sites may require high levels of visitation to remain financially viable. Wider appreciation and a positive on-site experience translate to greater return visitation and wider tourist involvement in geosites as a preferred destination type.

Successful interpretive guiding therefore provokes an emotional response in visitors that may not otherwise have arisen, leading to a more profound connection with the site. However, this desired outcome is not easily achieved, as today's guides are in competition with a media saturated 'sound-bite' audience with high expectations of instant gratification. It is easy to overlook just how much harder it is for a site-guide in the early 21st century to achieve an emotional response in their group than would have been the case in the early 20th century. Visitors to geosites 100 years ago would most likely have been generally infrequent travellers and have had little to no exposure to the experience before them and few preconceptions. As such they required relatively little additional stimulation beyond the attraction itself in order to have a deeply satisfying and enduring experience. Today this is simply not the case. Today's visitors are more stimulated than ever before, are accustomed to travel, have increasingly higher expectations of their experiences, and are often familiar with the site via electronic media well before arrival. They therefore require far more additional stimulation than did last century's visitors in order to achieve the same response and emotional connection.

In environmental interpretation there are a series of keys or 'triggers' that may be utilised by on-site guides to achieve the emotional connection between visitors and a site. One principle trigger is to deliberately confront the visitor with an experience that confounds their expectations, accentuating the difference in their experience to the everyday. The trend in making geotourist sites ever easier to access should not be at the expense of making the experience seem mundane. In the past there have been quite conscious efforts to suppress the very differences that make a site unique. These have often been well intentioned, even necessary, such as the construction of safe walkways constructed to national safety standards through the middle of a cave system. Today's visitors generally have expectations of a safe and secure environment also, which overlooks the fact that a cave is not always a safe or secure environment, and that there are enduring cultural connections to caves as places of danger, mystery and magic. Hence, by providing an experience that ensures visitors remain entirely within a comfort zone, we can remove a core motivation for visiting, and a potentially powerful emotional stimulus. An on-site interpretive guide can restore this balance without compromising visitor safety. By presenting a tour that maintains a sense of adventure and discovery, that lets visitors feel that they have been taken out of their comfort zone, the experience becomes a more enduring one.

Interpretation, therefore, requires planning, versatility, an understanding of visitor 'triggers' and can also require a willingness to use technology as a tool to assist in delivery and providing emotional stimuli. The traditional 'guided tour' concept may not be as sufficiently enticing as it once was, and this is a problem. Our guides must work even harder. We must offer an experience that is fresher, more challenging to the visitor and delivers a surprise factor. In reality, we are looking to evoke the same emotional response that guides of the 1880s achieved by simply turning on a single light switch. This is not to suggest the use of technology as a prop or special effect, rather to acknowledge that there is a necessity for innovation. How to achieve this? At Jenolan we have experimented with our lighting designs, creating lightscapes of great beauty but also lighting that surprises and confronts the visitors, lit to surprise, as well as please the eye leaving visitors a little dazed. Adventure tours continue to grow in popularity, combining the adventure seeking with the more intimate discovery and eco-experience that comes from leaving the pathways behind. Our guides need to be equipped with increasingly innovative tools to meet these modern challenges, to be ever more flexible in approach and presentation.

Training of new guides is also of an importance once overlooked. It is inadequate to recruit a new guide, present them with the necessary facts and figures and expect them to translate these into a meaningful experience for visitors. If we accept that the on-site experience can be the single greatest factor in establishing a long-term connection to both the site and the broader associated environment, then the quality of the on-site guide is of enormous significance. Training of guides in line with national units of competency, formal assessment programs, mentoring of new guides by suitable experience staff and encouraging self-development and cross training between sites are all elements to be considered by site managers. At Jenolan Caves our guides regard themselves, quite rightly, as professionals and possess a defined training framework and career path. The result is a team of highly motivated and enthusiastic individuals presenting a quality product.

Interpretive guiding is a craft, and its finest proponents do more than educate or entertain their visitors, they completely alter their perceptions of the site in which they are involved. In the case of show cave tourism, they leave visitors with an appreciation of the need for conservation and a finer understanding of the potential fragility that may be associated with geodiversity. These guides are the frontline element in any broad effort to create a public that is sympathetic and supportive of conservation and long term protection of cave and karst systems. Their quality and commitment is of the highest importance to long term management.

PRELIMINARY PROPOSAL FOR THE PROJECT »HEAVEN'S CAVE« (VIETNAM) ADAPTMENT FOR TOURIST PURPOSES

Bogdan Debevc[1]†, Martin Knez[2], Andrej Kranjc[2], Mitja Prelovšek[2], Aleš Semeja[3], Tadej Slabe[2]

[1] Turizem KRAS d.d., Jamska cesta 30, SI-6230 Postojna, Slovenia
[2] Karst Research Institute at ZRC SAZU, Titov trg 2, SI-6230 Postojna, Slovenia; knez@zrc-sazu.si, kranjc@zrc-sazu.si, mitja.prelovsek@zrc-sazu.si, slabe@zrc-sazu.si
[3] Sava TMC, Škofjeloška cesta 6, SI-4000 Kranj, Slovenia; ales.semeja@sava.si

Abstract: Heaven's cave is located in the centre of the Phong Nha-Ke Bang national park, about 500 km southern from the Vietnamese capital and 40 km from the city of Dong Hoi. Phong Nha-Ke Bang national park is protected also as a UNESCO world heritage site. Due to economic situation in this region as a result of lack of natural resources, karst tourism represents an important opportunity for raising the quality of living in the province. A proposal to adapt non touristic Heaven's cave for tourism was presented to Karst Research Institute at ZRC SAZU in 2006.

Keywords: Heaven's cave, Thien Duong cave, Phong Nha-Ke Bang, Vietnam, show cave

INTRODUCTION

Quang Binh Province, situated about 500 km southern from the capital Hanoi, is one of the poorest provinces of Vietnam (per capita GDP is half the Vietnamese average). With the aim of improving the economic situation in the area, the possibility has been raised of marketing sights in the Phong Nha-Ke Bang National Park, a UNESCO World Heritage Site as tourist attractions. Among these sights, as yet unexploited for tourism purposes, is Heaven's Cave (in Vietnamese Thien Duong).

The Phong Nha-Ke Bang National Park (Fig. 1) covers an area of 857.54 km^2 and is a UNESCO World Heritage Site, reflecting its global importance (World Heritage..., 2000). The park came under UNESCO protection in 2003 because of its extraordinary stratigraphical diversity (from the Precambrian to the present day – over 400 million years), the long development of its topography (from the Oligocene to the present day – over 36 million years) and the resulting extremely intensively developed karst formations. Over 300 karst caves have been recorded in the park, among which the most extensive is Hang Vom cave system with 15,310 m long cave

Fig. 1. Tropical karst in the middle of the Phong Nha-Ke Bang National Park. Photo: M. Knez

passages (Limbert, 2010). The park's geological and geomorphological diversity is closely followed by its considerable biodiversity in terms of both fauna and flora, and its extraordinarily well conserved tropical karst forests.

The central limestone area is bordered by impermeable strata which collect water on the surface and in the southern part of the park discharge it towards the Chay River lying further north. This inflow of allogenous water, combined with the long development, is the main factor of the development of the underground caves explored to date. Excellent examples of caves of this type are the Phong Nha (show cave) and Hang Vom cave systems. With the entrenchment of the Chay River, the underground flows shift lower and lower and leave fossil caves at the higher levels. Examples of such caves are Tien Son Cave, rich in calcite deposits and open to tourists as a show cave, and Heaven's cave. The caves follow the bedding planes into the thickly stratified Devonian-Carboniferous-Permian limestone and numerous faults tied to the predominantly N–S faults in the Alpine orogen (World Heritage..., 2000). Long-term karstification is also facilitated by limestone strata over 1,000 metres thick.

The first task was to measure the cave in order to establish its ground plan, longitudinal profile and significant cross-sections. At the same time a speleological evaluation of the cave is being carried out, in other words a description of the current state as regards geology, geomorphology, hydrology, meteorology, speleobiology and archaeology and palaeontology. The description of the current state includes a photographic inventory of significant elements of the cave. On the basis of these characteristics of the cave, the risks to and vulnerability of the cave is defined, and fundamental nature protection guidelines highlighted. The second part of the research presents a range of identified tourist attractions with a proposal of access to them (type and route of path for tourists) and a proposal of illumination. Use of the cave as a show cave must correspond to sustainable nature protection guidelines, since only in this way can we maintain the cave in its natural equilibrium. Access to the cave is very important. This is based on the proposed use of the cave as a show cave (number and type of visitors), the carrying capacity of the external environment and UNESCO guidelines.

GENERAL CAVE DESCRIPTION

Entrance to Heaven's cave is located at about 226 m a.s.l. under the vertical cliff. Entrance part is quite narrow since it leads through collapse blocks, which accumulated over the long geomorphic development at the foot of a cliff. The easiest access leads through 3 × 4 m void between collapse blocks. The continuation is developed as 65 m long slope with inclination 45°. The upper part is formed by solid rock whereas the lower part is developed as a steep scree. In the middle of a scree, two over 5 m high and 3 m wide stalagmites are located. Foot of a scree is covered by silty and loamy sediment and by bat guano. This part of the cave is actually a huge underground chamber 120 m long, 60 m wide and up to 30 m high (Fig. 2). At the southern side, dry water channel is located.

Fig. 2. Huge entrance chamber in Heaven's cave. Photo: M. Prelovšek

Downstream continuation is blocked with collapse material and loamy sediments, whereas the upper continuation of the cave leads toward the west. Bottom of the cave is covered with several meters wide rimstone dams, which are partially covered with mud but active since the calcite crystals are not corroded by mud deposits. The deepest exceed 1 m and is usually partly filled with water. The other seems to be mostly dry but the water can fill them after strong precipitation. Another area of rimstone dams is located south-western of the first ones. There, cave passage is developed as about 30 m wide and more than 20 m high nearly horizontal passage. All along this passage, dry water channel is incised into the sediment terrace at both sides of a passage. Where the channel meanders, left or right terrace are often absent. Since the terrace is the driest part of the cave bottom, several stalagmites and columns appear there. Rather than individually, they are formed as a group under the well-cracked and karstified carbonate rock. The most impressive was named after palm tree – Cot Nhu Da. Continuation of a passage is similar to the already described parts of the cave.

EVALUATION OF HEAVEN'S CAVE'S POTENTIAL FOR TOURISM

The cave is practically invulnerable in the meteorological sense, since at least in winter and summer it is extremely well ventilated. The absence of archaeological finds and palaeontological remains keeps it invulnerable in this sense too. The cave is most vulnerable in the sense of the morphology of deposited sediments (speleothems and loam). The most sensitive features are rimstone dams (Fig. 3). Walking alternately over loam and calcite surfaces results in the loam being transferred to the speleothem-covered surfaces. It is not possible to define speleobiological risks and guidelines on the basis of present research and knowledge. Further research indicating the numbers of animal species, their rarity and their protection, would be necessary. Due to high biodiversity of Phong Nha-Ke Bang national park and long geomorphic evolution, high biodiversity can be expected also in the cave. Periodical floods in Heaven's cave are serious threat to touristic infrastructure, if the cave will be developed as a show cave. Since the time of their appearance, frequency, durability and their height are of the highest value to estimate their potential threat to touristic development, monitoring of water level will be necessary in the future. At the end of our fied observations, data logger was installed to measure oscilation of water level and temperature in the main passage.

Large stalagmites and pillars, and rimstone dams are the greatest tourist attraction of the cave, since they are of above-average dimensions and are perfectly conserved (Fig. 3). Owing to their fragility they are also most at risk in the case of unsuitable walking through the cave. From the European and North American perspective, the location of cave formations so close to the entrance is surprising, but scientifically expected in a tropical climate due to the absence of frost weathering.

Fig. 3. Rimstone dams. Photo: M. Prelovšek

Another unique attraction is Heaven's cave's position as part of the long cave system of Hang

Vom, one of the longest and largest water caves in the world. Hang Vom itself is very dangerous for visitors because of the frequent and sudden floods, but the rise in the water level in Heaven's cave is presumably considerably slower, more predictable, the exit from the cave is higher than the highest possible flood and quite near the furthermost point of the measured section of the cave.

Heaven's cave has very good educational potential since it offers a good and varied insight into speleological and karst phenomena, while the route to the cave and the beautiful environment of the Chay River offer a good insight into the biological characteristics of a humid tropical forest on karst rock.

Tourism in Phong Nha-Ke Bang National Park is mainly concentrated in the area of the Phong Nha and Tien Son caves. Owing to their great attractiveness, these represent a considerable potential for tourism, which in our opinion, however, is far from being sufficiently exploited.

POSSIBILITIES OF SHOW CAVE EQUIPMENT FOR THE CAVE AND ACCESS

Adapting the Heaven's cave for tourism purposes is a technically demanding project because of its specific geographical position (remoteness), somewhat unstable sediments and alluvial deposits, high ceiling and unknown fluctuation of water level. The cave is a sensitive ecosystem and all touristic influences should be evaluated. Due to cave's location in the national and UNESCO park, necessary permission from the relevant ministries of the Vietnamese government, and from UNESCO should be acquired.

An outline plan for classic cave visit has been drawn up for the laying-out of a 550-metre footpath for mass tourism. It has been proposed that the walking surfaces in the cave should be made of non-corrosive materials and be light and removable. The whole path should be built on pillars in order to avoid major building work and damage to the floor of the cave (Fig. 5). Man-made tunnel below natural entrance would make the entrance easier for visitors. A proposal has been prepared of a 60-metre man-made tunnel that would enable

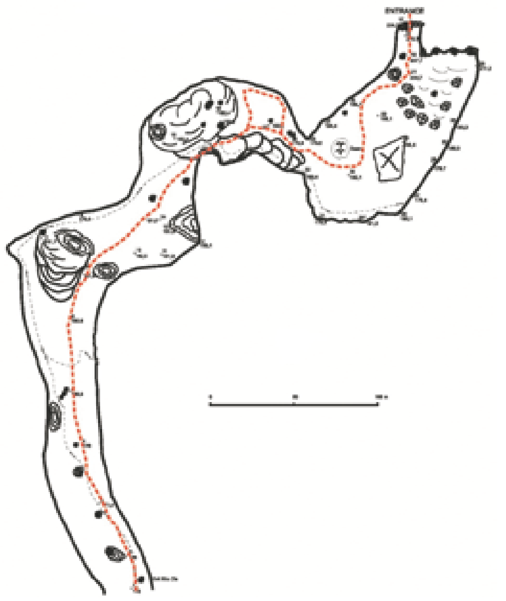


Fig. 4. Proposal for Trekking or Adventure visit.

visitors to avoid the steps that would otherwise be urgently necessary in the entrance section of the cave. This would probably increase the number of visitors, but here the opinion of UNESCO should be followed.

To access the cave's entrance we proposed three variants of access. Access by footpath would follow the existing path through the rainforest, along the river and end with a steep ascent towards the cave entrance. In view of the great biodiversity and historical importance of the area, it could also serve as a nature/history trail if suitable explanations were provided. Access by road envisages the construction of a road 3 km long and 4–5 m wide from the car park to an esplanade outside the cave entrance. The road would be exclusively intended for the transporting of visitors to the cave by minibus or roadmobile. Visitors would leave their vehicles in the car park by the main road, where other tourist infrastructure would be built (information centre, restaurant, souvenir shops, toilets, etc.). Access to the cave could also be implemented by constructing a gondola-type cable car to carry visitors to the top of the overhanging cliff above the cave. From here visitors would be transported to the cave by vehicles. The idea was presented at the

Fig. 5. Visualization of touristic infrastructure in the entrance chamber.

their visit to the national park), and also involved the development of secondary tourist activities (the range of services, level of quality, standards etc.).

request of the Vietnamese partners, although the prevailing opinion is that UNESCO would not permit construction of this kind in the natural environment of the park.

DEVELOPMENT OF AN INTEGRATED MARKETING MIX

The aim of the project to develop a base for establishing tourism in the Phong Nha-Ke Bang National Park is to set up a comprehensive marketing network which will help create an adequate range of primary tourist services to meet foreign tourists' needs, as well as a secondary range of tourist services, define relationships with tour operators and establish a comprehensive system for promoting the national park.

In view of the fact that tourism is still at a very basic level in Quang Binh province, where Phong Nha-Ke Bang National Park is situated, basic information about potential visitors, their structure, needs, preferences, etc. still had to be obtained.

Proposals for further development of primary tourist services were formulated on the basis of the collected data (the key attractions that bring in visitors and are the reason for

CONCLUSION

Heaven's cave, as part of one of the longest water cave systems in the world (Hang Vom), is a speleologically important part of Phong Nha-Ke Bang National Park. Although flood waters occasionally appear in the cave, these are believed to be considerably less intensive and of shorter duration than those in Hang Vom. From this point of view Heaven's cave is very suitable for the development of a more educational form of tourism in the sense of karstology and speleology in the wider area, while it also has a number of remarkable cave formations (rimstone dams, massive stalagmites and dripstone pillars). The biggest weakness of the cave is access, which in the case of major investment in the cave would require significant development in the park. From this point of view it would be essential to obtain the consent of UNESCO. The assessment of tourist potential will carry more weight once the completed questionnaires have been obtained. On their basis an integrated marketing mix will be developed for the park and for Heaven's cave.

Despite the fact that this criterion was considered slightly too weak for the park to be included on UNESCO's natural heritage list, we may still consider it to be exceptional. On the contrary, it appears that the potential for tourism is not being sufficiently exploited. It would make sense to include it in the route to Heaven's cave. The view that opens up of the varied relief around the cave could be incorporated into education about the characteristics and development of tropical cone karst.

References

Limbert H., 2010. Longest Caves of Vietnam. http://www.vietnamcaves.com.
World Heritage List Nomination Form: The Phong Nha-Ke Bang National Park, Vietnam. 2000.

MODEL OF DEVELOPING COMPETENCES OF THE SHOW CAVE GUIDES AND A SYSTEM OF PERMANENT MENTORSHIP (THE POSTOJNA CAVE, SLOVENIA)

Ksenija Dvorščak

Postojnska jama d. d., Jamska cesta 30, SI-6230 Postojna, Slovenia; ksenija.dvorscak@postojnska-jama.si

Abstract: At the Postojna Cave there are approximately 25 permanent cave guides, whereas during the main season (from May until the end of October) 70 of them are temporarily employed. Most of them are students. While tourism is a highly labour-intensive sector, a high level of competence development is one of the key success factors. A very important component part of the competence model is the skills management and guide training, which has been implemented in the company through a system of permanent mentorship in the guide service, where there is a large number of seasonal workers.

Keywords: show cave, guide training, mentorship, competence model

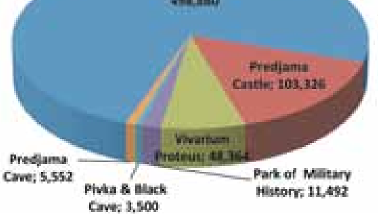
1. CHARACTERISTICS OF THE COMPANY TURIZEM KRAS D.D.

In this chapter, we present the characteristics that are connected to the field of human resource development.

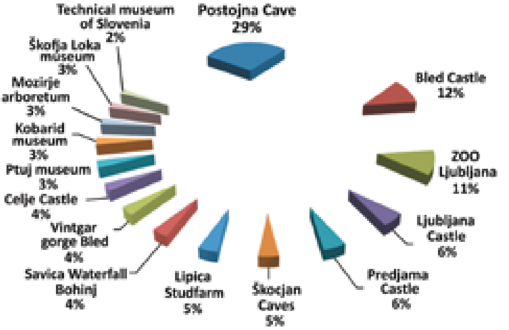
1.1. A hard-working company

Turizem KRAS d.d. is a tourism company, with a 192-year tradition of managing the Postojna Cave, where the main activity is offering services. Our company manages the Postojna cave system and the Predjama cave system, as well as the Predjama Castle; we organize and conduct tourist tours of the attractions mentioned. The company was granted a 20-year concession by the state for the management of the two cave systems. In addition to these main activities, the company is also developing activities of a restaurant, organization of events, accommodation and souvenir shops. In 2009, the tourist attractions which were managed by the company Turizem Kras, d.d. were visited by 671,114 visitors, which is 6 % less than in 2008, when there were 711,116 visitors (Picture 1). The percentage in 15 of the most visited Slovenian tourist attractions in 2008 amounted to 35 % (Picture 2).

Another important feature of the tourism business is the great seasonal fluctuation,



Picture 1: Structure of visits to tourist attractions in 2009. Source: S. Paternost: Annual report of the company Turizem KRAS for 2009 and 2008



Picture 2: Market percentage in Slovenia in 2008. Source: S. Paternost: Annual report of the company Turizem KRAS for 2009 and 2008

which is tied to the seasonal oscillation of visitors. This is why during the high season, which lasts from April to October, the number of employees greatly grows from approximately 125 to 160 employees during the season (Picture 3).

Due to such high fluctuation of employees, it is extremely important to train them in order to ensure the necessary quality. Only the employees that are sufficiently trained can contribute to achieving the strategies set by the company and, in addition to the natural values and cultural heritage, are a fundamental competitive advantage of the company. Therefore, two of the models that we have developed are of particular importance: the model of the competence of job positions and the permanent system of mentorship of new co-workers.

1.2. Guide service

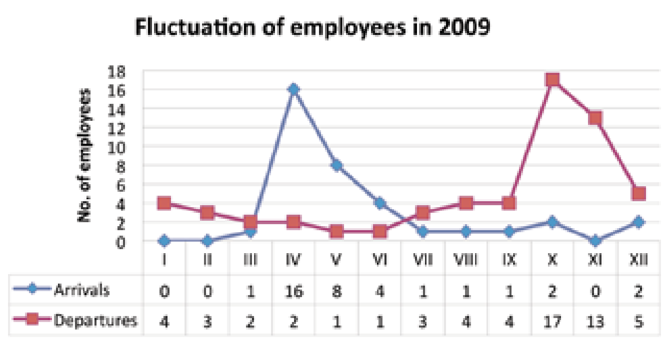
The job position of a cave guide / if the number in the company is at its greatest, seeing that the employed guides perform their job in the central activity. We have developed a system of career development for the guides and have anticipated the process of their progress through several stages.

- The initial level is the guard, who does not guide the guests, but begins with his training by accompanying the groups.
- The next stage is the assistant guide I, who is gradually included into guiding the Slovenian-speaking groups, and possibly combines guiding with driving the cave's train.
- The following stage is the assistant guide II who, in addition to the Slovenian group, guides in at least one foreign language.
- A first stage guide is a guide in at least one of the attractions, in Slovenian and two foreign languages.
- A second stage guide is a guide in all of the attractions, and alternates as necessary.
- A third stage guide also conducts more demanding adventure programs in the non-tourist parts, and conducts protocol and study visits.
- A fourth stage guide is a destination guide, having a license to be a regional guide (the Regional Institute for Tourism) and a national license from the Slovenian Chamber of Commerce. In our company, there are 13 guides with a national license.
- The highest stage is a mentor guide, who has ten years of experience and well-defined pedagogical skills.
-

In addition to this, experienced guides perform the job of an organizer or the so called on-duty guide, who is responsible for the daily schedule and leading the work; if necessary, he stands in for the head of the guide service.

We have defined the criteria for being promoted to the level of each title on the basis of the identified competences that are characteristic for a guide who knows how to create an experience. Yet, in practice, transition between different levels is also possible as the competences of guides are different.

The number of trained guides for a definite and indefinite time, required for the smooth conducting of tourist visits during the season, amounts to around 70 employees. Slightly less then a third of them are permanent employed, the rest of them are included according to the season's needs. All the guides refresh and perfect their skills annually. In addition to the guides, the job of guiding and driv-



Picture 3: Annual fluctuation of employees in the company Turizem KRAS in 2009. Source: Annual report by Tourism KRAS d. d. for 2009

ing is carried out by 6 – 8 drivers of the cave train, also carry out technical maintenance work in the cave who during the low season. In the following, we present a competence model of the guide service, which mainly serves for the selection and employment of new personnel, and for planning their education and training.

2. COMPETENCE MODEL

Competence signifies the strong characteristic of an employee who is strongly oriented to achieving excellent results at work. These characteristics may include motives, personality traits, values, attitudes, self-esteem, their own method of performing certain jobs, extensive expertise and various skills. This concerns the optimal combination of an individual's knowledge, skills, personality traits and motives. Competences directly determine behavioural patterns – how the best employees usually work and how they achieve the best results. The behavioural patterns of all employees in the organization determine the financial position or performance of the organization as a whole. This is the main reason why companies opt to discover the competences and their implementation in practice.

In the company Turizem KRAS d.d., it was necessary for us to design our own model of the required competences and the levels of development; therefore, what are the skills, knowledge and skills they need in an enterprise, and to what degree they need to be developed in order for them to be able to perform certain tasks, achieve goals and live with a vision.

2.1. The process of developing competences

When determining the required competences for the entire company and individual posts we have taken into consideration:

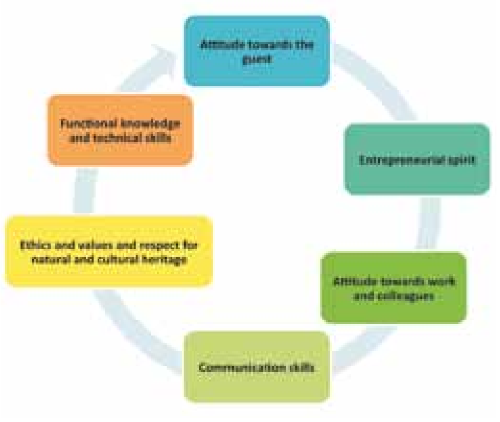
a. The vision, mission, strategy, values. The company's mission reflects a sustainable orientation: "*By tradition and knowledge, we are creating a unique experience of the Karst sights and attractions. We are preserving the natural and cultural heritage for our descendants.*"

b. The characteristics of the line of business and individual organizational units.

c. As the third fundamental starting point for designing the model of competences, we have emerged from the business goals set by the company.

In accordance to this, we then developed the appropriate competences which will help to realise this. The company Racio Razvoj assisted us in doing this. The first step was to train the staff on the significance and developing of competences.

The competences were then developed by the employees all together, at joint workshops, where a selected group of leaders and representatives of employees from various circles of work created a list of competences. At first, we the representatives of various organizational units developed **general competences** – the ones that concern all of those employed in the organization and mean the fundamental directing of operations. We determined the general competences according to the previously presented starting points and they apply to everyone employed in the organization. Within the individual organizational units, the only stage that changes is the one which is at the desired level of competence. It is adjusted according to the requirements of the work process and the difficulty of the job position.



Picture 4: General competences. Source: Manual for using competences (2008). Racio Razvoj & Turizem Kras d.d.: Postojna

The general competences are presented in Picture 4 and consist of: attitude towards the guest, entrepreneurial spirit, attitude towards work and colleagues, communication skills, ethics and values and respect for natural and cultural heritage, and functional knowledge and technical skills.

Through the joint workshop, in groups of job positions, we then developed **generic competences** for similar job positions or each organizational unit: catering activities, an investment and maintenance service, HRM, marketing and purchasing, R&D, finance and accounting, tourist attractions, where one guide service (Picture 5), accommodation, commercial activities

Picture 5: Generic competences of tourist attractions
Source: Manual for using competences. (2008). Racio Razvoj & Turizem Kras d.d.: Postojna

and generic competences for managers. We took the specificities resulting from the work process, key customer service and professional profiles for certain work performed into account.

Each competence that we have chosen has its own description of competence, behavioural style and recommended way of how to determine its competence. It is determined and defined in the Catalogue List (CL), which includes a dictionary of the competences.

The CL are primarily intended for leaders who assess the competence of individuals, and all of the employees should be familiar with what is involved in a job position of the competences identified. The document is available for insight to everyone in the company. Employees were asked to complete the model during the process of its development; we presented it at the regular annual interviews and encouraged them to thoroughly check the catalogue of competences for their area of work. On the basis of evaluations of how developed the competences of individuals are, at the regular annual discussions we formed personal business goals for individuals in the field of work, in the field of education, in the field of formal education and in the field of professional training.

2.2. The analysis results of the level of development in competences

The development level of competences was assessed in three studies: an analysis of the leaders, surveying the visitors and mystery shopping.

2.2.1. Analysis of the leaders

On the basis of the existing model, we carried out an analysis of the development level of competences for 23 employees in tourist attractions, namely the professional staff, **guides and assistant guides** and found that they are already very close to the expected level of development. The evaluation of competences is subjective. In order to ease the effect of subjectivity as much as possible, we included the head of the guide service, the head of one of the organizational units and the professional leader who have been most directly connected to the employees. The evaluation scale ranged from 1 to 5 (with 5 being the highest). We evaluated all the job positions in the tourist attractions, yet in this case, we will only present the results for the cave guides.

2.2.2. Surveying visitors on the development of competences

This was of course only one aspect of the evaluation of development level of competences – from the leaders' point of view, in which subjectivity is lacking. We wanted to also check this with our visitors, so we sent them a questionnaire.

Chart 1: Deviations from the desired levels of development in the wires and extra wires:

Competence	Deviation	Comment
Attitude towards guests	-0.8	Given the fact that the desired level of development is 5, the state of development seems to be good, but it can still be improved with training.
Entrepreneurship	-0.5	The deviation is not high, but it is urgent to continue training.
Attitudes towards work and co-workers	-0.2	Through the evaluation process we found that it would be better for the competence to be divided into two: the attitude towards work and, separately, the attitude towards co-workers. We evaluate that the attitude towards co-workers is a much better developed competence than the attitude towards work.
Communication skills	No deviations	On average at the desired level.
Functional knowledge and technical skills	-0.2	Low tolerance points to the fact that, during the off-season, guides also take on other job positions and, for the most part, are good at more jobs.
Ethics and values, respect for natural and cultural heritage	+0.2	On average, this concerns even exceeding the desired level of development; we mainly evaluated the relationship of natural and cultural heritage
Concern for safety	-0.1	No deviations.
Knowledge of foreign languages	-1.0	This is one of the greatest deviations, simply also because there are big differences between the skills of individual employees – from university to high school education, so education in this area is urgent.
Presentational and persuasive skills	-1.0	By this competence the deviation is also the largest; here we evaluated that it is necessary to provide employees with knowledge, particularly as far as interpretation is concerned.
General awareness	+0.7	Deviation in a positive sense. Yet it is true that the desired level of development is 3.
Resourcefulness	-0.1	On average, there are almost no variations – yet there are considerable differences between individuals.
Guiding and directing visitors	-0.8	This competence is very similar to the competence of presentational and persuasive skills – it is our proposal to merge them. Even tolerance is similar. Above all, there is a need for this to develop competence in the interpretation of natural and cultural heritage.
Managing machinery	+0.6	The positive deviation is a reflection of the fact that many guides also drive the train; however, this does not involve an unequal evaluation of girls and boys – because girls do not drive the train. We therefore suggest that, in the future, this competence should be combined with the competence of functional knowledge and technical skills.
Resolving conflicts	+0.9	The deviation is very positive.

a. How do you evaluate the actual development level of competences in the guide who took you on the tour of the tourist attraction?
b. What level of competence development (as a guest) do you expect from a guide?

The survey was conducted in July and August of 2008 among the visitors in the Postojna cave and in Predjama. There were 127 respondents.

The results show that, for certain competences, our model anticipates a higher level

Chart 2. Deviations from the model – evaluation and expectations from guests

The guide's competence	Expected level of development by model	Guest's evaluation of current level of development	Guest's evaluation of expected level of development
Functional knowledge and technical skills	Good	High	High
Resolving conflicts	Good	Good	High
Concern for safety	High	High	High
Knowledge of foreign languages and intercultural communication	Excellent	High	High
Presentational and persuasive skills	Excellent	Good / High	High
General awareness	Good	High	High
Resourcefulness	High	High	High
Guiding and directing visitors	Excellent	High	High
Attitude towards guests	Excellent	High/Excellent	High
Entrepreneurship	High	Good	Good
Attitudes towards work / co-workers	High	High	High
Communication skills	High	Excellent	High
Ethics and values, respect for natural and cultural heritage	High	High	High
Offering assistance and solutions	High	High	High

Source: Internal data from Tourism Karst d.d., Postojna 2009

of development than is expected by a guest; such an example is that of the knowledge of foreign languages, presentational and persuasive skills and entrepreneurship. We believe that this also a reflection of the goals which the company has built into the model. The guides are expected to encourage the guests to take advantage of as many different services (tours, souvenirs) as possible, as they are in direct contact with them. This may be disturbing to the guest if he feels that he is being pushed into doing something. It is also interesting to note that an excellent knowledge of foreign languages is not so important to a guest – the guide's attitude towards the guest seems to be more important to them.

Communicative competence and attitude towards a guest are even better developed than actually expected by the guest.

The solving of conflicts, the level of development in functional knowledge and technical skills and general knowledge in our model is anticipated to be lower than expected by the guest. Yet it is interesting that the latter two are already evaluated to be more developed than in the anticipated model. It is difficult for a guest to evaluate the general awareness of a guide during just one tour, if he does not come into personal contact with him, and it is also difficult for him to evaluate the guide's ability of resolving conflicts, if one does not occur.

The disadvantage of this analysis is that the visitors did not have the opportunity to examine the catalogue of competences – therefore, everyone might have different perceptions of individual competence

2.2.3. Mystery Shopping

In 2008, we conducted **a third form of research** which is known as Mystery Shopping. In this survey, the results of the level of competence development for each guide were obtained by asking random guests for their point of view. This was only carried out as a test – reference survey. In the future, it would be urgent to perform this regularly, since this is the only way to objectively evaluate the development level of competences for each guide and included them into the system of remuneration.

One of the aims of evaluating the level of development in competences is also for the employees, in which we noticed the highest level of development in competences, to be included into the system of mentorship for new employees who are employed seasonally. The mentorship program was developed according to the needs of individual processes through years of experience and feedback from employees who were included into the mentoring process.

3. MENTORSHIP IN THE COMPANY TURIZEM KRAS D.D.

Mentorship is one of the processes of continuous training in the company Turizem KRAS d.d. Two-thirds of the employees in the guide service are employees who are only with us over the season. These are mainly students who remain with us for 3 – 5 years. As each season begins, around 15 new guides begin with their training in the spring time. Before the training, a selection process to choose the staff is carried out by testing their functional knowledge, their use of foreign languages and their public performance skills.

3.1. The selection process

The developed competences (knowledge, skills and behaviour) are the starting point for creating training programs for cave guides. Cave guides should have at least a secondary education, actively speak at least two global foreign languages and have a good knowledge of the Postojna Karst and Cave, Karst and the Karst Caves across the world. It is necessary for guides to have a good knowledge of the characteristics of the cave's environment in order to be able to walk about the partially ordered or unorderly parts. They should know how to provide visitors at each visit with adequate information on the rules of behaviour in the cave and on the use of arrangements in the cave, which are not arranged according to standards in the field of construction. The steps for selection are as follows:

- Step 1: Public tender
- Step 2: The first informational interview with all the candidates in order to get an impression and check if everyone meets all of the tendered conditions. Everyone gets a book – a manual for guides, in which there are basic instructions for guiding. These are the standards on environmental protection, the guides' codex, the Rules concerning safety, the internal standards on guiding and basic information – so called texts and stories about individual attractions in the Slovenian, Italian, German, English, Spanish, French and Croatian language.
- Step 3: Testing the knowledge of foreign languages. Professors of the individual foreign languages and experienced guides take part in the evaluation.
- Step 4: A workshop for public performing. Candidates test themselves in public performing, they have a one-day workshop, in which they try to overcome their shortcomings and make a final performance.

3.2. The mentorship process

The preliminary selection process is usually passed by a third of the candidates. It is carried out during the mentorship process. We determine the content, trainers, methods and forms of work, and the forms of evaluation. The process lasts from 8 to 10 days within the period of one month. First, there is the group mentoring part:

- Step1: Becoming acquainted with the company, those in charge, the organization, the internal standards, a visit to the individual departments.
- Step 2: A technical visit to the Postojna Cave, where they learn about the train's traffic regime and the course of guiding, learning about the signalization that goes along with a visit, and the basic instructions in the field of safety. The person leading the visit is one of the caretakers of the cave – a mentor.
- Step 3: Becoming acquainted with the content of the Notranjska-Karst region, and the Postojna and Predjama cave system. Watching the film about the formation of the caves, the geomorphologic characteristics of the Karst region and the emergence of life in it.
- Step 4: A workshop on the theme of the Attitude towards guests. This is led by one of the experienced guides, a mentor.
- Step 5: The culinary aspect of Karst&a presentation of the typical cuisine from the Notranjska-Karst region, which is available in our central restaurant facility – Jamski dvorec (Cave Hall). The presentation is carried out by the head of the Jamski dvorec kitchen.
- Step 6: The social aspects of Karst – a presentation of the most important characteristics that visitors encounter. Everything visitors can see while travelling across Slovenia, what they are interested in and what they often ask.
- Step 7: A tour of all the attractions that the company manages. This is led by those in charge of the individual attractions.
- Step 8: A workshop concerning safety at work (in a group) and passing a test.
- Step 9: A workshop concerning the protection of the radiation.
- Step 10: A medical examination.

By this, the group part of mentorship is completed. Individual coaching follows.

- Step 1: Each candidate receives a personal mentor, with whom they work individually. Each mentor has also previously completed a training course for mentorship. They arrange with the apprentices when to begin with the training. The procedure proceeds in such a way that the apprentice first monitors and watches the mentor, later taking over the guiding of individual parts of the tour, until he is able to guide the entire tour independently. Once the supervisor assesses that the apprentice is ready, he takes a test, in which both the mentor and the head of the guide service are present and he can then begin guiding independently. Usually, up to 10 visits are necessary. We recommend that the apprentices also join in the guiding of the other guides in order for them to create a better picture of what is expected of them and to develop their method of guiding.
- Step 2: The mentor prepares a report regarding the mentorship (the course of events, the number of hours completed, the tours, opinion about the candidate).
- Step 3: The apprentices are invited to complete a survey on the course of mentorship, where we get feedback on the mentor's work and any necessary improvements.
- Step 4: After the season, an evaluative workshop follows, where the apprentices are invited to so as to suggest possible improvements on the basis of their experiences and observations. Because they are not "poisoned" by the routine yet, they can sometimes be more insightful and observe with more sense, and their suggestions are often very qualitative.

3.3. Challenges for the future

Through experiences, certain shortcomings have of course shown up. It is necessary to pay more attention to the mentor alone. Currently, their remuneration is stimulated in terms of quantity and not quality. It is urgent for the quality of the mentors to be better rewarded, and to provide extra training to those who have poorer results. In short, as the manager, we have to be more consistent in our actions.

The second area is the introduction of written examinations of knowledge about

Karstology. This is urgent for the apprentices, and I think that it would also be welcome for the mentors and permanent guides – in conjunction with the annual refreshing Karstological workshops.

Third is the area of interpretation. Tourism is nowadays much more of an interdisciplinary line of business than it was in the past and that is why the tasks of tourism are also greater. In addition to the development, supply, marketing and sale of tourist destination services, tourism performs the task of preserving the natural and cultural heritage, preserving the identity of the area, preserving biodiversity, education and concern for personal growth. Interpretation can therefore greatly contribute to a higher added value of products for tourists and thus to the economic efficiency of tourism (Carter, J.: 2010).

The contemporary guide will nowadays have to become an interpreter for the natural and cultural heritage, a cave guide and an interpreter for the caves. We are forced into this by contemporary tourist trends and guests' demands. Tilden, who is known as the founder of interpretation (1957) described interpretation as "*...a form of service, which awakes a revelation of beauty for the visitor, it evokes admiration, inspiration and the spiritual meaning which hides behind the object of interpretation, and which the visitor can detect with his senses.*" According to Tilden, interpreting is not only telling people what is important, yet trying to convince them of nature's value and encouraging them to preserve it as well. "*From experiencing to understanding, from understanding to respecting, from respecting to preserving!*"

Four communication activities, which need to be carefully planned, carried out, evaluated and improved as necessary, are important for the quality of a visitor's experience: informing, presentation, animation and interpretation. All four of these activities have their place in the planning of experiences and in tourism – and each has its own objectives and tasks. In practice, they are often intertwined. But absolutely none of the first three can replace interpretation (Keršič Svetel, 2010).

This is why it is vital for both the permanent and the seasonal guides to receive regular seasonal training which, in addition to the language refreshing, Karstology and attitude towards guests, also include training in the field of interpretation, which is installed into the model of competences.

CONCLUSION

In the implementation of the competences, we were only partly successful, yet considering the short period, we can be satisfied. The advantage of this type of model lies in the fact that individual employees may be more motivated for work where they have the opportunity to be involved in additional activities, for which they may also be rewarded. The model proved to be very successful in the process of selecting seasonal staff and in staff development. In the area of staff development, we introduced a systematic procedure of mentorship. The model of competences was welcome to us in the planning of trainings. At the regular annual discussions, we agreed, on the basis of deviations from the desired development of competences, what kind of training we can use to fill the gap.

Of course, the introduction of competences requires complete consistency inside the company, good preparation and perseverance. The motivation of employees can deteriorate rapidly if we are inconsistent. And the implementation of the model of competences will not achieve its purpose if it is installed into the system of remuneration in an appropriate way. Thus, the greatest challenge for the future integration is to include the model of competences into the system of performance evaluation. It is also necessary to fill the gap between the actual realization of personal work goals and the criteria for the evaluation of performance. The profiles of the competences have not yet been determined to the extent that they can already be used as a basis for the variable component of remuneration. This requires a thorough evaluation system and the implementation of evaluation – Mystery Shopping is one of the recommended methods.

I evaluate that some of the levels of development for competences in the model have been set too high and that it is unrealistic to expect the highest level of development in all of the competences. This has been proved by the visitors' expectations. In certain areas, the expectations of the guests and the manager differ – e.g. in the acceleration of sales or the guides' entrepreneurial spirit.

It turned out that the model of competences is alive; we immediately discovered that certain changes are necessary, it is necessary to continually upgrade it, depending on the guests' needs and the manager's expectations. The different expectations of both the guests and the manager can be met with the proper upgrading of competences, which will include more interpretational techniques and tools. This concerns the use of effective means of communication, in which all of the senses take part. These can greatly attract the attention and curiosity of a guest, and they relate to the personal experiences of individuals in everyday life, revealing a wider sense and new realisations about things already known and, above all, they cause an emotional reaction and experience.

Interpretation has been widely adopted in the protected areas and I think that it's time for us to also start implementing it in the show caves! Next year, a tender by the Environmental Agency of the Republic of Slovenia, at the Ministry of the Environment and Spatial Planning, for a national provider of training for cave guides is anticipated in Slovenia. As manager of the Postojna Cave, we are one of the most serious candidates. We believe that our experience, knowledge and skills – in one word, competence, which is based on our nearly 200-year-old tourist tradition, are a good basis for the development of an international centre for training cave guides.

References

Carter, J.: *A Sense of Place, An interpretive planning handbook*; Scottish Natural Heritage; available at http://www.scotinterpnet.org.uk/, dated 16 July 2010

Cvetko, R. 1999: *Razvijanje delovne kariere (Developing a Job Career);* Koper: Scientific-Research Centre of the Republic of Slovenia; Ljubljana: Faculty of Social Sciences.

Černigoj-Sadar, N. (2008): *Kariera: Konceptualna* izhodišča (Career: A Conceptual Starting point). Reading material for lectures on the theme of Career Planning and Career Guidance; Faculty of Social Sciences, Ljubljana

Česnik, M. (2006): *Načrtovanje in razvoj kariere v organizaciji (Designing and developing a career within an organization);* A diploma thesis; Faculty of Social Sciences, Ljubljana

Greenhaus, Jeffrey K. (2002): Career Management. The Dryden Press Series in Management

Kohont, A. 2005: *Kompetenčni profili slovenskih strokovnjakov za upravljanje človeških virov. (Competence profiles of Slovenian experts in human resource management);* An MSc dissertation; Ljubljana: Faculty of Social Sciences.

Keršič – Svetel, M.: *Interpretacije žive dediščine podzemnih jam (Interpretations of the Living Heritage of Underground Caves);* A lecture at professional consultation entitled Biodiversity and interpretation, Postojna, 14 April 2010

Annual Report for 2008: Turizem Kras d.d.: Postojna

Annual Report for 2009: Turizem Kras d.d: Postojna

Pavlin, S. 2007: *Vpliv tihega in izraženega znanja na profesionalizacijo poklicev (The impact of silent and expressed knowledge on the professionalization of occupations)*; A doctoral dissertation; Ljubljana: Faculty of Social Sciences.

Racio Razvoj (2008): *Priročnik za uporabo kompetenc(Manual for Using Competences),* Turizem KRAS d. d. Postojna

Tilden, F. (1957) *Interpreting Our Heritage.* University of North Carolina Press, North Carolina

THE NEW ELECTRICAL SYSTEM OF THE GROTTA GIGANTE: COMPLIANCE WITH THE LAWS IN FORCE AND LIGHTING STUDY THE GROTTA GIGANTE AS A TOURIST AND SCIENTIFIC CENTRE

Alessio Fabbricatore

Grotta Gigante, Società Alpina delle Giulie – sezione di Trieste del Club Alpino Italiano, Borgo Grotta Gigante 42/A, I-34010 Sgonico (TS), Italy

Abstract: The *Grotta Gigante*, which opens into the Mesozoic limestone, is a large cave, and the only one to be open to the public among the caves of the Trieste Karst and it has always been an object of scientific study. The important union of tourism and scientific research made it possible for the *Grotta Gigante* to be constantly monitored in order to ensure ecocompatibility between the flow of tourists and the delicate underground environment of the cave.
In December 2005 the new *Visitors reception centre of the Grotta Gigante* was inaugurated: a multipurpose building which blends in with the surrounding karstic environment. It was deemed necessary to replace the electrical and lighting systems, in accordance with the laws in force, and to ensure the cave's full compliance with safety measures. These measures were taken in order to ensure the safety of both the staff and the visitors, as well as to enhance the natural beauty of the *Grotta Gigante*, thanks to an appropriate lighting system.
The new electrical system takes into account the reduction of operating costs, by reducing energy consumption, and at the same time the importance of the spectacular effect, by emphasizing the concretions and natural colours of the cave. The paths open to the public are provided with luminous bodies fitted to special supports for emergency and safety lighting and these emergency lamps are connected to a specific uninterruptible power supply exclusively dedicated to this circuit.
A new audio system was installed and a radio transmission network (Motorola), provided with an auxiliary relay, was chosen, in order to be able to communicate from anywhere inside the cave with the external operator or vice versa.

Keywords: Karst, Grotta Gigante, Trieste, giant cave, pendulums

The *Grotta Gigante* (Jama v Briščikih – Riesengrotte) is situated in the municipality of Sgonico, province of Trieste, in north-east Italy: lat 45°42'34" Nord-long 13°45'54" East.

The *Grotta Gigante*, which opens into the Mesozoic limestone, is a large cave, and the only one to be open to the public among the caves of the Trieste Karst. Its central cave entered the Guinness Book of Records in 1995 as the largest show cave in the world. The cave is 107 metres high and 130 metres wide, and has a volume of 600,000 m^3. The first documented mention of the Grotta Gigante dates back to 1851. The Grotta was opened to the public in 1908 by the Club Touristi Triestini (Trieste tourist club). Due to the new political climate, in 1922 the *Club touristi triestini* was forced to sell the *Grotta Gigante* to the *Società Alpina delle Giulie sezione di Trieste del Club alpino italiano* (The Julian Alps Association, division of Trieste of the Italian Alpine Club). At that time the Società Alpina delle Giulie also came into possession of other caves in the province of Trieste, which used to belong to the Alpenverein and the Planinsko Društvo (*San Canziano, Corgnale, Sottocorona, Grotta del fumo*).

After the Second World War, the *Commissione Grotte Eugenio Boegan* (Eugenio Boegan Cave Commission) of the Società Alpina delle Giulie took charge of the *Grotta Gigante*. The structure was reinforced and a new acetylene lighting system was installed.

Fig. 1. The new Visitors reception centre of the Grotta Gigante. Photo: A. Fabbricatore

Fig. 2. The new Visitors reception centre of the Grotta Gigante by night. Photo: A. Fabbricatore

Between 1957 and 1963 two buildings were built, one for the ticket office and the other for the Speleological Museum, the first museum of this kind in Italy. Thanks to substantial modernization and maintenance work, which was concluded in 1996, the number of visitors increased considerably, reaching 70,000 – 80,000 visitors per year, with a few peaks of 100,000 annual visitors.

Later on, in December 2005, the new *Visitors reception centre of the Grotta Gigante* was inaugurated, a multipurpose building which blends in with the surrounding karstic environment.

The Grotta Gigante, with its seventy thousand annual visitors, is the second tourist centre in the province of Trieste and one of the first in the Friuli Venezia Giulia region.

Almost half of the seventy thousand annual visitors consists of students from schools of all kinds and levels, from preschool to university, for whom special educational programmes have been conceived in order for them to make the most of their visit to the *Grotta Gigante*.

The *Grotta Gigante* is a very important centre of scientific research. Inside the cave, *pendulums,* i.e. sensitive instruments able to detect the movements of the earth's crust, were installed. The *pendulums* provide a unique historical series of continuous measurements of the deformation of the earth's crust. These measurements are carried out by the *Department of Earth Sciences of the University of Trieste* and the National *Institute of Geophysics and Volcanology*. Inside the cave you can also find the digital, broad band *Seismographic Station* run by the *National Institute of Oceanography and Experimental Geophysics* and the *Department of Geosciences of the University of Trieste*, thanks to a cooperation agreement. Outside the *Grotta Gigante,* in the surrounding green area, you can find the *Climatological Observatory of the Karst* and the *Epigean station for the measurement of karstic dissolution*.

The *Climatological Observatory of the Karst*, which has been operating since 1966, is part of the regional meteorological network of Friuli Venezia Giulia and the Trans-European network. The traditional mechanical instruments have been complemented by a new-generation, electronic meteorological station equipped with GPRS data transmission and real time data display on the Web and on the maxi screen in the waiting room of the *Visitors reception centre*.

The *Epigean station for the measurement of karstic dissolution*, which has been operating since 1979, investigates the extent of the lowering of calcareous rock surfaces due to meteoric water. Measurements are taken in accordance with the *Department of Geosciences of the University of Trieste.*

It is also worth mentioning the studies concerning *radiography*, by means of cosmic rays, for the *Chooz experiment,* which a *Muon radiography* of the *Grotta Gigante* made it possible*,* i.e. the reconstruction of the shape of the cave's vault from the measurements of the flow of cosmic rays coming from various directions, which were compared with available geological data. The radiography was carried out thanks to the collaboration between the *National Institute of Oceanography and Experimental Geophysics* and the *National Institute of Nuclear Physics*.

We should not forget the archaeological studies carried out by the *Environmental, Architectural, Archaeological, Artistic and Historical Heritage Office* of the Friuli Venezia Giulia region and by the *Dipartimento di Storia e Culture dall'antichità al Mondo Contemporaneo of the University of Trieste*. They show that the cave was used from the Neolithic Age to the Early or Middle Bronze Age, the palaeontological studies carried out by the *Municipal Natural History Museum* of Trieste and the biology stations (underground fauna and flora, i.e. *Lampenflora*), thanks to the collaboration between the *Municipal Natural History Museum* and the *University of Trieste*.

The *Agenzia regionale per la protezione dell'ambiente* (*Regional agency for the protection of the environment*), with reference to the measurements of radon in the *Grotta Gigante*, in compliance with legislative decree no. 241/00, drew up the final technical report which includes the results of the measurements taken on the tourist pathway. According to this report "the action level does not exceed the limits fixed by the above-mentioned decree".

The important union of tourism and scientific research made it possible for the *Grotta Gigante* to be constantly monitored in order to ensure ecocompatibility between the flow of tourists and the delicate underground environment of the cave.

Radon monitoring. The *Agenzia regionale per la protezione dell'ambiente (Regional agency for the protection of the environment*), with reference to the measurements of radon in the *Grotta Gigante*, in compliance with legislative decree no. 241/00, drew up the final technical report which includes the results of the measurements taken on the tourist pathway. According to this report "the action level does not exceed the limits fixed by the above-mentioned decree".

THE NEW ELECTRICAL SYSTEM OF THE GROTTA GIGANTE: COMPLIANCE WITH THE LAWS IN FORCE AND LIGHTING STUDY (PROJECT BY *ARCHITECT ALESSIO FABBRICATORE*)

In December 2005, the new *Visitors reception centre of the Grotta Gigante* was inaugurated and it was deemed necessary to replace the electrical and lighting systems, in accordance with the laws in force, and to ensure the cave's full compliance with safety measures for the following reasons: due to the tourism potential of the *Grotta Gigante*, which has become a fixed point of reference for tourists visiting Trieste and its surroundings and an important attraction for the many tourist groups, both Italian and foreign, visiting the region; and due to the cultural value of the cave, attested by the trips organised by schools of all kinds and levels coming from all over Italy.

These measures were taken in order to ensure the safety of both the staff and the visitors of the cave, as well as to enhance the natural beauty of the Grotta Gigante, *thanks to an appropriate lighting system*

It is to note that the first electrical lighting system was carried out in 1957 by the *Società alpina delle Giulie sezione di Trieste del Club Alpino Italiano (The Julian Alps Association – division of Trieste of the Italian Alpine Club)* and the cave's original carbide lamps were replaced by an electrical lighting system

Environmental and safety measures

During the work in 2009 for the replacement of the electrical system to comply with the laws in force and to make the existing handrail in the Grotta Gigante safe, all the unused and polluting (non-inert) materials, which had been deposited at the bottom of the cave since it was opened to the public 100 years ago, were cleared and taken to the municipal rubbish dump. This waste mainly consisted of maintenance materials which had not been disposed of, such as the synthetic sheaths covering the pendulum cables (which were deposited at the bottom of the cave), but also of highly polluting wooden elements in the cave (wood causes the development of bacteria and insects, of external origin, which would otherwise not be able to develop). All potentially polluting materials were therefore removed from the *Grotta Gigante*.

As far as staff safety is concerned (guides and administrative staff), a *Document for risk evaluation* was drawn up for the employees of the Società Alpina delle Giulie, owner of the *Grotta Gigante*, and a safety manager was appointed. The *Agenzia regionale per la protezione dell'ambiente* (*Regional agency for the protection of the environment*), with reference to the measurements of radon in the *Grotta Gigante*, in compliance with legislative decree no. 241/00, drew up the final technical report which includes the results of the measurements taken on the tourist pathway. According to this report "the action level does not exceed the limits fixed by the above-mentioned decree".

General features of the electrical system

The existing electrical power supply is *Low Tension*; with reference to the neutral state, the system is a TT, three-phase, 400 V, 50 Hz system, with a subscribed demand of 70 kW. The origin of the electrical installation is slightly downstream of the electrical power supply point of the distributing company (ENEL), inside a concrete box near the cave's entrance. Inside this box you can also find the utility main switch equipped with an emergency release coil, to which the main riser, which consists of FG7 cables, is connected, and takes up to the main utility switchboard, which is located in a special technical room in the basement of the *Visitors reception centre of the Grotta Gigante*. This switchboard is equipped with special protections for the entire electrical system, which is divided into two main areas, one for the circuits relating to the *Visitors reception centre* and the other one for the circuits relating to the cave. The electrical system is entirely protected by an uninterruptible power supply, always *on-line*, located next to the main switchboard in the same room. It is also protected by a diesel generating set, in a separate room, for emergency use in the event of unavoidable malfunctioning or black-outs of the system. The earthing system consists of a 50 mm^2-section bare copper wire connected to the reinforcing bars of the foundation plinths of the *Visitors reception centre* building. This wire is connected to the main earthing terminal within the main utility switchboard, from which the various protective conductors, with the same section as phase conductors, are distributed to the circuits.

Replacement of the electrical system

The former electrical system inside the cave was the result of all sorts of work, with no overall plan, carried out to satisfy the needs that had occurred over the years. The functioning of the system was guaranteed by ordinary and extraordinary maintenance operations.

The above-mentioned electrical system was divided into four parts:

1. regular lighting;
2. emergency lighting provided with self-powered lamps and generating set for regular lighting;
3. utility outlets;
4. signalling systems for staff communication.

The former electrical system did not comply with the law and, what is more, was obsolete in terms of energy saving and lighting performance, which made it extremely difficult for the visitors to appreciate the special features of the cave, with a consequent loss of interest on their part.

The new electrical system takes into account the reduction of operating costs, by reducing energy consumption, and at the same time the importance of the spectacular effect, by emphasizing the concretions and natural colours of the cave.

On the occasion of the building of the new *Visitors reception centre of the Grotta Gigante*, and upon request for an increase in the power supply (70 kW), the Società Alpina delle Giulie disposed of the existing generating set, which was no longer reliable, and bought a new one with appropriate electrical features (50 kVA), in order to coordinate its functioning with the new uninterruptible power supply. The combined functioning of these two equipments enables the entire electrical system (in the cave and the *Visitors reception centre*), except for the conditioning system in the *Visitors centre*, to continue working under any conditions, preventing any interruption in power supply. This operation also aimed at protecting the scientific equipment inside the cave, used by the University of Trieste (pendulums) and by the Experimental Geophysics Observatory (seismograph), and outside the *Visitors centre* (meteorological station).

Upon request for the official certification of the earthing system (in compliance with the laws in force) to the A.S.S. of Trieste (the Local Health Authority), and in particular to the *Servizio verifiche periodiche (Periodical check service)*, an inspection of the system was made by the person in charge, who drew up a report stating that, as regards the use of the *Grotta Gigante* for guided tours and art shows and the use of the other *premises*, it is a "...place of public show and entertainment in compliance with the IEC regulation no. 64-8/7, paragraph 752.2.".

As a consequence, the criteria for the replacement of the above-mentioned electrical system were defined and the following operations were carried out:

a) Exactly defining and renaming the devices relating to the circuit of the cave within the Switchboard of the *Visitors Reception Centre,* in order to be able to identify the relative downstream circuits.

b) Checking the mechanical and electrical features of the existing main supply cable (riser), and measuring the isolation voltage, referring to its junction box as well. The above-mentioned riser is a multicore cable with a 70 mm^2-section, ensuring the voltage drop maximum value, which is 4 %, it has a 380 V voltage and supplies power to the newly-installed section switchboards.

c) Installing the section switchboards (Q1, ..., Q6), which consist of watertight boxes, suitable for their laying position and for housing the protection devices of the various downstream circuits and of the terminal boards for the branch connection from the main riser.

d) Installing different types of luminous bodies, with different optics according to the *object* or the *scene* to be lit up, provided with lamps characterized by different power and colour temperature in order to emphasize the natural beauty of the cave.

Description of the luminous bodies

1. Double insulated symmetric rhodium 3 (HPS-T 250W). Body without frame: in pressure die-cast aluminium, with cooling fin. Reflector: symmetric, in hammered 99.85 aluminium, anodized, 3-micron thick and polished. Diffuser: 5 mm tempered glass, thermal shock and impact resistant (UNI EN 12150 tests – 1:2001). Coating: polyester powder painting in graphite grey, corrosion and salt spray resistant. Lamp holder: in ceramic with silver contacts. Wiring: 230V/50Hz supply with thermal protection. Flexible wire with tinned brass terminals, insulated with fibreglass braid, 1 mm^2 section. 2P+T terminal board with a maximum conductor section of 4 mm^2. Equipment: silicone rubber gasket. Fibreglass nylon cable gland, ½ inch gas diameter. Anticorrosion and antiseizing steel captive screws. Steel bracket with protractor scale. The front glass opens on hinges without the use of tools and stays attached to the body of the appliance. Provided with air recirculation valve. Locking devices in AISA316L steel with safety screw. Regulations: produced in compliance with the EN60598 – IEC 34 – 21 regulations. Degree of protection in compliance with the EN60529 regulations. HPS-T 250W. *Master CityWhite CDO-TT* metal halide discharge lamp with E40 fitting, colour temperature 2,800 K.

2. Double insulated asymmetric rhodium 3 (HPS-T 250W). Body without frame: in pressure die-cast aluminium, with cooling fin. Reflector: asymmetric, in hammered 99.85 aluminium, anodized, 3-micron thick and polished. Diffuser: 5 mm tempered glass, thermal shock and impact resistant (UNI EN 12150 tests – 1:2001). Coating: polyester powder painting in graphite grey, corrosion and salt spray resistant. Lamp holder: in ceramic with silver contacts. Wiring: 230V/50Hz supply with thermal protection. Flexible wire with tinned brass terminals, insulated with fibreglass braid, 1 mm^2 section. 2P+T terminal board with a maximum conductor section of 4 mm^2. Equipment: silicone rubber gasket. Fibreglass nylon cable gland. ½ inch gas diameter. Anticorrosion and antiseizing steel captive screws. Steel bracket with protractor scale. The front glass opens on hinges without the use of tools and stays attached to the body of the appliance. Provided with air recirculation valve. Locking devices in AISA316L steel with safety screw. Regulations: produced in compliance with the EN60598 – IEC 34 – 21 regulations. Degree of protection in compliance with the EN60529 regulations. HPS-T 250W. Master CityWhite CDO-TT metal halide discharge lamp with E40 fitting, colour temperature 2,800 K.

3. Maxiwoody (iGuzzini). Pressure die-cast aluminium floodlight, coated with liquid acrylic paint. Super-pure aluminium reflector. MasterColour CDM-T 250W discharge lamp, with *E40* fitting, colour temperature 3,000 K. Spot light distribution (*spot optics*). The floodlight can be adjusted vertically by means of a painted steel bracket, provided with a graduated scale with a 10° pitch and with mechanical locking devices which ensure the correct orientation of the light beam, and horizontally by means of a hot-dip galvanized painted plate to fix it to the ground. The technical features of the appliances comply with the EN60598-1 regulations and specific requirements. IP67 IK08. F mark. IMQ-ENEC certification. IMQ Performance. Protection class II.

4. Platea (iGuzzini) 10° super-spot aluminium floodlight. Super-pure aluminium reflector. 10° super-spot optics. 250 W power supply, Osram Powerball HCI-T metal halide discharge lamp with E40 fitting, colour temperature 3,000 K. Stainless steel screws. The technical features of the appliances comply with the EN60598-1 regulations and specific requirements. IP66 IK04/08. F mark. IMQ-ENEC certification. IMQ Performance. Protection class II. The appliance complies with the requirements of the UNI 10819 regulations, zone 1 (light pollution).

5. Miniwoody (iGuzzini). Floodlight with base and built-in electronic power supply. Designed for the use of discharge light sources. Composed of an optical unit and a support. Aluminium alloy optical unit, arm, base and frame. Optical unit connected to the components' unit by means of a silicone armoured cable with protection steel plait. M14X1 nickel-plated brass cable gland connecting the wiring unit to the lamp unit. Reflector made of annealed 99.96 % super-pure aluminium sheet, which underwent roughening, polishing and 2/4 micron electrochemical anodization treatment. Spot optics and surface partly painted in black. Lamp holder support made of galvanized steel. Polyamide PG11 cable gland. Electronic power supply, MasterColour CDM-Tm Mini 20W metal halide lamp with PGJ5 fitting, colour temperature 3,000 K. Openings on frame for rainwater discharge. All screws are made of A2 stainless steel. The technical features of the appliances comply with the EN60598-1 regulations and specific requirements. IP66 IK08. F mark. IMQ-ENEC certification. IMQ Performance. Protection class I.

6. Woody (iGuzzini). Aluminium alloy optical unit and frame. EN1706AC 46100LF treated with phosphochromatising, double primer, passivation at 120 °C, coated with liquid acrylic paint highly weather- and UV-resistant, baking at 150 °C; spot optics; soda-lime tempered glass cover, transparent, colourless, 4 mm thick, fixed with captive screws; stainless steel safety cable; reflector made of annealed 99.98 % super-pure aluminium sheet, which underwent roughening, polishing and 2-4 micron anodization treatment with a nickel salt fixing bath; aluminium lamp holder support; openings on frame for rainwater discharge; PG11 nickel-plated brass cable gland. Removable component tray, made of hot-dip galvanized EN10142 DX 51D+Z(ZF) steel sheet, which underwent roughening treatment; box and cover in painted EN1706AC 46100LF aluminium alloy; spacers and captive screws; power supply unit provided with anti-explosion power factor correction capacitor, ballast, igniter and fast-connecting terminals. All screws are made of A2 stainless steel. The technical features of the appliances comply with the EN60598-1 regulations and specific requirements. IP66 IK07. F mark. IMQ-ENEC certification. IMQ Performance. Protection class II. MasterColour CDM-T 70W discharge lamp with G12 fitting, colour temperature 3,000 K.

7. Double insulated symmetric rhodium 2 (HPS-T 250W). Body without frame: in pressure die-cast aluminium, with cooling fin. Reflector: symmetric, in hammered 99.85 aluminium, anodized, 3-micron thick and polished. Diffuser: 5 mm tempered glass, thermal shock and impact resistant (UNI EN 12150 tests – 1:2001). Coating: polyester powder painting in graphite grey, corrosion and salt spray resistant. Lamp holder: in ceramic with silver contacts. Wiring: 230V/50Hz power supply with thermal protection. Flexible wire with tinned brass terminals, insulated with fibreglass braid, 1 mm^2 section. 2P+T terminal board with a maximum conductor section of 4 mm^2. Equipment: silicone rubber gasket. Fibreglass nylon cable gland, ½ inch gas diameter. Anticorrosion and antiseizing steel captive screws. Steel bracket with protractor scale. The front glass opens on hinges without the use of tools and stays attached to the body of the appliance. Provided with air recirculation valve. Locking devices in AISA316L steel with safety screw. Regulations: produced in compliance with the EN60598 – IEC 34 – 21 regulations. Degree of protection in compliance with the EN60529 regulations. HPS-T 250W. MasterColour metal halide discharge lamp with Rx7s fitting, colour temperature 3,000.

8. Double insulated asymmetric rhodium 2 (HPS-T 250W). Body without frame: in pressure die-cast aluminium, with cooling fin. Reflector: asymmetric, in hammered 99.85 aluminium, anodized, 3-micron thick and polished. Diffuser: 5 mm tempered glass, thermal shock and impact resistant (UNI EN 12150 tests – 1:2001). Coating: polyester powder painting in graphite grey, corrosion and salt spray resistant. Lamp holder: in ceramic with silver contacts. Wiring: 230V/50Hz power supply with thermal protection. Flexible wire with tinned brass terminals, insulated with fibreglass braid, 1 mm^2 section. 2P+T terminal board with a maximum conductor section of 4 mm^2. Equipment: silicone rubber gasket. Fibreglass nylon cable gland, ½ inch gas diameter. Anticorrosion and antiseizing steel captive screws. Steel bracket with protractor scale. The front glass opens on hinges without the use of tools and stays attached to the body of the appliance. Provided with air recirculation valve. Locking devices in AISA316L steel with safety screw. Regulations: produced in compliance with the EN60598 – IEC 34 – 21 regulations. Degree of protection in compliance with the EN60529 regulations. HPS-T 250W. MasterColour metal halide discharge lamp with Rx7s fitting, colour temperature 3,000.

e) The luminous bodies are fitted to special supports for emergency and safety lighting of all the cave's pathways open to the public and are on "always ON" mode, thereby ensuring a minimum light of 5 lux on the steps and 3 lux on the level. These emergency lamps are connected to a specific uninterruptible power supply exclusively dedicated to this circuit. The emergency lighting panel (Q0) and the relative uninterruptible power supply are located in a box at the bottom of the cave.

Security lamps

1. Glim Cube (iGuzzini) (wall lamp with a 3-LED electronic transformer). Wall lighting device designed for the use of LED light sources composed of a screen and a support base. Polymethyl methacrylate ribbed screen, support base in pressure die-cast aluminium, catch plate in stainless steel and grains M5x10; stainless steel PG11 cable gland; power supply unit provided with a 3W – 350 mA electronic power supply. All screws are made of A2 stainless steel. The technical features of the appliances comply with the EN60598-1 regulations and specific requirements. IP66. IMQ-ENEC certification. Protection class II. 322 *Glim Cube* lamps were fitted, 305 of which in the cave and 17 on the exit pathway.

2. Fluorescent lamps. Luminous body provided with a base to be fitted on a low wall, 14W fluorescent lamp, *Warm White* light, equipped with anti-glare screen. 19 lamps were fitted in the artificial tunnel.

Lampenflora

The development of *Lampenflora* (algae, moss, cyanobacteria and other opportunistic plants) is induced by the lights in show caves. These photosynthetic species can seriously damage the underground ecosystems.

In order to ensure the appreciation of the cave and to minimize the ecological and aesthetic impact, the *Grotta Gigante* was mainly lit by MasterColor metal halide lamps, with a colour temperature of 3,000 K.

Furthermore, after thorough research and after checking market availability, it was deemed necessary to use auxiliary germicidal lamps, provided with an electronic starter, like the TUV Xtra 36W fluorescent tubes produced by *Philips*, which obtained the *2008 Green certificate* (Photo 3), in order to inhibit the development of *Lampenflora* and to ensure an environmentally-friendly use of the cave.

23 double ceiling lights, like the AISI 316 2X36 W, and 5 single ceiling lights, like the AISI 316 1X36 W, were fitted. Both types are provided with an electronic ballast and made of tempered glass. These lamps, whose use aims at keeping the development of *Lampenflora* under control, turn on when all the other lights in the cave are turned off.

Digital amplification system (en 60849 certification)

A new audio amplification system was installed, in compliance with the IEC 60849 requirements, and divided into two racks, one inside the cave, provided with all the power amplifiers, and the other outside the cave, with the control station, its sources and a microphone for general announcements, connected to a ring optical fibre system, to ensure the functioning of the system in case of an interruption on the system cable.

There are three positions for guided tours, and thanks to a local keyboard it is possible to deliver a descriptive message in the desired language. It is also possible to use radio microphones inside the cave for conferences and other events.

The loudspeakers were chosen after a series of tests carried out inside the cave by means of acoustic instruments, and are produced by the well-known German company "LB LAUTSPRECHER", which carried out a suitable customization for use in a difficult environment, such as a cave.

At the end of each line of loudspeakers an electronic card communicates the correct functioning of the system to the control station. In the event of a failure, a LED flashes on the microphone station and an alarm beep warns the operator. Furthermore, in the event of a failure of one of the amplifiers, a back-up amplifier comes into operation, thereby ensuring the correct functioning of the system.

Radio communication system

As regards communication between the inside of the cave and the fixed listening position, located in the ticket office of the *Grotta Gigante,* a radio transmission network (*Motorola*), provided with an auxiliary relay, was chosen, in order to be able to communicate from anywhere inside the cave with the external operator or vice versa.

The *Motorola* radio system, characterised by DMR technology, consists of:

a. 1 *Motorola DM3000* relay station, located in a watertight steel cabinet and provided with a 20W heater, power supply system and antenna splitter;

b. 1 internal/external antenna system composed of a Uhf RF330NZ omnidirectional antenna and a Uhf RF611NZ directional antenna;

c. 1 *Motorola DM3600* base station to be installed at the ticket office counter and equipped with power supply, buffer battery, microphone and internal antenna;

d. 6 *Motorola DP3601* portable radios equipped with battery, antenna, belt clip and battery charger.

This radio system has been designed for communicating inside the cave and for emergency use. For standard conversations operators can talk to each other from one portable radio to another and with the base station, by simply pressing the PTT button on their portable radio or on the base station. All portable devices have an orange button on the upper part of the radio: in the event of an emergency, by pressing this button a fixed transmission cycle is activated and for 15 seconds the operator is able to voice-communicate his/her position and to explain the reason for the emergency to the other devices and to the base station. After 15 seconds the radio resets and the base station and the other portable radios will be able to communicate with the operator who signalled the emergency. The portable devices are also provided with a *man down* function which automatically sends an emergency call when the portable radio is kept in a non-vertical position.

Scientific installation

The power-supplied scientific instruments (the University pendulums and the O.G.S. seismograph) are protected with special differential thermal-magnetic devices. Furthermore, 2 divisional metering devices for consumption meter reading were installed.

Temperature monitor

Inside the *Grotta Gigante* a temperature sensor was installed. The data relating to this sensor are displayed on the maxi screen, which is also used for meteorological data, located in the waiting room of the *Visitors reception centre*. The temperature sensor used in the cave consists of a Pt100 platinum thermal-resistance element with a response curve in compliance with DIN 43760 regulations, class 1/3. The transducer belongs to the category of intelligent sensors since it is equipped with an internal microprocessor which checks the correct functioning and also has data pre-processing and A/D electric signal conversion functions and so on. These features guarantee highly accurate and reliable data. The transducer complies with the European EMC standards, is protected against overvoltage and fully complies with the WMO (World Meteorological Organisation) requirements.

Consumption

As well as considerably improving the cave lighting and installing safe equipment, the electrical system's energy consumption was certainly reduced, by sizing the distribution cables of the various circuits and the protection devices with back-up function, whose section was increate. The main switchboard, located in a special technical room in the basement of the *Visitors centre,* is provided with special equipment for the measurement of power parameters, in particular *voltage* and *current*, which can be checked at any time. The average absorption of electricity amounts to 45 A, which means that the resultant active power of the entire electrical system (*Cave* and *Visitors centre*) is almost 50 % lower than it was before the replacement of the system.

Making the existing handrail safe

The steep stairs and aerial pathways which extend throughout the *Grotta Gigante* are provided with handrails which protect visitors from dangerous falls. Most parapets had already been carried out in compliance with the safety measures in force (1 m minimum height and vertical elements at a minimum interaxial distance of 10 cm) and in non-deteriorating and non-polluting material in the cave environment (stainless steel).

36 metres of obsolete parapets were replaced with others of the same kind and material (stainless steel) as the recently installed ones and 6 metres of stainless steel handrail were also installed.

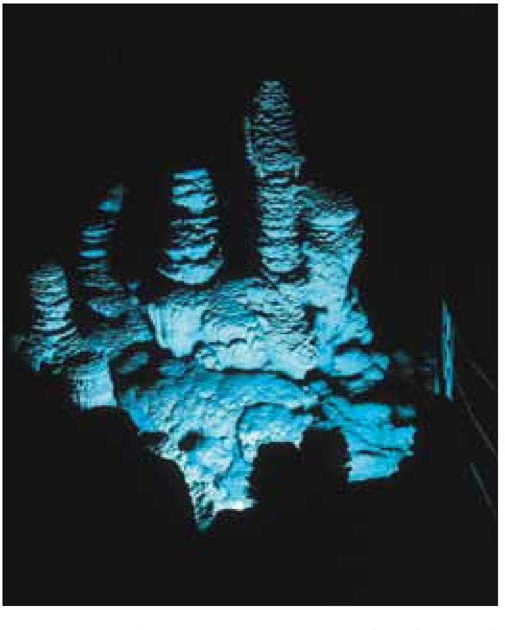


Fig. 3. Speleothems in Grotta Gigante (this photograph was taken thanks to the lighting of the TUV Xtra 36W fluorescent tubes). Photo: A. Fabbricatore

ASSOCIAZIONE GROTTE TURISTICHE ITALIANE (A.G.T.I.)

Alessio Fabbricatore

Associazione Grotte Turistiche Italiane, Grotta Gigante, Borgo Grotta Gigante 42/A, I-34010 Sgonico (TS), Italy

Man's habitual presence in caves does not belong to recent history, in fact man lived in caves for thousands of years, and even when he left them his ancestral relationship with the underground world never really ceased. Evidence of refined artistic skills dating back to the Upper Paleolithic era (fifteen thousand years ago) can be found in the wall paintings found in renowned caves, such as the *Cueva de Altamira* (Spain), discovered in 1879, and the *Grotte Henri Cosquer* (France), discovered in 1991. Ancient Greek mythology, with its myth of Orpheus and Eurydice, which is also mentioned by Plato in his *Convivium* hardly needs to be mentioned. Among the several pagan rites carried out in caves it is worth mentioning the *Mithraic Mysteries*. It was not only pagans who placed the *Underworld* in the bowels of the earth, it is sufficient to mention the *Inferno* by Dante Alighieri.

However these are stories which belong to the past. The use of caves for scientific, exploration and tourist purposes dates back to about 200 years ago and started in the territories which used to belong to the Austrian Empire and the Kingdom of Hungary, whose best-known cave is the Postojnska jama. Today there are thousands of show caves around the world.

In Italy show caves are associated with the *Associazione Grotte Turistiche Italiane – A.G.T.I.* (Italian Show Caves Association), which is a member of the *International Show Caves Association (I.S.C.A.).* Furthermore, Italian scientific and exploration speleology is grouped together either under the *Società Speleologica Italiana – S.S.I.* (Italian Speleological Association) or the *Commissione Speleologica del Club Alpino Italiano – C.A.I.* (Speleological Commission of the Italian Alpine Club), which is in charge of the School for Exploration Technique in particular. The *Corpo Nazionale Soccorso Alpino e Speleologico C.N.S.A.S.* (National Alpine and Speleological Rescue Corps) operates within the *C.A.I.* and rescues injured people both in the mountains and in caves. The *International Union of Speleology* (U.I.S.) is an international body under which all speleological activities are grouped together and which also includes a Commission for the protection of show caves.

WHAT IS THE ASSOCIAZIONE GROTTE TURISTICHE ITALIANE?

The Associazione Grotte Turistiche Italiane – A.G.T.I. (Italian Show Caves Association), founded in 1994, was created to satisfy the need for the operators in this sector to exchange mutual experiences in the management, technical and promotional fields in order to choose the best solutions and thereby discard the ones that had led to negative results.

The main objectives of the A.G.T.I. are:

1. To promote and popularize the main aspects of surface and underground karst phenomena.
2. To analyse all problems directly or indirectly involved in the organization of show caves.
3. To protect the environment of show caves and the surrounding karst sites.
4. To promote an overall image of show caves capable of attracting more and more visitors to the underground world.
5. To continually search for better solutions in order to meet the above-mentioned goals and optimize services offered to visitors.

A.G.T.I. is also a guarantee of quality: not all the caves can join the Association. In order to be accepted they have to meet specific requirements, such as:

- easy and practicable paths to walk along safely, without having to use torches or special clothing,

- an efficient and reliable electrical lighting system,
- correct information on the part of guides,
- taking the necessary precautions to preserve the environment,
- precise opening hours and periods in order to ensure that visits are carried out according to schedule.

THE ASSOCIATION HAS 24 MEMBERS, 16 OF WHICH ARE MEMBERS OF THE I.S.C.A., WHICH MEANS THAT 20 % OF THE I.S.C.A. MEMBERS COME FROM ITALY.

Every year over one million people from all over the world come to visit the caves which belong to the Association. All the best-known caves in Italy are members of the A.G.T.I.

The architect Alessio Fabbricatore, who is also the director of the Grotta Gigante, has been the president of A.G.T.I. since 2009.

In August 2010 A.G.T.I. introduced a bill before the Italian Parliament for the development of tourism in caves and the rearrangement of some legal aspects concerning Italian show caves.

At the beginning of 2010 the new brochure was printed, in which you can find a description of each A.G.T.I. cave member. The website has been completely renewed and many foreign languages will be introduced: www.grotteturistiche.it

After the last general assembly (September 2010) a Special Commission headed by Alessio Fabbricatore was established in order to organize a national school for the certification of tour guides for Italian show caves. The general assembly decided that all A.G.T.I. show cave guides must wear a high-visibility jacket during cave visits in order to be easily recognized by visitors.

A.G.T.I. also decided to organize a "Bat Weekly" every year in order to arouse people's and institutions' interest in the fact that there are fewer and fewer bats in Italy. The zoologists from the Natural History Museum of the University of Florence (Italy) designed a special artificial roost, the bat box, to give shelter to the most common bat species in our towns during the summer time. A.G.T.I. would like to suggest that a "Bat weekly" be organized not only by Italian caves but also by other I.S.C.A. caves.

Special reductions

Visitors who have already visited an A.G.T.I. cave are entitled to a reduction. Don't forget to keep the ticket: you will be given a special discount on your visit to the next cave!

A.G.T.I. Members

Grotte di Oliero (Valstagna – Vicenza)
Grotta Gigante (Sgonico – Trieste)
Grotta di Bossea (Frabosa Soprana – Cuneo)
Grotte di Toirano (Tirano – Savona)
Grotte di Borgio Verezzi (Borgio Verezzi – Savona)
Grotte Antro del Corchia (Levigliani – Lucca)
Grotta del Vento (Vergemoli – Lucca)
Grotte di Frasassi (San Vittore di Genga – Ancona)
Grotta del Cavallone (Lama dei Peligni – Taranta Peligna – Chieti)
Grotte di Val de' Varri (Pescorocchiano – Rieti)
Grotta di Collepardo (Collepardo – Frosinone)
Grotte di Pastena (Pastena – Frosinone)
Grotte di Castelcivita (Castelcivita – Salerno)
Grotte dell'Angelo (Pertosa – Salerno)
Grotta di Santa Croce (Bisceglie – Bari)
Grotte di Castellana (Castellana Grotte – Bari)
Grotta Zinzulusa (Castro Marina – Lecce)
Grotta di Nettuno (Alghero – Sassari)

Grotta di Ispinigoli (Dorgali – Nuoro)
Grotte del Bue Marino (Dorgali – Nuoro)
Grotta del Fico (Baunei – Ogliastra)
Grotta Su Marmuri (Ulassai – Ogliastra)
Grotte di Su Mannau (Fluminimaggiore – Cagliari)
Grotte Is Zuddas (Santadi – Cagliari)

Board of Governors

President: *Alessio Fabbricatore* – Grotta Gigante (Trieste)
Vice-president: *Maurizio Pace* – Grotte di Castellana (Bari)

Councillors
Emiliano Babboni – Grotte Antro del Corchia (Lucca)
Claudio Calzoni – Grotta del Fico (Ogliastra)
Francescantonio D'Orilia – Grotte dell'Angelo a Pertosa (Salerno)
Elio Berardino Ginnetti – Val de Varri (Rieti)
Vittorio Verole Bozzello – Grotta del Vento (Lucca)

Auditors
Barozzi Gabriella – Grotte di Borgio Verezzi (Savona)
Virgilio Gay – Grotte dell'Angelo a Pertosa (Salerno)
Giulia Monaco – Grotte di Castellana (Bari)

Arbitrators
Fabio Forti – karst expert, "Eugenio Boegan" Cave Commission of the Società Alpina delle Giulie, sezione di Trieste del Club alpino italiano.
Peter Štefin – past vice-president of I.S.C.A., Postojnska jama (Slovenia)

Contact: info@grotteturistiche.it
Secretary's Office:
Associazione Grotte Turistiche Italiane (A.G.T.I.)
c/o Grotta Gigante
Borgo Grotta Gigante, 42/A
I-34010 Sgonico (TS)
Italy

RADON CONCENTRATION TREND IN A TOURIST CAVE (GROTTA GIGANTE, NORTH-EAST ITALY)

Alessio Fabbricatore[1], Massimo Garavaglia[2], Concetta Giovani[2], Luca Piccini[2], Franco Cucchi[3], Luca Zini[3]

[1] *Grotta Gigante, Società Alpina delle Giulie – sezione di Trieste del Club Alpino Italiano, Borgo Grotta Gigante 42/A, I-34010 Sgonico (TS), Italy*
[2] *Friuli Venezia Giulia Regional Agency of Environmental Protection, Italy*
[3] *Geosciences Department, Trieste University, Italy*

Elevated concentrations of Rn-222 have been recorded in many limestone caves throughout the world. In some cases it represents an impact and risk for those who work in caves and it is necessary to estimate the safety level for workers. In any case it is interesting to study the spatial distribution and time variation of radon concentration inside caves.

A study was carried out in the Grotta Gigante, a very large tourist cave near Trieste (North-East Italy), for over one year. After a first study which excluded risks for workers and visitors, a more detailed study was performed to analyze the distribution of radon concentrations in the different parts of the cave and observe the trend over the year. Different kinds of measurements were performed: short-term measurements by E-Perm electrets to study radon concentration distribution in the cave and long-term measurements by active RAD-7 instruments to study the radon concentration trend over the year and any correlation of radon concentration with the internal and external temperature of the cave and other parameters. Radon concentrations over 20,000 Bq.m^{-3} were measured in summer in a non-tourist part of the cave. In the same site radon concentrations below 100 Bq.m^{-3} were recorded during colder seasons.

Radon monitoring is a worldwide problem. In Italy radon monitoring must be carried out by law in schools and public and private offices, as radon may represent a danger for public health.

In Italy the law provides that the rate must not exceed 400 becquerels pro cubic meter in workplaces, and if radon exceeds allowed levels workers should undergo particular medical check-ups.

As the Grotta Gigante is a workplace, we began monitoring radon and the Agenzia regionale per la protezione dell' ambiente (Regional agency for the protection of the environment), in compliance with the Italian law, drew up the final technical report, which includes the results of the measurements taken on the tourist pathway. Radon levels do not exceed the limits imposed by the Italian law, that is to say 400 becquerels.

At the same time we decided to continue the survey in collaboration with ARPA (Regional agency for the protection of the environment), Grotta Gigante and the University of Trieste.

The survey gave surprising results: a high peak of 20,000 becquerels was detected, and the day after the value dropped to zero.

It is to be noticed that the value was detected in a closed gallery, very close to the surface, where tourists and staff never go.

Therefore, the cause of these anomalous values is currently under investigation, as well as a correlation with the data of the official weather station of the Regional agency for the protection of the environment outside the cave (the outside data storage dates back to 40 years ago).

Data, both in the outside and the underground station, are collected and recorded every 15 minutes (temperature, barometric pressure). So we want to investigate whether there is a correlation between the data of the climatological and meteorological station and the values of radon, considering that the best parameters for the monitoring of radon are the meteorological ones.

Besides, this high value does not imply special medical examinations for the staff since it has been detected from time to time and the normal average is below 400 becquerels, and for the same reason there is no problem for visitors.

WISKI – A WORLD WIDE USED ENVIRONMENTAL MONITORING SYSTEM

Robert Gál

KISTERS AG, Charlottenburger Allee 5, 52068 Aachen, Germany; robert.gal@kisters.de

Abstract: WISKI 7 is the latest version of a, since now more than 20 years experienced information management system, that provides modern tools for advanced analysis of environmental monitoring data. It is based on the KISTERS Time Series Management core solution, which brings together solutions for all actual requirements of modern environmental monitoring with its quantitative and qualitative parameters. The modular system includes data acquisition, storage management, data analysis and computation, data exchange, data presentation including spatial projection, web publishing and alarm management.

Keywords: environmental monitoring, hydrology, water quality, air quality, information management systems, WISKI, TSM, GIS

INTRODUCTION

The management of water as natural resources is one of the central challenges of our generation, and how we act today has consequences for all future generations. System states and changes must be traceable, and decisions must be based on facts for future verifiability. The general task is to transfer the natural world and its dynamics into a world of data points which can be recalled, transferred, validated and stored in periodic intervals.

In many technical and commercial software systems, it is necessary to acquire process and archive mass data in the form of time series. In addition to many specialist technical aspects, rapid processing and quick data access are of the utmost importance. These demands call for specific software solutions, which up until now were typically developed independently for each application.

WISKI 7 INFORMATION MANAGEMENT SYSTEM

The Water Management Information System WISKI with its newest version 7 brings together solutions for all actual requirements of modern environmental monitoring, including data acquisition, storage management, data analysis and computation, data exchange, data presentation as a spatial projection or web publishing. WISKI presents a high-performance data management system with broad application flexibility and unlimited scalability combined with security and reliability, state-of-the-art technology and a future proof design. According to the robustness of monitoring system and its requirements for data acquisition and management there are various types of system architecture from simple basic up to complex, redundant system (Fig. 1).

MAIN CHARACTERISTICS

All data as metadata and time series data are stored in a structural relational database. The hierarchical system is based on station concept, which is the core of the WISKI 7 data structure. A station basically consists of a set of metadata that are type-specific and one or many parameters. Each parameter can hold one or more time series. The time series can be linked together with calculation methods. For example in case of the surface water station, is also used to determine the river flow (gauging station). The flow time series is derived from the continuous stage time series through a set of rating curves. The summary statistics for flow are derived from the continuous flow time series.

The core technology, which provides the backbone of key services for water management data processing is called KISTERS Time Series Management (KiTSM). KiTSM is combining interdisciplinary demands on time series processing with regard to mass data capabilities, scalability, modular design and flexibility to work in diverse specialist areas, high level of automation, reliability, security, integration potential, broad platform independence, redundancy and resilience.

Standard time series data structure contains time stamp, value, quality and interpolation type. Time interval of time series can be regular or flexible, with possibility to add time offset. Between two points is clearly defined the interpolation type, which could be changed over the time.

All calculations and auto validation routines comprise the organic part of execution system.

Data operations as algorithms, in WISKI terminology called Agents are operating on time series data and their main purpose is to either auto validate time series or derive other time series. Agents are generally triggered on data change events and executed automatically each time the data is accessed (such as by reports, graphs, exports, calculations); with KiTSM time series are also automatically updated in the background.

WISKI 7 as a client application is a strong, modern desktop tool connected to all metadata and time series data. The WISKI7 Explorer is the central window of the application. Key lists and basic data are organised in different hierarchies. Generally time series can be graphed by selecting the time series, setting the time range or displayed also in tables. Environment of graphical view allows providing various types of data corrections, arranging graphical layout and elements as well as print, copy or save the graph (Andjelic *et al.* 2010)

META DATA MANAGEMENT

Meta data are organized in hierarchical structure based on site-station-parameter concept. Site level could be customized as for example administration or geographical unit.

The requirements on Station Meta Data differ from customer to customer. WISKI7 is asked in various Implementation Projects to support regional and local standards. In the past the Meta Data System was extended with customer specific requirements. Because of the experience of more than 20 years in water industries and environmental monitoring, WISKI7 offers a very flexible and configurable Meta Data Management framework.

Set of metadata is configurable by administrators at configuration time. Standard Meta Data fields such as strings, numbers, dates, text fields and check boxes can be associated to any definable station type. More advanced metadata objects such as histories or even key lists can be flexible defined as Additional sta-

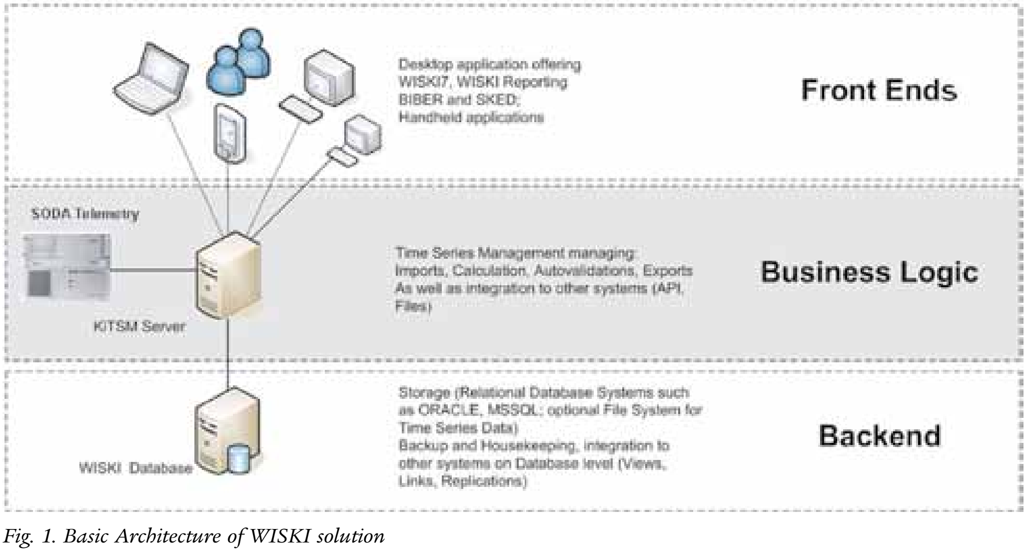


Fig. 1. Basic Architecture of WISKI solution

tion attributes. Metadata attributes are coupled to a station type/characteristic. A station can have multiple characteristics at the same time.

Precipitation, water level, flow, humidity, air temperature, water temperature, wind velocity, etc. are parameter types. Parameter type could be also technical parameters of equipment like e.g. battery voltage or in case of show caves number of visitors. Like other important definitions the parameter types are defined centrally.

KISTERS TSM (TIME SERIES MANAGEMENT)

The KISTERS TSM system is the new shared system core of all KISTERS products where time series are involved. It represents the business layer of a 3-layer architecture, and provides all services necessary for time series management and calculation to applications built upon it.

Data acquisition and integration

In order to support a more integrated approach to environmental data management, a modern monitoring information system has to acquire and store all types of data from a wide range of parameters. Not only the commonly used parameters such as water stage and discharge, but also, for example climate parameters to allow analysis within the same system.

Typical data input sources are remote data acquisition from field data loggers, import of third party data via input files in different formats, read out of field devices, digitisation from graphical charts or manual input using the interactive time series editor.

The import process should be automated as much as possible to free staff resources from manually entering data. The WISKI data acquisition server allows the automatic collection of data from field data loggers. The Import Server can scan directories and import data files, which are saved via the TSM layer into the database. When the user digitises graphical charts, the digitised data is imported automatically afterwards, without user intervention.

Data storage

Due to the complexity of data modelling, WISKI stores data in relational database systems (RDBMS). The storage of recorded or calculated time series data is managed by the central TSM. Additional station information available and other meta data are stored in a separate submodel. As historical data plays a fundamental role in environmental monitoring, one of the greatest challenges is to achieve a high level of performance when dealing with large amounts of measured data; this is a key objective of the developers. Another fundamental aspect is to allow multiple users to work on the same system simultaneously. They can benefit from working on the same data whilst also preventing users from editing the same data at the same time. The TSM data model was developed to deal with large amounts of recorded data. Therefore it has all the necessary functionality to manage time series on such a level. Another important topic is time series classification. One of the major differences found, is the distinction between equidistant data (e.g. 15minute water stage values) and non-equidistant data (e.g. rainfall event, singular observations).

DATA PROCESSING

Data validation

Identifying abnormalities in the data is normally the first step of the validation process. As a result of malfunctioning of field sensors and other devices, or due to the maintenance of those devices, recorded data is likely to have a range of different quality that has to be corrected. To help the user locate data of poor quality, KISTERS TSM has auto validation routines. These routines can be used to apply the organizations' business rules to validate the data using predefined criteria and place remarks for user notification each time one of the criteria is violated. Examples of these quality controls are identification of gaps, maximum/minimum exceedance of thresholds, variations from to neighbouring stations or other user defined formulas and rules.

Data editing

The stored data can be accessed through the graphical user interface (GUI) of the WISKI workbench (Fig. 2). The WISKI workbench client is developed for MS-Windows platforms. Therefore, WISKI has a modern interactive graphical time series editor, to allow graphical editing of time series. Following the data flow through the system, WISKI is able to deliver the following processes and functionalities.

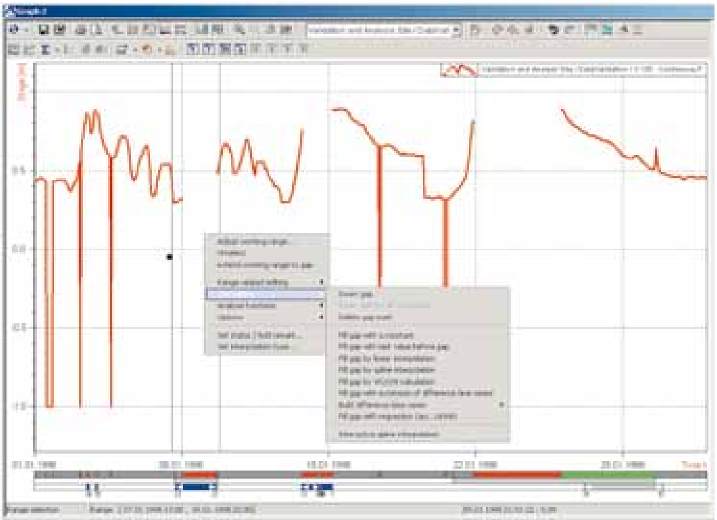


Fig. 2. Interactive Data Editing and Validation in Graph

Data correction

For editing purposes, WISKI provides efficient data editing functionality using an interactive graph or table to allow graphical editing using the computer mouse and keyboard. Examples of functions and methods to correct errors in time series are the filling of gaps with interactive linear or spline interpolation, adjusted data from neighbouring stations or regressions or e.g. vertical or horizontal stretching of the trace.

WISKI allows 255 user-defined data quality flags to be assigned to each data value. This will identify the primary quality for example Good, Suspect, Estimated, Unchecked, Missing. Standard remarks from a pick list and free text comments added by users can be used provide additional information about the data.

WISKI keeps a record of who changed the data, for which period and automatically records the name of the method applied for the predefined editing functions listed above. The original data is not edited; instead a "production" time series is defined which stores a copy of the original values, which can be viewed, edited, and validated.

Working within a multi-user environment also implies being able to regulate access to the data by defining roles with corresponding access rights. This allows the hierarchy of the organization to be represented by the information system.

Derived and summary values

While validation takes place on high resolution time series, WISKI calculates the derived summary time series for further analysis and dissemination. The daily, monthly and yearly values are derived from the high resolution time series and are calculated automatically. In combination with built in reports, the user can rapidly generate these reports without exporting data to external publishing software. An internal mechanism ensures that each time the underlying high resolution time series are modified, the derived summary time series are updated automatically. This mechanism, prevents a user from publishing or exporting out of date data, and prevents them from having to keep a record of when to update derived time series (Kudo *et al.* 2009).

Rating curves and statistical analysis

WISKI has a fully integrated rating curve editor. Based on flow measurements, and other filed collected data rating curves can be managed without having to leave the main application. Following validation of the stage data all necessary functionality is available to perform the complex task of defining the water stage/flow relationship of a river. The flow is calculated automatically, or can be triggered by opening the corresponding time series in a graph or table.

For the advanced analysis of recorded data, WISKI offers statistical analysis tools such as linear and non-linear regression analysis, statistical analysis of durations, flood and low flow frequencies, double mass plots, rain storm frequency analysis. The WISKI statistical analysis tools were developed in close collaboration with hydrologists, and are based on national and international standards, such as the United States Geological Survey, the World Meteorological Organization and ISO standards.

Data dissemination

WISKI has an open data model based on the core TSM/WISKI model. The user can add attributes and objects as required by his organisational structures and workflows. A generic C++ & Java-APIs for report generation, external data access or model integration is integrated into WISKI software. This API has the same flexibility and security in data access as the software itself.

Additionally, the easy to learn WISKI scripting language KiScript brings flexibility to the user to add their own calculations, queries, reports, or exports into the system and interface to Excel or other software products.

WISKI standard reports, written in KiScript, can be adopted easily to an organization's reporting requirements. Today, the Internet has become one of the key gateways for exchanging information. For this purpose a web module has been developed for WISKI for disseminating data on the Internet/Intranet using a web browser as a GUI. Moreover, WISKI supports fully automated services such as the sending of data files via FTP (file transfer protocol) or email.

MAPPING AND GIS INTEGRATION

The display of spatially referenced information is made in several ways – following the different objectives required by the user:

The WISKI Web provides browser based access to the data and shows maps with station locations.

Data can be published based on services like WaterOneFlow, WFS, WMS, and Oracle Spatial and may be used in all applications using this protocols.

The WISKI-ArcGIS extension retrieves information from the database and integrates it into the ArcGIS session; subsequently the whole range of ArcGIS-functionality (e.g. mapping, selections, classifications, exports...) is available Simple maps can be shown in the WISKI client software for navigation purposes (Kudo *et al.* 2009).

WISKI 7 IN FOCUS ON SHOW CAVES MONITORING – SCENARIO EXAMPLE OBJECTIVES OF SHOW CAVES MONITORING

Modern technological applications used for measuring equipments and software solutions brings the most effective way for environmental monitoring and protection. Special approach is important for show caves monitoring where number of visitors could have a significant impact on local microclimatic and microbiological balance. The great improvement achieved in the last decades are mainly due to the new technology and particularly to the inexpensive data loggers which record unattended a great number of data (Cigna 2002). Presented scenario is based on general knowledge of cave monitoring using fictive metadata and time series.

METADATA STRUCTURE

Stations are located outside around the cave on the surface and inside of the cave system. All stations are grouped under the Site which could be cave respectively name of the cave. There are several station types in monitoring network (Fig. 3). Depending on measured parameters the station belongs to one or more station types. Each station type has own tab page with relevant additional attributes.

Monitoring parameters are relevant hydrometeorological phenomena on the surface as water level, discharge, water temperature, water quality parameters air temperature, precipitation, snow, etc. and inside the cave as water level, discharge, water temperature, air temperature, relative humidity, wind direction and velocity, water and air quality as CO_2 concentration or radon concentration. At the entrance of the cave is localized presence sen-

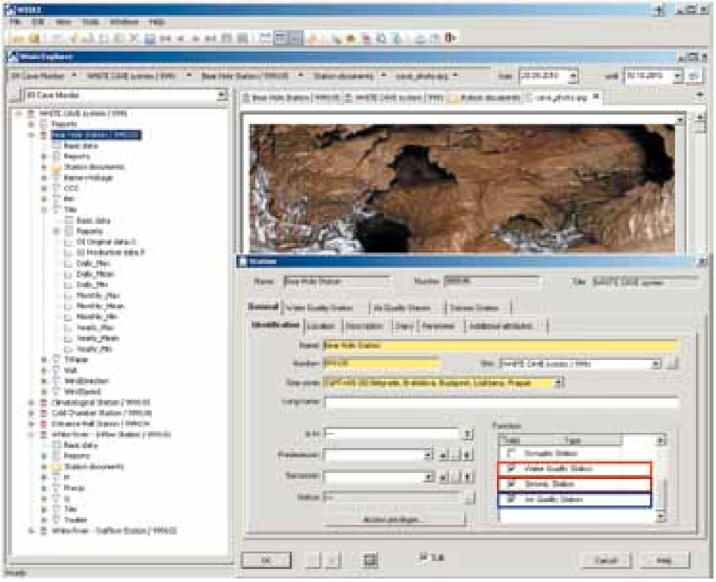


Fig. 3. Metadata and time series structure

sor for additional parameter as number of visitors inside the cave. Each measured parameter is assigned to specific station type but it could be also general for all station types.

Station documentation contains pictures, schemas or equipment certificates stored in various formats, as well related web links. While the WISKI has own user policy the Work folder is arranged by each user customizing his working field.

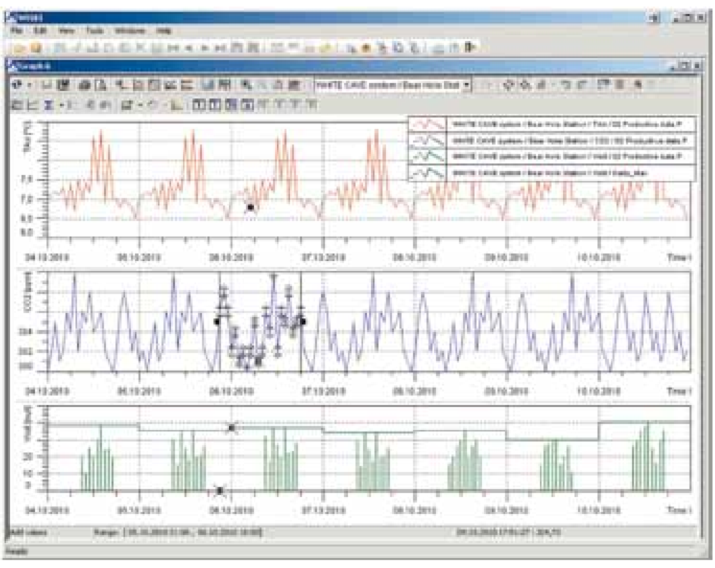


Fig. 4. Graphical presentation and time series data correction

DATA ACQUISITION

Monitoring of different variables in heterogeneous measurement network with various sensors and data loggers, types and formats of data input requires a special data acquisition approach. These tasks are provided by online data acquisition system with several possibilities of transmission methods (GSM, FTP, TCP/IP). Data are imported from file formats as zrx, csv, xml or using configurable importer tool for specific data structure or just with simple copy and paste from spreadsheet as well.

TIME SERIES STRUCTURE AND DATA PROCESSING

Basic structure of time series data consists of original data, productive data and computed or aggregated time series as characteristic values during selected time period (day, month and year). In case of several sources of original data e.g. automatic station and observation, both sources could be merged into one productive time series. Special programming tool can compute new time series from time series of different parameter. For example the sediment load is computed from sediment concentration and discharge.

Analyzing and verifying the data in graphical environment provide an effective work for operator (Fig. 4). Using various statistics the operator can evaluate natural and anthropogenous influences on cave environment.

SUMMARY

WISKI system integrates and significantly improves data and information management practices at various organizations world wide which are involved in environmental monitoring. The WISKI system provides a reliable and flexible archive enabling a central, consolidated source of information. It can provide a modern software platform with sufficient flexibility to encompass future business change and data demands. Its implementation within different authorities reduces costs for support and maintenance, frees up staff resources to improve data quality, undertake more comprehensive analysis and to convert data into information for managing the environment.

Binding with other KISTERS solutions as SODA system for simultaneous online data acquisition, KiDSM for automation of services and Alarm Manager for information and message management in exceptional situations WISKI system provides a whole range of complex and effective monitoring.

Acknowledgment

KISTERS is very grateful to International Show Caves Association and Slovak Caves Administration for the possibility to present this short paper. Thanks to all speleological researchers for their inspirational works and ideas on such interesting and important field of environmental supervision as the cave monitoring.

KISTERS would like to thank all cooperative customers who are improving the KISTERS TSM based hydrological information system WISKI.

References

Andjelic M., Langsholt E., Gal R., Stevanovic S., Kovacevic N., 2010: An Outline of WISKI 7 and HBV Systems Implemented at the Hydrometeorological Service of Serbia. BALWOIS Conference.Bourges F., Genthon P., Mangin A., D'Hulst D., 2006: Microclimates of l'Aven d'Orgnac and other French limestone caves (Chauvet, Esparros, Marsoulas). International Journal of Climatology, 26, 12, 1651-1670.

Calaforra J. 3M., Fernandez-Cortes A., Gazques-Parra J. A., 2004: Low-cost telemetry monitoring of cave environment: Sorbas gypsum karst, Spain. Cave and Karst Science 31, 1, 37-41.

Carrasco F., Vadillo I., Liñán C., Andreo B., Durán J. J., 2002: Control of environmental parameters for management and conservation of Nerja Cave (Malaga, Spain). Acta Carsologica 31, 1, 105-122.

Cigna A. A., 2002: Modern trend in cave monitoring. Acta Carsologica 31, 1, 35-54.

Gabrovšek F., Peric B., 2006: Monitoring the flood pulses in the epiphreatic zone of karst aquifers: The case of Reka river system, Karst plateau, SW Slovenia. Acta Carsologica 35, 1, 35-45.

Jemcov I., Petrič M., 2010: Time series analysis, modelling and assessment of optimal exploitation of the Nemanja karst springs, Serbia. Acta Carsologica 39, 2, 187-200.

KISTERS, 2010: WISKI 7 manuals, documentation and installation reports; Internal reports.

Kudo E., Arata Y., Funke R., 2009: Time Series Management for Operational Water Management. The 4th Symposium on Hydrologic Investigation.

TOWARDS A NETWORK ON THE DEVELOPMENT AND PROTECTION OF THE CAVES OF ARCHAEOLOGICAL AND PALEONTOLOGICAL INTEREST IN THE ISLAND OF CRETE

Vassilis Giannopoulos, Evangelos Kambouroglou, Sissy Kontaxi

Ministry of Culture, Department of Paleoanthropology-Speleology, Ardittou 34b, 11636 Athens, Greece

Abstract: The department of Paleoanthropology-Speleology of the Greek Ministry of Culture has proposed the creation of a network on the development and the protection of 8 caves of archaeological and paleontological interest in the island of Crete. The aim of this project is the promotion of the speleotourism in Crete, the scientific study of caves as physical and archaeological monuments and the protection of their environment.

Keywords: development, protection, archaeology, paleontology, Crete

The department of Palaeoanthropology-Speleology of the Greek Ministry of Culture is responsible for the research, the study and the protection of the Greek caves. Among the research programs of this department, a project for the creation of a network on the development and protection of the caves of Crete has been undertaken. The aims of this program are primarily the protection of the caves and secondly the augmentation of the speleotourism.

The island of Crete has been chosen for two reasons:

1. Crete is an island which receives more than 2,000,000 visitors, with a permanent stay of 7 to 10 days.
2. There are more than 6,000 caves, with speleological interest, most of them having also archaeological or paleontological interest.

The network includes 8 caves: 3 already developed archaeological caves, 4 caves of archaeological interest, visited by people and 1 cave of

Fig. 1. The island of Crete and the caves of the network

paleontological interest (Fig. 1). The particularity of each cave and its special characteristics must be taken under consideration, in order to attain the proper development.

The first group includes three already developed caves:

1. **Zoniana Cave.** This cave has been opened to the public in 1996, after an excavation research which has brought to light archaeological remains from neolithic to roman period. The cave receives more than 30,000 visitors per year.
2. **Melidoni Cave.** The cave has been developed in 1988 and receives about 10.000 visitors per year. The excavation that took place in the cave has also revealed archaeological remains from neolithic to roman period.
3. **Diktaion Andron (Psychro).** This cave is related to the Greek mythology and to the myth of Zeus (Davaras, 1989). The excavation research has proved that the cave has been used as a sanctuary of Zeus, fact that is strongly supported by the large number of findings, such as pots, votive figurines, ornaments, etc., dating mostly from Minoan to archaic period (1800 BC-700 BC). The cave became touristic in 1976, and receives more than 100,000 visitors per year.

In the second group, there are four caves which present archaeological interest and are visited by people, without been developed:

1. **Idaion Andron.** The cave is connected with the myth of the birth of Zeus. The excavation research brought to light very rich archaeological remains from neolithic to roman period, among them many votive items of silver and gold (Sakellarakis, 1996). Nowdays, works of development are in progress, including the improvement of the access to the cave and the construction of a ramp inside the first chamber of it. These works are undertaken by the local Municipality in collaboration with the Greek Ministry of Culture.
2. **Milatos Cave.** The cave of Milatos presents archaeological and historical interest and there is a small chapel inside it. A stone path leading to the cave has been constructed by the Municipality and excavations are in progress, revealing findings from minoan to byzantine period.
3. **Pelekita Cave.** This cave has archaeological remains dating from the minoan period. An archaeological research has been planned, while studies in collaboration with the University of Crete, the Ministry of Culture and the Municipality of the region are in progress, in order to develop the cave.

The main suggestions for these two groups of caves which present archaeological interest are the followings:

– More scientific work must be done aiming both to the protection of the environment of the caves and the safety of the visitors. Geological and static studies, biological research and environmental studies are some of the works that will contribute to the better development of the caves.

– The archaeological research is planned to continue in the caves where it is not yet accomplished. Anyhow, the excavation research must come before the development, although the two works can take place at the same time.

– Information must be given to the visitors about the history of each cave and its use during the ancient times. The planning of educational material and posters, the establishing of tables with pictures, photos and

Fig. 2. Draft of the cave of elephants

informative texts, as well as the setting of models and representations of the archaeological finds in some cases are some of the aims of this project.

THE CAVE OF ELEPHANTS

In the third group there is a cave of very important paleontological interest. Its entrance is now 10 m under the sea level and leads to a main chamber, yet above sea level, 125 m length and 20 m width (Fig. 2).

The "cave of elephants", at Vamos in Chania, presents a great interest, both as a natural monument and a scientific finding. The underwater geological and paleontological research brought to light a large number of elephant bones (Symeonidis *et al.* 2001), which associated with the rich stalagmitic decoration and generally the morphology of the cave, made it unique. Therefore, the touristic development of the cave has been proposed, using new methods, making the cave a very important site for the tourism (Giannopoulos, 2006).

A suggestion for the construction of an underwater transparent corridor for entering the cave has been made (Fig.3). This solution permits the visitors to have a unique view of an underwater cave and at the same time prevents the damage of the speleo-environment caused by the entrance of people. It is self-evident that environmental studies will procede the realization of this project, along with a number of other studies, such as geological, hydrogeological and seismic studies.

Fig. 3. Representation of the underwater corridor in the cave of elephants

SOME GENERAL PROPOSALS

In addition, some general proposals have been submitted:

– The establishment of a central administration for the management and the promotion of the network.
– The publication of a guide book with all the information concerning the caves and their history.
– The motivation of the public to visit the caves of the network, establishing reduced prices, one ticket for all caves, etc.

This project will hopefully contribute to the conservation and protection of these caves, as well as to the increase of the speleotourism in Crete, making some of the most important Greek caves well known to the large public.

References

Davaras, K., 1989. The Cave of Psychro, Athens.

Giannopoulos V., 2006. The cave of elephants, Vamos, Chania, Crete: Past and future. 3rd Cretan Speleological Symposium, Rethymno.

Rutkowski B., Nowicki K., 1996. The Psychro Cave and other sacred grottoes in Crete. Studies and Monographs in Mediterranean Archaeology and Civilization, II, 1, Art and Archaeology, Warsaw.

Sakellarakis, I., 1996. Digging for the past, Athens.

Symeonidis, N., Theodorou, G., Giannopoulos, V., 2001. New data on *elephas chaniensis* (Vamos, Chania, Crete). *Proceedings of the 1st International Congress "The World of Elephants"*, p. 510-515, Rome.

CLIMATIC SYSTEM OF THE DOBŠINSKÁ ICE CAVE

Magdalena Korzystka[1], Jacek Piasecki[1], Tymoteusz Sawiński[1], Ján Zelinka[2]

[1] Department of Climatology & Atmosphere Protection, Geographical Institute of Geography & Regional Development, University of Wrocław, pl. Uniwersytecki 1, 50-137 Wrocław, Poland; magdalena.korzystka@uni.wroc.pl, jacek.piasecki@uni.wroc.pl, tymoteusz.sawinski@uni.wroc.pl
[2] State Nature Conservancy of the Slovak Republic – Slovak Caves Administration, Hodžova 11, 031 01 Liptovský Mikuláš, Slovakia; zelinka@ssj.sk

Abstract: The paper presents the most important characteristics of the Dobšinská Ice Cave climate. To determine the cave climate, the time and spatial changes of several meteorological parameters as well as the in-cave ice processes were studied. To resume, six cave climate-ice complexes were distinguished. They reflect interactions and interdependencies between individual factors which form Dobšinská Ice Cave climate and also they can characterize the state of climatic system of the cave in a given time.

Keywords: Dobšinská Ice Cave, cave climate, air exchange, thermal conditions, humidity conditions, ice conditions

INTRODUCTION

In case of caves open for tourists, the environmental processes and conditions of the caves as well as of any other underground cave-like system are extremely important factors to know. A good knowledge of the factors mentioned above allows us to explore and to exploit the caves properly; it is also necessary to protect their environmental, cultural and historical values. The climatic factors influence environment a lot and, if we want to preserve it in a good way, we need a good knowledge of these factors (Christoforou *et al.* 1996; Cigna 2002; Deacon 2006; Fajmon *et al.* 2006; Fernández-Cortés *et al.* 2006; Russel & MacLean 2008).

The paper presents selected results of climatological studies carried out in the Dobšinská Ice Cave the aim of which was to define typical characteristics of time-space changeability of air temperature and humidity, air exchange and ice conditions inside the cave. The second step in the studies was to determine the factors that drive the changes of climatic conditions inside the cave and the third one was to provide a complex description of the cave climatic system. As an instrument to describe particular states of the system, determined by specific meteorological conditions, both inside the cave and in its surroundings, the classification of climate-ice complexes has been devised. Its construction has based on the analysis of the cave environment "behaviour" in the model meteorological situations which may be observed in the cave surroundings (freeze and warm periods, periods with and without snow cower, periods with and without precipitation etc.).

STUDY AREA

The Dobšinská Ice Cave is situated in the karst area of Spiš – Gemer, in the Stratena nature reserve which, in turn, is a part of the Slovak Paradise National Park. The cave opens for tourists mid May and closes end of September. The number of tourists visiting is estimated to be at 100,000. Since 2000 the Dobšinská Ice Cave figures on the UNESCO World Heritage List.

The entrance of the cave is situated on the NW slope of the Duča karst massif, 969 m. a. s. l. and 130 m above the bottom of fhe Hnilec river valley. The cave's origins date back to the Neogen, when the paleo – Hnilec eroded the limestones of the Duča massif (Tulis & Novotný 1989). As to the genesis, the Dobšinská Ice Cave is a part of the Stratenská Cave system; however, the two cave systems are

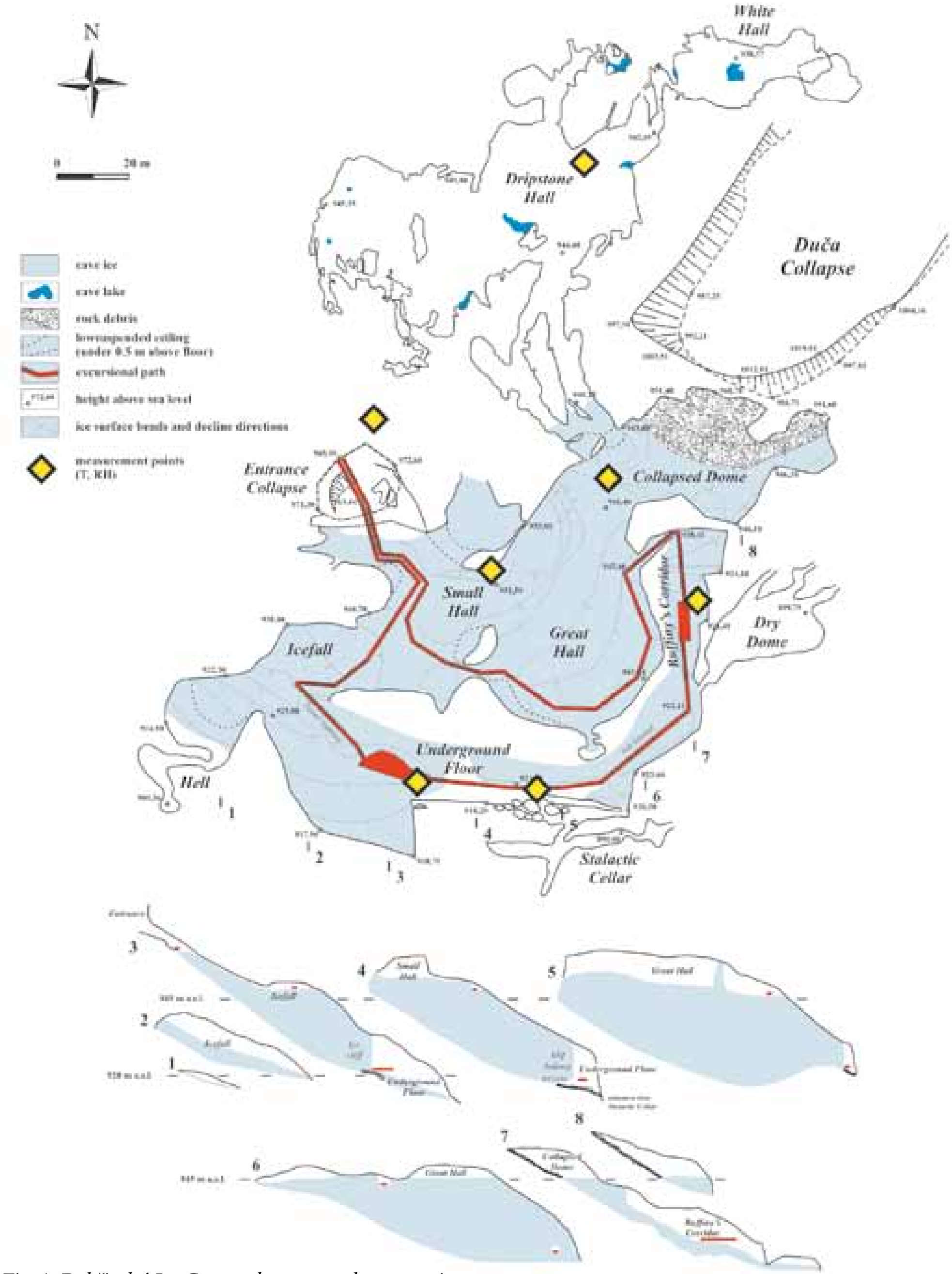


Fig. 1. Dobšinská Ice Cave – the map and cross-sections.

now separated. The caves lost the connection probably in Pleistocene after the ceilings of the cave collapsed (Novotný 1995). As a result of that phenomenon the Duča collapse arose and separated both the Dobšinská and the Stratenská Cave.

The main part of the cave is a large chamber that appeared as a result of a collapse of ceiling that separated the two main morphological cave levels. The chamber is fulfilled with the ice monolith, the volume of which is estimated at 110,000 m^3 (Tulis & Novotný

1995). The monolith – by contact with the chamber's ceiling – separates the chamber into two main parts (Fig. 1). The difference in altitude of these two parts is about 30 m. In the upper part, the chamber divides into three halls: Small Hall, Great Hall and Collapsed Dome and they are all situated in the north and central parts of the chamber. The ice floor of the halls is the upper level of the cave glaciation. Underground Floor and Ruffiny's Corridor are situated in the south of the halls mentioned above and below of them and make the lower part of the cave. 20 m high ice cliffs, which limits these halls from north and north-west (Fig. 1) make theirs peculiar feature. The surface of halls floor consisted of ice and rock debris indicates the lower level of the cave glaciation. Halls of the upper and of the lower cave parts are connected one with another with the Icefall area (which join Small Hall and Underground Floor). Adequate connection between Ruffiny's Corridor and Great Hall is provided by opening, located under the ceiling of the Corridor in its north part (Fig. 1).

The halls of the upper and lower cave parts are still connected with the remains of primary, pre-collapse corridors and halls system, which are Hell, Stalactic Cellar and Dry Dome (in the lower level) and Dripstone Hall as well as other neighbour halls (the upper level). These parts of the cave are ice-free and it is only in Stalactic Celar where one may find ice.

The cave is connected with its external surroundings by the main entrance hole situated in the north-west part of the cave, about 20 m above the ice surface of the near-entrance area (Small Hall), as well as by fissures that give to the Small Hall and Icefall. The complex of fissures developed in the rock debris in between the Collapsed Dome and the bottom of the Duča Collapse also connect the cave with the outside. The Collapsed Dome is about 40 m below the Duča Collapse and the above position of the complex makes the air exchange caused by chimney effect.

DATA SOURCES AND MEASUREMENTS

The air temperature (T_{AIR}) and the air humidity (RH) were the main data used in the cave climate investigation. Both quantities were measured inside and outside of the Dobšinská Ice Cave for several years (from February 2001 to October 2007) and they were recorded by the cave climate monitoring network.. The measurements were taken automatically with the data loggers L3120 and L0141 "Black Box" manufactured by Comet System: five of them were situated in the icy part of the cave, one in the free-of-ice part of the cave (Dripstone Hall) and the last one was situated outside the cave (Fig. 1.). The accuracy of the recorded data was: 0.2 °C for the T_{AIR} and 2 % for the

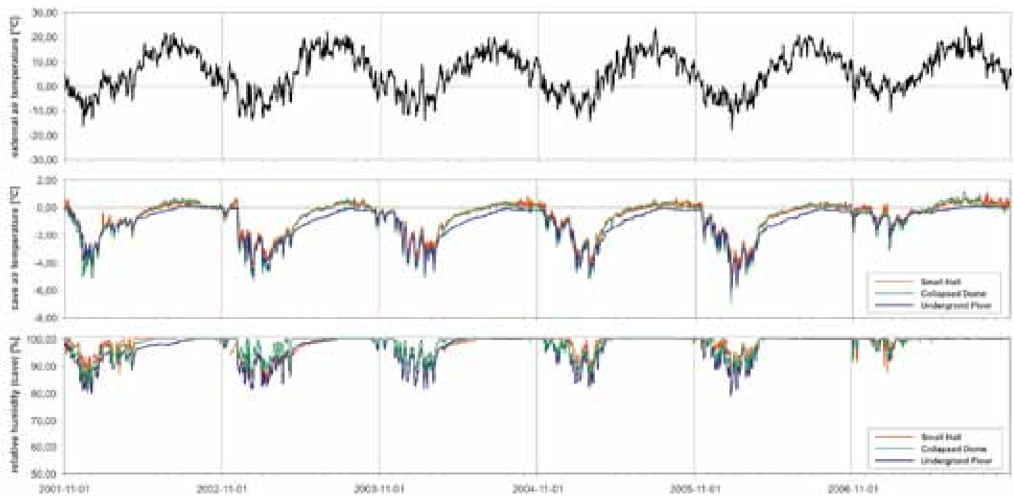


Fig. 2. The course of the air temperature and the relative humidity changes at the selected measurement points inside and outside the cave in the hydrological years 2001 – 2007.

RH, respectively. The frequency of data recording depended on the period of a year: from October to May the data were recorded every hour; from May to September, when the cave opens for tourists, the data were recorded every 10 minutes. The process of air exchange in the cave was an investigation subject in the years of 2002 – 2007 (Pflitsch *et al.* 2007; Piasecki *et al.* 2004, 2005, 2008). Here, the data were recorded with frequency of 1 minute by ultrasonic anemometers USA-1 made by METEK GmbH, which accuracy was 1° for wind direction and 0.01 ms^{-1} for wind velocity. In the years of 2002 to 2007 the periodical observations and measurements of the ice phenomena were also taken. The mass balance of ice monolith and the processes of development and degradation of the sublimation ice crystals were studied with the intervals of 2 to 3 months, and so we were given a great piece of valuable information on the spatial diversity and dynamics of the in-cave climatic processes that depend on the phase transitions of water (Strug *et al.* 2004; Pflitsch *et al.* 2007; Strug *et al.* 2008; Strug & Zelinka 2008). As a completion of the climatological data obtained in present surveys archival data of rock temperature (monthly averages) were also used. These were recorded in the years of 1980 – 1984 and published by J. Halaš (1985, 1986).

THE DOBŠINSKÁ ICE CAVE MICROCLIMATE

Thermal conditions

In the 2001 – 2007 investigation period the air temperature of the icy part of the cave was about 0 °C in summer to a few Centigrade above zero in winter. In winter period the course of T_{AIR} changes inside the cave was in correlation with the corresponding characteristic outside the cave and the amplitude of changes of in-cave temperature reached a few of Centigrade (Fig. 2). In the summer half-year only the temperature of the Collapse Dome was influenced by the outside air temperature, however, the daily difference in the T_{AIR} did not exceed 1.0 °C. The air temperature measured in the Dripstone Hall (fragment of the free-of-ice parts of the cave) was about 3.0 °C all year and the amplitude of seasonal changes of T_{AIR} in this area did not exceed 0.5 °C (Fig. 2).

The mean annual air temperature indicates the coldest parts of the cave, which are Underground Floor (lower part) and Collapsed Dome (upper part of the cave); Small Hall and Ruffiny's Corridor are warmer than the parts of the cave mentioned above. This untypical temperature distribution (Luetsher & Jeannin 2004; Mavlyudov 1997; Wirgley & Brown 1976), results from cave's icy part configuration as well as from the course of air exchange in winter period (November to April). In the contrary to the winter period, the temperature distribution in the summer period can be qualified as typical. The cold zone with the T_{AIR} below 0 °C appeared in the halls of the lower level of the cave, the upper level of the cave was warmer and the T_{AIR} here was slightly above 0 °C. Presented patterns of air temperature distribution occur every year despite the outside weather condition. And so, one may compare here the distribution of the T_{AIR} in the cold year (2006) with the distribution of T_{AIR} in the warm one (2007) (Fig. 3).

The course of changes of the air temperature inside the cave is different in each season of the year. In the free-of-ice part of the cave (Dripstone Hall) we observe only seasonal changes of air temperature and they are not significant. However, the icy part of the cave is a place where the dynamic of air temperature changes is much more visible and where we may observe the seasonal as well as the short-term variations of air temperature. For this part of the cave three types (patterns) of air temperature changes were distinguished. Each time, the dynamics as well as the scale of changes are different.

Type-1. The first type of air temperature changes appears in winter. Here, the in-cave T_{AIR} changes result from the ones from the outside of the cave (Fig. 4). These are short-term changes and their range can reach several Centigrade, however, the amplitude of those changes is always lower than the one of the outside of the cave. As to the spatial distribution of this quantity, Collapsed Dome and Underground Floor are the two places of the highest amplitude; its value is lower in Small Hall and the lowest in Ruffiny's Corridor area.

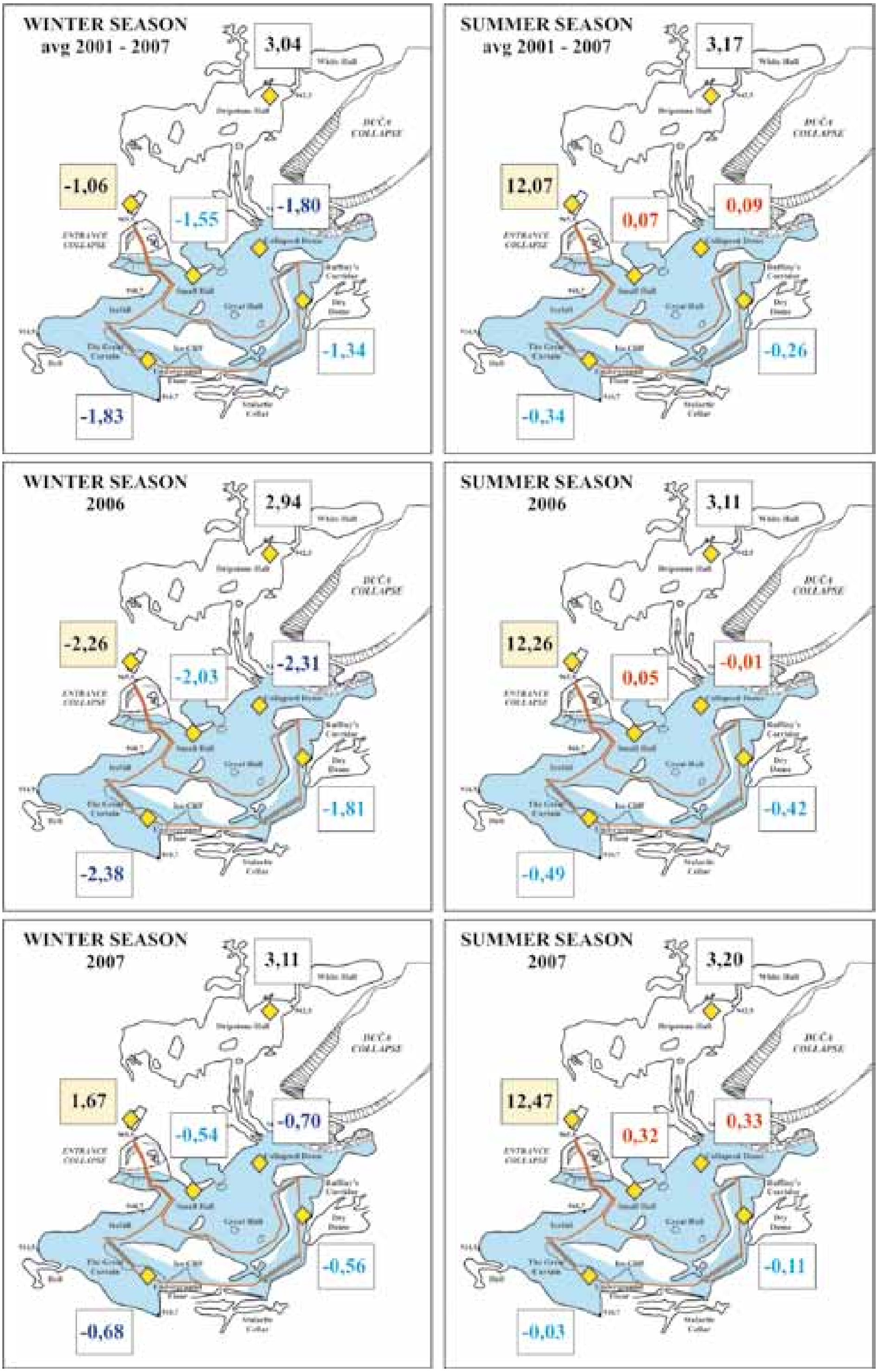


Fig. 3. The distribution of air temperature in summer and winter seasons in hydrological years 2006 and 2007 against mean long-term seasonal air temperature in the 2001–2007 period.

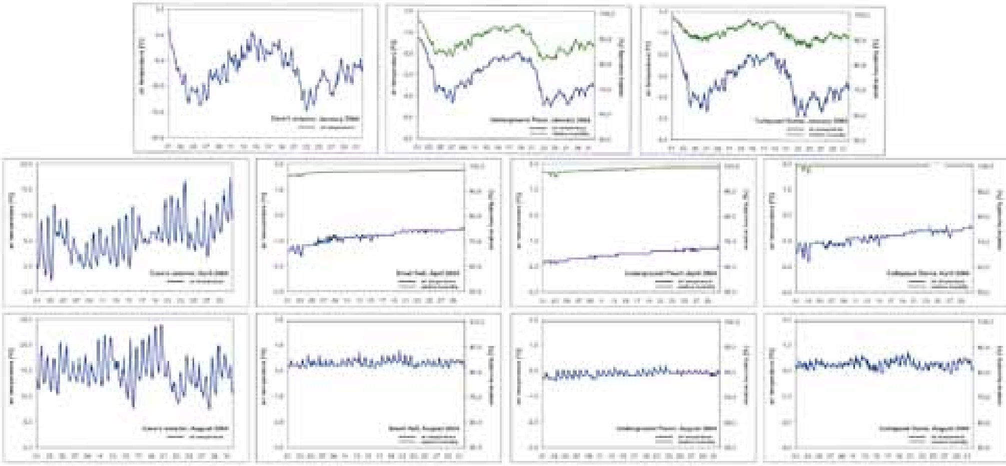


Fig. 4. The types of the course air temperature changes and relative humidity changes at the selected measurement points in Dobšinská Ice Cave against the air temperature changes outside the cave (hourly means). Type-1 on the top, Type-2 in the middle, Type-3 on the bottom of the graph.

Type-2. This pattern of the air temperature changes appears in spring and in warm periods of winter. The short-term changes of the T_{AIR} that are typical for winter does not exist in this pattern. The increasing trend in the air temperature is well visible here; however, the rate of increase does not exceed 0.1 °C / 24 h (Fig. 4). This pattern of air temperature changes persist until the T_{AIR} stabilize at 0 °C, which can differ in time: T_{AIR} of halls of the upper level of the cave gets stabilized at the beginning of summer (June/July) while the T_{AIR} of lower level of the cave stabilizes much later – depending on the cave temperature. It is quite possible that, in case of extreme events, the T_{AIR} in this part of the cave does not reach 0 °C in the warm period.

Type-3. Type 3 represents a typical pattern of summer changes of air temperature. The T_{AIR} gets stabilized at around 0 °C; however diurnal changes are well visible because of tourism. Only the Ta variation of the Collapsed Dom was marked with the daily rhythm of changes of the external air conditions (Fig. 4).

As to the spatial distribution, both air and rock temperature (T_{ROCK}), have similar annual distribution. The zone of cold of the halls of the lower level of the cave is well visible in the rock temperature distribution; as well as thermal privilege of the Small Hall and the Ruffiny's Corridor areas. In a summer half-year the temperature of rock massif of the lower level of the cave is below 0 °C, while the rock temperature of the halls of the upper level of the cave may be above 0 °C. The T_{ROCK} exceeds 0 °C in about a month after the relevant T_{AIR} increase (Tab. 1). The difference between T_{AIR} and T_{ROCK} indicate the heat transfer direction. The energy flux is from rock to air ($T_{ROCK} > T_{AIR}$) from November to February: the rock massif cools down and the cave air warms up (Tab. 1). The above air and rock temperature changes are explicable and confirmed. Thus, the genesis of the January anomalies of the upper level of the cave, when the air temperature is higher than the rock temperature, is still not clear. In spring as well as during the whole warm period of a year, the energy flux is from air to rock ($T_{ROCK} < T_{AIR}$).

Humidity conditions

The annual course of relative humidity changes inside the cave is similar in dynamics to the dynamics of the changes of air temperature. In winter, the RH value in the icy part of the cave varies form 80 to 95 % (Fig. 2 and 4). The lowest RH values were observed in Underground Floor and Collapsed Dome, which are the coldest parts of the cave. In the halls of the upper level of the cave (Small Hall and Great Hall) as well as in the Ruffiny's Corridor both, T_{AIR} and RH have greater values and so the amount of water

Table 1. The mean monthly temperature (T) of cave air (AIR) and rock surface temperature (ROCK) and the temperature difference between air and rock surface (Δ) at the selected measurement points inside the Dobšinská Ice Cave in the years of 1980 – 1984 (on the basis of Halaš 1986).

Measurement point	**T**	**Months**											
		I	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**	**XI**	**XII**
Small Hall	Air	-2.28	-2.85	-1.93	-1.08	-0.53	-0.13	0.08	0.18	0.23	0.18	-0.60	-1.36
	ROCK	-2.33	-2.63	-2.00	-1.23	-0.78	-0.30	-0.15	0.03	0.13	0.10	-0.58	-1.20
	Δ	0.05	-0.23	0.08	0.15	0.25	0.18	0.23	0.15	0.10	0.08	-0.02	-0.16
Great Hall/ Collapsed Dome	Air	-2.40	-3.10	-1.95	-1.08	-0.58	-0.20	-0.08	0.03	0.15	0.10	-0.66	-1.54
	ROCK	-2.60	-2.80	-1.88	-1.28	-0.75	-0.35	-0.23	-0.03	0.10	0.06	-0.52	-1.36
	Δ	0.20	-0.30	-0.08	0.20	0.18	0.15	0.15	0.05	0.05	0.04	-0.14	-0.18
Ruffiny's Corridor	Air	-2.55	-2.83	-1.93	-1.50	-0.78	-0.38	-0.10	0.05	0.05	-0.04	-0.70	-1.68
	ROCK	-2.40	-2.75	-1.90	-1.55	-1.08	-0.78	-0.60	-0.25	-0.13	-0.06	-0.70	-1.52
	Δ	-0.15	-0.08	-0.03	0.05	0.30	0.40	0.50	0.30	0.18	0.02	0.00	-0.16
Icefall	air	-3.63	-3.93	-2.58	-1.90	-0.90	-0.48	-0.38	-0.25	-0.13	-0.16	-1.12	-2.18
	ROCK	-3.38	-3.40	-2.70	-2.05	-1.20	-0.70	-0.53	-0.35	-0.25	-0.34	-0.92	-2.08
	Δ	-0.25	-0.53	0.13	0.15	0.30	0.23	0.15	0.10	0.13	0.18	-0.20	-0.10

vapour contained in the air is more significant in those areas. As the spring comes, the type nr 2 of the air temperature changes appears and RH value stops changing. The relative humidity inside the cave increases and the cave air quickly becomes almost saturated (RH > 95 %). The abovementioned conditions are the typical ones for spring and summer; after the first autumn freeze appears relative humidity inside the cave drop down (Fig. 2 and 4). In the free-of-ice part of the cave (Dripstone Hall) the humidity conditions do not change – the air is always almost saturated.

Air exchange

The studies on the air exchange in the Dobšinská Ice Cave proved the chimney effect to be the one that forms the process of cave ventilation. There is the complex of fissured debris that separates the cave interior from the Duča Collapse that play a role of a cave "chimney" (Pflitsch *et al.* 2007; Piasecki *et al.* 2004, 2005, 2008). The course of air exchange depends on the flux variation of the value and direction of the air temperature gradient between the inside and the outside of the cave. Thus, the seasonal variation of the air exchange is observed in the cave and one may distinguish here two air exchange types: the winter and the summer one.

Winter type of the air exchange appears when: the air temperature in the cave surroundings is below 0 °C and, in the same time, lower than in-cave air temperature. The difference in the air density makes the cold air flow into the cave via the entrance hole. In the entrance zone (Small Hall) the main air stream divides into two sub-streams, one of which passes on ice floor – through the halls of the upper level of the cave (Small Hall, Great Hall), than it goes to the Collapsed Dome and to the cave "chimney" (fissured debris complex in Collapsed Dome). The second sub-stream goes down to the halls of the lower level of the cave – it passes through the Icefall and Underground Floor in its way to the Ruffiny's Corridor (Fig. 5). The rock massif warms the two air streams up which process activates sublimation of cave ice. As a result the water vapour content in the cave air increases. Because of the longer way to go,

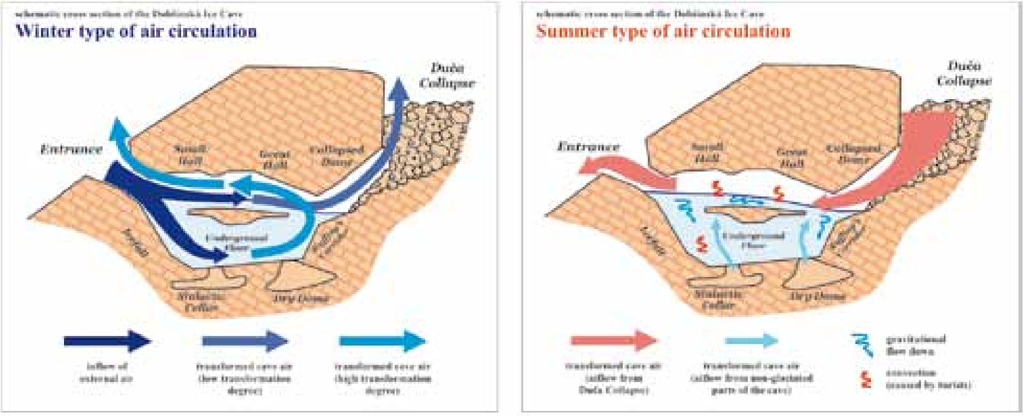


Fig. 5. The patterns of air exchange in the Dobšinská Ice Cave.

the air of the lower sub-stream is much more transformed than the air of the sub-stream which flows through the upper cave part (see Fig. 1 and 5). And so, the T_{AIR} in the Ruffiny's Corridor is higher than the T_{AIR} in the Great Hall (sometime the air temperature difference of these areas may increase up to 3 °C). In the cases like that the convective outflow of relatively warm and moist air stream from the Ruffiny's Corridor is observed. In Great Hall the stream moves under the cave ceiling in its way to Small Hall, and next it flows out the cave through entrance hole and near-entrance fissures. The relevant warm air flow that would be expected here (from Ruffiny's Corridor in a way to Collapsed Dome and cave "chimney") does not exist, because of the low ceiling that separates the Collapsed Dome from the Great Hall.

The under-ceiling flow of air in the halls of the upper part of the cave diversifies the air-flow structure in the area, which is particularly visible in the entrance zone. Two air streams are observed here and each of these two streams is in the opposite to the other. The above-floor stream is a stream of external air which flows into the cave and the under-ceiling stream of air lead the transformed in-cave air out of the underground system (Fig. 5).

The second type of air exchange is a summer type. This type appears when the external air temperature is higher than the in-cave temperature. Here, this is the difference in temperature, that makes the relatively heavy air, that accumulates in the chimney, go down (summer phase of the chimney effect). Then, the air passes through the halls of the upper level of the cave (Collapsed Dome, Small Hall and Great Hall) in their way to the cave entrance. Permanent air leakage from chimney fissures is compensated with the air sucked in its upper part, what causes intensive exchange of heat between air and rock inside the chimney. The in-flowing external air warms the chimney up, in the contrary, the air cools down and its relative humidity increases. The overall processes make the relatively warm and moist air flow into the icy part of the cave. According to the investigation results, the temperature of the flowing-out air was at 1.0 ° to 1.5 °C in July and August and its RH value was about 100 %.

In the lower part of the cave and during the summer air exchange phase, the outflow of air is observed, that comes from the holes connecting the Underground Floor and Ruffiny's Corridor with the free-of-ice parts of the cave (Stalactic Cellar and Dry Dome), as well as from the fissures developed under the ice monolith (Piasecki *et al.* 2008). The above outflow needs the same conditions to be active as the summer air flow of the upper cave part. This fact indicates that the genesis of the two air flows is exactly the same and the lower parts of the cave must be connected with the surface by chimney-like joining system. The air that flows out the fissures of the lower level of the cave is colder than the air that flows into the Collapsed Dome; in this case, the T_{AIR} may be above 0 °C but only at the end of the summer half-year. The difference results probably from the greater cooling of the lower part of the cave and from the less intensive air outflow there.

The summer air exchange appears mostly in the summer period. However, it was also observed in warm periods of winter. Both types of the air exchange may occur in turn in spring and autumn in a form of episode. The episodes take from several hours to a few days and they depend on the outside weather conditions.

Ice conditions

The dynamics of the ice processes of the Dobšinská Ice Cave and development of ice forms depend on the water conditions, on the ventilation processes and on the heat transfer between: the cave air, the rock massif, the cave ice and the infiltration water (Halaš 1980, 1986, 1989; Strug *et al.* 2004; Pflitsch *et al.* 2007; Strug & Zelinka 2008). All around a year, the ice forms of the cave can result from freezing of the infiltration water (which, in this case are the ice monolith and the ice speleothems) or from the development of the re-sublimation ice (ice crystals sediment). All the ice forms develop in a three-phase process which includes: winter phase, ice creation phase and ice degradation phase.

In winter phase, most of the precipitation water is accumulated in the snow cover and there is a lack of infiltration water in the winter phase. As the cold air flows into the cave (the outside temperature is below 0 °C) the rock massif, as well as the ice monolith, cool down (winter type of the air exchange). Because of the heat exchange, the cave air warms up. The increase in air temperature causes the increase of saturation deficit in the air, in turn; the sublimation process on the ice floor becomes very intensive. The influence of thermal and humidity conditions and also the airflow may result in lost of the ice volume in the monolith surface, which may be from a few to as many as several of millimetres (Strug & Zelinka 2008). At the entrance zone of the cave, the re-sublimation ice crystals appear. These crystals develop as a result of the air stream that passes through Ruffiny's Corridor in its way to the cave entrance. The air is relatively warm and moist, and with the contact with the cold rock in the near-entrance zone it cools down until the dew point temperature. The above conditions activate the re-sublimation processes and the ice crystals development (Strug *et al.* 2004; Pflitsch *et al.* 2007).

Ice creation phase. This phase is a typical one for spring, when the snow cover in the cave surroundings melts in a fast way. The cave interior is cold (the in-cave air and rock temperature is below zero) so the snowmelt water which infiltrates from the surface freezes inside. The above conditions make the ice speleothems appear; this is also a phase of the ice monolith increase (the increase in the ice monolith volume may be up to several of cm). The increase in the air temperature outside the cave makes the summer type of the air exchange begin: warm and moist air flows into the cave. As the rock massif is cold, the air cools down and the intensive growth in ice crystal cover is well visible overall the cave.

The phase of the ice creation may appear also in warm periods of winter, when snow cover melts. As the warm period of winter ends and the air temperature is low again, the water infiltration stops and soon after that the winter ice-phase reactivates (Strug *et al.* 2004; Pflitsch *et al.* 2007; Strug & Zelinka 2008).

The third phase is the **phase of the ice degradation**. The phase processes begin if the rock massif temperature is 0 °C or higher and the amount of cold accumulated in the ice monolith is not enough to freeze water. In the same time the covers of ice crystals and the ice speleothems on the cave ceiling disappear. The loss in ice volume may result from the heat supply caused by: the air exchange, the infiltration of water after a period of precipitation and the heat transfer from the rock massif. The anthropogenic heat is another factor that contributes to the ice mass loss. The phase of the ice degradation of the upper part of the cave begins in June/July. As to the lower level of the cave it may happen, that the ice mass may not loose its volume and, which is also possible, the ice mass may increase until the next winter ice-phase begins (Strug *et al.* 2004; Pflitsch *et al.* 2007; Strug *et al.* 2008; Strug & Zelinka 2008).

DOBŠINSKÁ ICE CAVE CLIMATIC SYSTEM

The Dobšinská Ice Cave climatic system is a system where the air exchange, the heat transfer (to and from the rock massif), the water infiltration as well as the ice mass development and degradation (which depend from actual weather conditions and from a season of a year) play a main role. The relationships and the dependencies between the above processes were crucial to distinguish six cave climate-ice complexes (from C-1 to C-6; see Tab. 2), that can describe the variable state of the cave climatic system. All the complexes were based on the characteristics of the typical meteorological situations which may be observed in the cave exterior (autumn and winter freezes, winter warmings, deep spring warmings, spring freezes, dry summer periods and summer periods with precipitations). The external meteorological conditions are the most important ones here and influence on the dynamics and on the climatic conditions of the cave interior a lot. Morphology of the cave, local tectonics and geology, cave sediments, ways and places of the water infiltration are constant factors and they are much less important for the cave climate, because they do not influence directly on the dynamics of climatic processes in short-time periods.

The cave climate-ice complexes C-1 and C-4 are the ones, where the cave cools down systematically as the cold air form the outside flows into the cave (this situation corresponds with Type-1 of air temperature changes). The above complexes may take as long as 100 days a year. While C-2 or C-3 activate, the air temperature of the cave system goes up (Type-2 of the air temperature changes). When C-3 is active, one may observe the most intensive development of the ice mass inside the cave. The C-5 and C-6 complexes are the ones with the important degradation of the ice volume (it is even much more evident when the 6th complex is active). In this time air temperature inside the cave is around 0 °C (this is the Type-3 of air temperature changes).

In the above typology the anthropogenic heat supply (caused by visitors and the cave lights) is not included. The amount of this heat is estimated at 83,965,016 – 89,781,316 kJ/year (Halaš 1986, 1989) and it is used for ice melting as well as for the cave ceilings heating (because of convective lifting of relatively warm air). The Dobšinská Ice Cave is opened for tourists for six months and so the anthropogenic heat income is limited in time.

The 1980' the studies on the cave energy balance revealed that these are the C-1 and C-4 complexes that play a key role in the cave climate. In the cold periods of a year, when the air temperature in the cave surroundings is below 0 °C, the cave system looses about -186,751,872 kJ, while the mean heat value that enters to the cave system in warm periods is estimated to be at 54,330,048 kJ (plus the anthropogenic heat). The cold that had been stored in the cave in winter allows the ice mass balance to be positive and the annual increase in the ice mass is estimated to be at 11 – 13 mm (Halaš 1986, 1989). The analysis of thermal conditions of the 2006 and the 2007 years (year 2006 was the coldest year of the investigation period and the year 2007 was the warmest one; Fig. 2) prove that this is the length of a particular weather pattern than influences the most the energy balance. Short-term periods of cold in winter (2006/2007) and relatively high air temperature made the cave not cool down. What's more, after the winter period in the whole icy part of the cave (including its lower part) the air temperature rapidly arose up to 0 °C (Fig. 6). As a result the phase of the ice degradation was 1.5 month longer than its mean annual length. Energy equilibrium in the cave system was also disturbed – not all the energy was used in the process of ice melting and its excesses did cause noticeable growth of temperature in the cave upper part (Fig. 6).

SUMMARY

These are the Dobšinská Ice Cave location and configuration formed by collapse event that made the great ice monolith appear. The monolith is an important component of the cave climatic system. The processes of development and degradation of cave ice moderate the cave microclimate and they are in close relation with the other in-cave climatic processes.

Table 2. The characteristics of the cave climatic-ice complexes in the Dobšinská Ice Cave in dependence on the weather type outside the cave.

weather type outside the cave	cave climatic-ice complexes	course of air exchange	characteristic of water infiltration process	ice conditoins	characteristic of thermal and humidity conditions inside the cave	characteristic of energy exchange
autumn and winter freezes	**C-1**	winter type	lack of infiltration or limited infiltration	ice sublimation on the ice monolith surface; development of the re-sublimation ice (ice crystals sediment) on the cave ceiling	T_{AIR} below 0 °C, significant variations of T_{AIR}; RH value varies form 80 to 95 %; **Type-1** of air temperature changes	direction of heat transfer – from rock surface to cave air ($T_{ROCK}>T_{AIR}$) – the rock massif cools down and the cave air warms up; the cave cooling is intensified by latent heat absorbing (sublimation process); part of the latent heat is returned in re-sublimation process
winter warmings	**C-2**	summer type	limited infiltration (lack of infiltration also possible)	development of the re-sublimation ice (ice crystals sediment) in the whole cave area	T_{AIR} below 0 °C, constant increase of T_{AIR}; RH value stops changing and increases rapidly to 100 %; **Type-2** of air temperature changes	heat supply caused by air flowing into the cave and by latent heat from (re-sublimation process); heat supply caused by infiltration water and latent heat (freezing processes) also possible; direction of heat transfer – from air to cold rock surface ($T_{AIR}>T_{ROCK}$)
deep spring warmings	**C-3**	summer type	intensive infiltration	freezing of infiltration water; development of the re-sublimation ice (ice crystals sediment) in the whole cave area	T_{AIR} below 0 °C, constant increase of T_{AIR}; RH value stops changing and increases rapidly to 100 %; **Type-2** of air temperature changes	heat supply caused by air flowing into the cave, by infiltration water and by latent heat (re-sublimation process, freezing process); direction of heat transfer – from air to cold rock surface ($T_{AIR}>T_{ROCK}$)
spring freezes	**C-4**	winter type	limited infiltration (possible with high snow-melt water resources in ground and rock massif)	if infiltrations occurs – intensive freezing of water; lack of infiltrations – ice sublimation on the ice monolith surface; development of the re-sublimation ice (ice crystals sediment) possible	T_{AIR} below 0 °C, significant variations of T_{AIR}; RH value varies form 80 to 95 %; **Type-1** of air temperature changes	direction of heat transfer – from rock surface to cave air ($T_{ROCK}>T_{AIR}$) – the rock massif cools down and the cave air warms up; the cave cooling is intensified by latent heat absorbing (sublimation process); part of the latent heat is returned in re-sublimation and water freezing processes
dry summer periods	**C-5**	summer type	limited infiltration or lack of infiltration (drought)	low intensive ice melting on the ice monolith surface; intensive degradation of ice crystals sediment (air flowing impact)	T_{AIR} around 0 °C; RH around 100 %; **Type-3** of air temperature changes	heat supply caused by air flowing into the cave; this heat is absorbed in ice melting process and is used in rock heating ($T_{AIR}>T_{ROCK}$)
summer periods with precipitations	**C-6**	summer type	water infiltration into the cave (infiltrations depends on intensity of precipitations)	intensive degradation of the cave ice	T_{AIR} around 0 °C; RH around 100 %; **Type-3** of air temperature changes	heat supply caused by air flowing into the cave and by infiltration water; this heat is absorbed in ice melting process and is used in rock heating ($T_{AIR}>T_{ROCK}$)

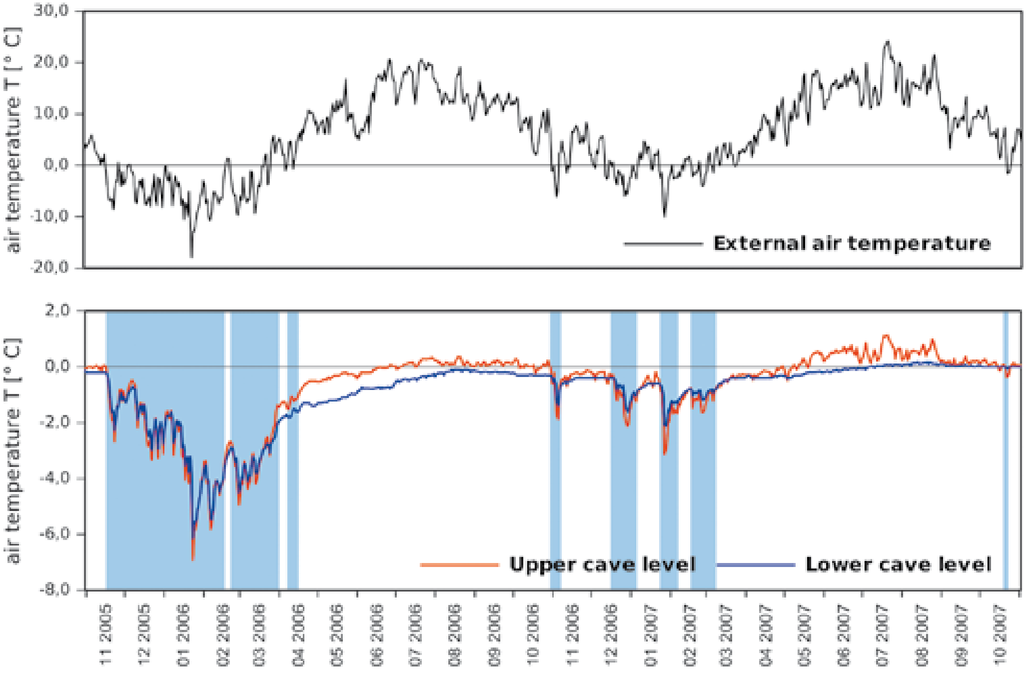


Fig. 6. Comparison of thermal conditions inside and outside the cave in the hydrological years 2006 and 2007. The grey colour indicates periods when the first (C-1) and the fourth (C-4) climate-ice complexes (CWC-3) occurred.

According to the cave climate studies, the seasonal changes in the air exchange between the cave and its surroundings as well as the in-cave air exchange are the main climatogenic factors in the cave climate system. Spatial distribution of the air temperature and humidity and energy balance of the cave depend on them and also (in indirect way) the cave ice development and degradation. There are two types of air exchange: the winter one and the summer one. Each of them dominates in a particular season of a year. However, it happens quite often, that both of them may appear in turns, especially in spring and autumn. The first type of air exchange cools the cave system down while the second is an important component in the process of development (in spring) and in degradation (summer) of the cave ice. As an effect of interaction between ice processes and air exchange processes one can point the characteristic patterns of air temperature and humidity changes which can be observed inside the cave.

Cave climate-ice complexes distinguished in the paper result from the overall changes and dependencies of the cave microclimate. The main characteristics used in the complexes description are: external meteorological conditions, in-cave meteorological conditions, air exchange, simple characteristics of energy exchange and course of ice processes. Definition of the complexes is an attempt to comprehensive description of the climatic conditions of the Dobšinská Ice Cave.

References

Christoforou, Ch. H., Salmon, L. G. & Cass, G. R. 1996: Air exchange within the Buddhist cave temples at Yungang, China. Atmospheric Environment, 30, 23, 3995 – 4006.

Cigna, A. A. 2002: Modern trend in cave monitoring. Acta Carsologica, 31, 1, 35 – 54.

Deacon, J. 2006: Rock art conservation and tourism. Journal of Archeological Method and Theory, 13, 4, 379 – 399.

Fajmon, J., Štelcl, J. & Sas, D. 2006: Antropogenic CO_2 flux into cave atmosphere and its environmental impact: A case study in the Cisařská Cave (Moravian Karst, Czech Republic). Science of the Total Environment, 369, 231 – 245.

Fernández-Cortés, A., Calaforra, J. M., Jiménez-Espinosa R. & Sánchez-Martos, F. 2006: Geostatistical spatiatemporal analysis of air temperature as an aid to delineating thermal stability zones in a potential show cave: Implications for environmental managment. Journal of Environmental Managment, 81, 371 – 383.

Halaš, J. 1980: Vplyv fyzikálnych veličín ovzdušia na genézu ľadových útvarov v Dobšinskej a Demänovskej ľadovej jaskyni. Slovenský kras, 18, 139 – 145.

Halaš, J. 1985: Novše poznatky z merania teploty horninového plášťa. Slovenský kras, 23, 69 – 88.

Halaš, J. 1986: Tepelná bilancia Dobšinskej ľadovej jaskyne. Kandidátska dizertačná práca, Vysoká škola technická – Banícka fakulta, Košice, manuskript, archív Správy slovenských jaskýň, 119 p.

Halaš, J. 1989: Tepelná bilancia Dobšinskej ľadovej jaskyne. Slovenský kras, 27, 57 – 71.

Luetscher, M. & Jeannin, P.-Y. 2004: A process-based clasification of alpine ice caves. Theoretical and Applied Karstology (Special Issue on Ice Caves), 17, 5 – 10.

Mavlyudov, B. R. 1997: Caves climatic systems. *Proceedings of the 4th International Congress of Speleology, Symposium 7: Physical Speleology,* La Chaux-De-Fonds, 191 – 194.

Novotný, L. 1995: K veku jaskynného systému Stratenskej jaskyne. *Ochrana ľadových jaskýň, Zborník referátov z odborného seminára,* Dobšinská Ľadová Jaskyňa, 21. – 22. 9. 1995, Liptovský Mikuláš, 37 – 41.

Pflitsch, A., Piasecki, J., Sawiński, T., Strug, K. & Zelinka, J. 2007: Development and degradation of ice cristals sediment in Dobšinská Ice Cave (Slovakia). In Zelinka, J. (ed.): *2nd International Workshop on Ice Caves, Proceedings,* 38 – 49.

Piasecki, J., Sawiński, T. & Zelinka, J. 2005: The spatial differentiation of air temperature in the entrance collapse of Dobšinská Ice Cave as a contribution to the recognition of air exchange between the cave and its environment. Slovenský kras, 43, 81 – 97.

Piasecki, J., Sawinski, T. & Zelinka, J. 2008: The structure of air flow inside the lower part of the Dobšinská Ice Cave (the Underground Floor – Ice Cliff area). Slovenský kras, 46/1, 127-141.

Piasecki, J., Zelinka, J., Pflitsch, A. & Sawiński, T. 2004: Structure of air flow im the upper parts of the Dobšinská Ice Cave. *Výskum, využívanie a ochrana jaskýň, Zborník referátov zo 4. vedeckej konferencie,* 113 – 124.

Russel, M. J. & MacLean, V. L. 2008: Management issues in a Tasmanian tourist cave: Potential microclimatic impacts of cave modifications. Journal of Environmental Management, 87, 474-483.

Strug, K., Piasecki, J., Sawiński, T. & Zelinka, J. 2004: The ice crystals deposit in the Dobšinská Ice Cave. *Výskum, využívanie a ochrana jaskýň, Zborník referátov zo 4. vedeckej konferencie*, 125 – 133.

Strug, K., Perşoiu, A. & Zelinka, J. 2008: Preliminary results of ice temperature measurements in the Dobšinská Ice Cave (Slovakia) and Scărişoara Ice Cave (Romania). *3rd International Workshop on Ice Caves, Proceedings*, 16 – 22.

Strug, K. & Zelinka, J. 2008: The influence of extremely different external thermal conditions on the ice forms occurrence in slovak ice caves in the 2005 – 2007 period. *3rd International Workshop on Ice Caves, Proceedings*, 74 – 84.

Tulis, J. & Novotný, L. 1989: Jaskynný systém Stratenskej jaskyne. Osveta, Martin, 464 p.

Tulis, J. & Novotný, L. 1995: Čiastková správa o morfometrických parametroch v zaľadnených častiach Dobšinskej ľadovej jaskyne. *Ochrana ľadových jaskýň, Zborník referátov z odborného seminára*, Dobšinská Ľadová Jaskyňa 21. – 22.9.1995., Liptovský Mikuláš, 25 – 28.

Wigley, T. M. L. & Brown, M. C. 1976: Cave Meteorology. In Ford, T. D. & Cullingford, C. H. D. (eds.): *The Science of Speleology*, Academie Press, 329 – 344.

PRESERVATION OF CAVE FLOOR AND ITS IMPORTANCE FOR INTERPRETATION

Matej Kržič

Bloška Polica 9, 1384 Grahovo, Slovenia

Abstract: The cave consists of floor, walls and ceiling. The conservation and interpretation of cave floor is often neglected at the expense of parts of the cave rich in cave inventory. Some managers are showing sensitivity to floor conservation and interpretation. They manage cave infrastructure in a way the least possible damage to the cave floor is done. We can not present the universal solutions for the conservation of cave floor. It is necessary to take into account the specifics of each cave. In particular the number and the target groups of visitors.

Keywords: show caves, cave floor, conservation, interpretation

The cave consists of floor, walls and ceiling. Visiting show caves in France, Italy and Slovenia, we noticed that conservation of cave floor is been often neglected in the past at the expense of parts of the cave rich in cave inventory. Paths through show caves must be located and arranged in a way that allows visitors easy and safe movement. In many cases, builders exaggerated the width of the path that is not necessary for the movement through the cave. They built massive fences and stairs in places that are not dangerous for visitors.

Fig. 1. The massive construction. Archive of Križna jama.

This type of building destroys number of interesting shapes on the cave floor, causes losing the natural look of the cave and prevents good interpretation of speleogenesis. Despite the fact that most show caves in Europe are visited by small groups of visitors (up to 20 people at once) and also have a small total annual number of visit (less than 1,000 visitors), the cave floors in many show caves are completely covered by sand and concrete. It would be enough for the safe movement of visitors through the cave if the path was much narrower. Exaggeration is also present in the construction of the massive iron structures as fences and stairs seen in Fig. 1. Fences are very massive, the stairs are built for few 10 times greater capacity than the total weight of visitors.

Some managers are showing sensitivity to floor conservation and interpretation. They manage cave infrastructure in a way the least possible damage to the cave floor is done. As it is an example in the Križna jama cave in Slovenia. In this cave we see an alternative way of building path, which keeps the floor of the cave natural as much as possible. The path through the cave is only 100 cm wide. It is wider only in places where visitors stop and look at the important features of the cave: rocky formation, the bones of

Fig. 2. The path through the cave covers a small part of the cave floor. Archive of Križna jama.

cave bears. The trail is marked by two white plastic stripes, which can be easily removed or replaced. Most of the cave floor is preserved in its natural form (Fig. 2).

To a large extent contact between cave walls and floor is also preserved. Usual construction of paths hides or covers this contact with layers of sand or concrete. To preserve the cave floor we can use narrow higher leveled path made of steel or concrete as it was done in Postojnska jama seen on Fig. 4. Using such methods of construction and installation it is easier to show and interprete the processes that have formed the cave in the distant past. It is also easier to explain the current processes. The advantage of the method described above can be seen at a time of extreme events such as floods in the cave. On Fig. 3. we see sediments that were deposited by flood waters on the cave path. We could remove sediments from the path, but in that case we would lose the interpretation of extreme events.

Fig. 3. Sediment deposition on the tourist path. Archive of Križna jama.

Fig. 4. Method of construction that keeps the cave floor more natural. Archive of Križna jama.

We can not present the universal solutions for the conservation of cave floor. It is necessary to take into account the specifics of each cave. In particular the number and the target groups of visitors. A sustainable way of installing path as it is done in Križna jama is suitable for dry caves with a small number of visitors and naturally preserved caves, which are not suitable for hard-moving people and people with disabilities. It is necessary to establish and build the path in a different way in caves with large numbers of visitors and wider represented target groups of visitors such as young children, older people, people with decreased abilities. Our opinion is that building infrastructure should follow the principle of minimalism in all types of caves. Paths should be constructed as narrowly as possible. The rest of the cave floor should remain naturally preserved.

CAVE TOURISM IN THE POLISH-SLOVAK TRANSFRONTIER AREA

Łukasz Lewkowicz

Maria Curie-Skłodowska University in Lublin; e-mail: lewkowicz83@gmail.com

Abstract: The aim of this paper is to present the issues of cave tourism on the Polish-Slovak borderland, either in the present or in the past. In the presentation, the beginnings of the cave tourism in the 18th and 19th century century and the first facilitated caves will be introduced. However, the main considerations will be focused on the present day, when touring the caves became not only a popular form of spending one's spare time, but also an important branch of local economy. All of the caves on the borderland, which are currently opened for tourists, will be characterised. The specific of the Polish and Slovak caves will be presented as well.

Keywords: cave tourism, show caves, speleohistory, borderland

INTRODUCTION

Today there are many caves available for visitors in the world. Each year millions of people practice cave tourism. It is one of the most dynamically developing forms of tourism. Polish-Slovak borderland has notably great potential in this field. The area is the one of the richest karst regions of Poland and Slovakia. Since the 19th century there have been an intensive development in cave tourism there. Today there are 7 caves available for tourists on Polish side of the borderland, including 6 in Tatra Mountains (Mroźna, Mylna, Raptawicka, Obłazkowa, Smocza Jama, Dziura) and one in Silesian Beskids (Malinowska Cave). In turn on Slovak side of the border there are 6 caves opened for visitors (Demianowska Cave of Liberty, Demianovska Ice Cave, Bielska, Ważecka, Dobszyńska Ice Cave, Staniszowska). The borderland is taken as a whole in this paper due to the geographical closeness and large interest of Polish tourists in Slovak caves.

The aim of this article is to present comprehensively an issue of cave tourism on Polish-Slovak borderland, both in contemporary and historical point of view. To start with, the origins of cave tourism in the 19th and the beginning of 20th century will be presented. However, the main considerations will focus on current situation – the times when visiting caves is not only a way of spending spare time, but also an important branch of local economy. All caves, which are currently available for tourists on the borderland, will be characterized. The uniqueness of Polish and Slovak show caves will be presented as well. The opportunities and threats of the development of cave tourism on common borderland will also be described. The conclusions of this article could be used for creating a strategy of development of cave tourism by managing institutions, which function in that region, particularly by Slovak Caves Administration and Tatra National Park Administration.

HISTORY OF THE BORDERLAND CAVE TOURISM

The caves from the borderland have been penetrated since the end of the 13th century. At the beginning the most accessible ones were used as shelters for hunters and shepherds. Since the 14th century gold-diggers and miners started to search the caves. Locals also visited them in search of mythic treasures or natural values, which could be used, for example, in curing. In 1672 the first notification about Tatra cave was published. The description of what was supposed to be Magurska Cave, was made by Johann Peterson Hain, who was a physician in Presov. In the beginning of the 18th century the caves of Bielskie Tatra were examined by the chancellor of Kežmarok high school, Georg Bohusch. Later on, Georg Buchholz Junior, who became the chancellor of the same school, also examined caves, for example Demianovska Ice Cave, of which he produced the first plan. The research that Bohusch and Buchholz did was used by Matej Bel in his historical and geographical works (Parma *et al.* 1989: 50-51).

With the beginning of 19th century a new era of Tatra caves' exploration started. It lasted until 1860s Tourism development contributed in progressive discovering of caves' values, which resulted in their exploitation in tourist and scientific aims. The greatest interest of that time focused on caves in Kościeliska Valley, as well as Magurska Cave and Dziura. In Bielske Tatra the most popular cave was Alabaster Cave. A Polish poet, Seweryn Goszczyński, visited Wodna pod Pisaną Cave for several times in 1832. Because of the his motivation of this underground trip, which was simply curiosity, he is recognized as a trailblazer of cave tourism. On the other hand, the first scientist who examined Tatra caves was Ludwik Zejszner. He was a geologist and in 1849 he undertook hydrological research in Lower Kasprowa Cave. Between 1881 and 1882 Gotfryd Ossowski also conducted some archeological research at Tatra region (Siarzewski 2005: 54-56).

After 1860s the interest in caves on the borderland increased, so some of the first ones were opened for tourists. That was the time when the access to Demianowska Ice Cave was provided. The same thing happened with Dobszyńska Ice Cave in 1871. What is more, in 1887 an artificial lighting has been installed there. Owing to that Dobszyńska Ice Cave is recognized as the first illuminated cave in the world. Bielska Cave, which was re-discovered in 1881, was made available for tourist a year later and very quickly also became a popular tourist attraction (Bella 2003: 11-30). The development of cave tourism on Polish side of the borderland was strictly connected with the speleological activity of Jan Gwalbert Pawlikowski. Between 1879 and 1885, together with a guide, Maciej Sieczka, he searched Tatras looking for caves. He published the results of his exploration in an article entitled *Podziemne Kościeliska (The Underground of Kościeliska)*. It consisted of descriptions or a least short notices of more than 30 caves, including some in Slovakia (Brestovska, Bielska). Additionally schematic plans of Mylna and Raptawicka Caves were attached. Pawlikowski was also the first to determine the tourist values of these caves: hidden entrance, scope of the view, forest location, branching of passages, existence of an alternative entrance, dripstone structures, occurrence of water and ice, acoustics and light. He also addressed a postulate to forbid using torches in the caves due to the damages they cause to the walls (Pawlikowski 1887: 33-48). Pawlikowski took an initiative on blazing the trails to Mylna Cave and Zbójnickie Okna, which were done by the Tatra Association in 1886. In the following year paths to Raptawicka and Zimna Caves were built, moreover, in 1889 a trail to Magurska Cave was renewed (Siarzewski 2005: 56-57).

The information about the tourist caves in the borderland were published in popular Polish guidebooks by the end of the 19th century. *Ilustrowany Przewodnik do Tatr, Pienin i Szczawnic* (*Illustrated Guidebook for Tatra, Pieniny and Szczawnice Mountains*) by Walery Eliasz, which was published in 1870, contained information about several Tatra caves, including Magurska Cave. In the second edition of that book author added descriptions of his visits to Demianowska Ice and Dobszyńska Caves, and later on in the third version he also mentioned about Bielska Cave. In the interwar period these descriptions were used by Tadeusz Zwoliński in his own guidebooks. All caves of the borderland were characterized only in 1885 in Antoni Rehman's book, entitled *Karpaty opisane pod względem fizyczno-geograficznym* (*Capathian Mountains described in respect of physical and geographical terms*) (Lalkovič 1998: 105-106; Wójcik 2005: 68-71).

In the interwar period the most significant issue connected with cave tourism was the discovery of Demianowska Cave of Liberty by Alois Král in 1921 – it was also known as the Chram Slobody (Temple of Liberty), in honor of newly created Czechoslovakia. The charm of the cave resulted in undertaking certain activities to provide access to the cave for visitors. Within a year a special commission for making Demianowska Caves available was established. In 1923 an artificial lighting was installed and in 1924 the first section was opened for tourists. In a year, the commitments of the commission were taken by a new institution – Demianowska Caves Association. In the 1930s other parts of the cave were opened for visitors, as well as new entrance was dug. One of the chambers was named the "Polish House". The discovery of Demianowska Caves gave an impulse to develop speleology and cave tourism in Slovakia. Another searching for caves started being organized. Already in 1922 Ważecka Cave was found. The same year, František Havránek rented it for next 30 years. At that time he started works providing access to the cave. The opening celebration took place in 1928. After a complete renovation it was reopened in 1954. Same works were held after the II World War in Demianowska Ice Cave, which was made available for the second time in 1952 (Bella 2003: 19-59). Since the 1950s works for providing access to Demianowska Cave of Peace were also undertaken, however, eventually it has never been ready to receive visitors. Since 2010 tourist are able to see Small Staniszowska Cave, which is located in Low Tatras.

The interwar period on the Polish side of the borderline was characterized, on the one hand, by stagnation in cave tourism, while on the other hand, by remarkable speleological activity of two brothers, Tadeusz and Stefan Zwoliński. One of the aims of their works was to find caves in Polish Tatras with rich dripstone structures, which, similarly to Bielska Cave, could be available for tourists. In 1934 Stefan Zwoliński discovered Mroźna Cave. It was opened for visitors in 1953. In the following years some further modernizing works were conducted. Lighting system was also installed. Finally, the Mroźna Cave was opened for mass tourist traffic in 1959. Zwoliński brothers discovered also some new sections in Mylna and Obłazkowa Caves (Parma *et al.* 1989: 79-80). Malinowska Cave, which is located in Silesian Beskids, is relatively new object available for individual tourists (Szewczyk *et al.* 2009: 93-94).

REVIEW OF THE BORDERLAND SHOW CAVES

Most of the caves on Polish borderland are situated in Western Tatra Mountains, strictly in Kościeliska Valley. The best-known tourist attraction there is Mroźna Cave, located in the Organy massif in the eastern part of Kościeliska Valley. The cave forms a nearly 500 m corridor, piercing through the whole massif. The time of touring is estimated 30 – 40 min. The most interesting sections of the cave are: the Great Chamber, the Garden, the Sabała Lake, and Sand Lakes. It is the only cave on Polish borderland that is equipped with lighting. Moreover, only in this one a fee for touring is collected.

Another cave that is available for visitors is Smocza Jama, which is located in Cracow Ravine. The cave itself it is just a steeply inclined and slightly curved rocky tunnel through calcareous rocks. Tourist route is 40 m long and it could be passed within a couple of minutes. The passage is steep and it is secured with protective chains. Own lighting is required.

Three other caves are located on the hillside of Raptawicka Peak. The first one is Raptawicka Cave itself. The entrance hole is situated about 120 m above the bottom of Kościeliska Valley. You come in the initial chamber through a steel ladder. The chamber has a cluttered character and its bottom is filled with calcareous blocks. Periodically an underground rain occurs there, which in the winter results with dripstones. A few others corridors are available for tourists as well. In one of those corridors there is a little chapel. Entirely, the cave is about 150 m long. It is available a whole year round. For visiting the deepest sections of the cave own lighting is required.

The second cave of Raptawicka Peak is Obłazkowa Cave. It does not consist of dripstone structures. In early spring some icy dripstones occur only just by the entrance to the cave. The length of the whole cave is 120 m, however, only first 20 m are available for tourists. It is opened year long. Own lighting is necessary.

Just by Obłazkowa Cave there is one of the most interesting caves from the point of view of average tourist. It is called Mylna Cave. It forms a really complex maze of corridors and chambers, were it is highly likely to get lost – in 1945 a tourist died there. In total, the length of the cave is estimated 1300 m, of which about 270 m are provided for tourist traffic. The tour takes around 60 min. The most enchanting sections of that cave are: Pawlikowski's Windows, the Great Chamber, the Choirs and the White Street. Own lighting is required.

The last cave that is available for tourists in Polish Tatras is Dziura Cave, which is located in the direct vicinity of Zakopane, in the Towards the Dziura Valley. It is 180 m long, while the drop is 43 m. In touring the cave an additional lighting might be helpful. The main attraction of that cave is a 9 m high stone chimney tipped with the upper entrance. During the winter icy dripstones could be found there (Barczyk *et al.* 2007: 35-41).

The only cave described in this paper, which is located outside Tatra Mountains, is Malinowska Cave. It is placed in Silesian Beskids. Its length is 230 m, of which 100 m are available for visitors. It is not a karst cave, so it does not have any dripstone structures. It consist of numerous corridors and chambers created in Carpathian flysch. The cave is wet and in many places a cave rain occurs as well. Own lighting, proper equipment, clothing and footwear are required.

Bielska Cave is the only one that is available for tourists in Slovak Tatras. It is located in the northern slope of Kobyli Wierch in Bielskie Tatras. The cave is 3018 m long, of which 1370 m are open for visitors. The approximate time of touring is 70 min. The cave has rich dripstone structures. It is worth to pay attention on gathering waterfalls, pagoda stalagmites and underground lakes.

Ważecka Cave is situated in so-called Ważecki Karst in Slovak Sub-Tatra region. The length of the cave is 530 m and the tourist route is 235 m long. The cave has a very interesting yellow dripstones. Simultaneously, it is an important palaeontological site. Numerous bones of cave bear have been found there.

Demianowska Cave of Liberty is located in Demianowska Valley in the northern part of Low Tatras. The cave is 8126 m long. There are two tourist routes prepared there: the long one, which is 2150 m for 100 min, and traditional, when within 60 m you pass 1145 m. The cave is abounding in multicolored dripstone structures. Special attention should be paid on dripstones resembling water lilies, flowstone waterfalls, sphaerolitic stalactites, moonmilk and cave pearls. Two conical stalagmites, often called "Rococo Girls" are symbols of that cave. The most charming places in the cave are: the Pink Hall, Royal Gallery and the Great Dome.

There is also Demianowska Ice Cave in the same valley. Its length is 1975 m, of which 850 m are available for tourists. The tour usually lasts 45 min. In the lower sections of the cave there is an ample accumulation of ice. It also has attractive icy dripstone structures. The walls of the one of the chambers are full of inscriptions, which come from the 18th century and the following years. In the past, there could be found some bones of different vertebrates there, including cave bear.

Janska Valley in Low Tatras locates another show cave – Small Staniszowska Cave. This structure is 730 m long, however, tourist can visit only a route of 410 m. The time of touring is 45 – 60 min. There are some inscriptions from the beginning of the 20th century there. A shamanic village is placed there as well. The cave does not consist of artificial lighting, so by the entrance tourist are given helmets equipped with lamps.

The last cave, called Dobszyńska Ice Cave, is located in Slovak Paradise. It is the only cave on the borderland which is on UNESCO List. The cave is 1,483 m long, of which 515 m are available for visitors. The tour lasts about 40 min. What is specific about this cave are the enormous amounts of ice – it is 26.5 m in the thickest extent. Due to the type of glaciation that cave is one of the most valuable ice caves in the world (Bella 2003: 10-59).

CHARACTERISTICS OF THE BORDERLAND SHOW CAVES

The above characterization indicates to some differences between caves on Polish and Slovak sides of the borderland. Apart from Mroźna Cave, all others on the Polish borderland are not adapted for mass tourist traffic (undeveloped caves). There are relatively short and small (variety of 20 – 500 m). They do not consist artificial lighting. Moreover, there are no concrete, or at least wooden pavements installed inside. There are no guided tours organized there, as well as any tolls for the visit are provided – there is only a fee for entering the Tatra National Park and Mroźna Cave, which is 3 pln (0,8 euro). Tatra caves have been used as a tourist attraction for 150 years and that is why their conditions are far from the original state. The caves are devastated and strongly distorted. They do not have dripstone decoration. Due to the research made by Tatra National Park Administration in 1999 the Smocza Jama cave was visited by 214,000 people, Mroźna Cave had nearly 200,000 visitors, about 100,000 people toured Obłazkowa, Raptawicka and first part of Mylna Caves, and through the Dziura, situated just by Zakopane, around 60 000 people walked. Yearly, Tatra caves are visited by about 750,000 – 800,000 tourists (Siarzewski 2002: 4). There are no sufficient information in terms of Malinowska Cave. It is visited mostly by individual tourists. Some private firms organize integrational courses for their employees there (refers to Association of Cave Protection "Malinka" Group 2010).

However, caves in Slovakia can be characterized in totally opposite way. All of that local caves are prepared for mass tourist traffic. The cave are relatively big and long (variety of 235 – 2150 m). They are provided with high standard tourist infrastructure. There are educational boards placed along the path to the caves. Tickets offices offer souvenirs, such as albums, books or postcards, in Polish as well. Apart from Small Staniszowska Cave, all caves own artificial lighting. The access to the caves is paid between 4 and 14 euro. Guided tours are available for visitors as well. The guides play recordings in many different languages, including Polish. From time to time classic music is played too. It should also be emphasized that Slovak caves are not only used in strictly tourist purposes. Dobszyńska Ice Cave is the best example, where in 1890 a concert in memory of Karl Ludwig of Habsburgs was organized there, while since 1893 summer ice skating park have been arranged there too. Moreover, between 1993 and 1998 a speleotherapy sessions were held in Demianowska Cave of Liberty.

Slovak caves, similarly to Polish ones, are in tourist use since the 19th century. The number of tourists visiting those places is increasing year by year. In 1931 about 21,000 people visited Dobszyńska Cave. The same year, the attendance to Demianowska Cave of Liberty amounted 10,000 visitors, and in 1932 it was already 12,000 (Przegląd Turystyczny 1933: 15). According to the data of Slovak Caves Administration from 2008 over 180,000 people toured Demianowska Cave of Liberty, while in case of Bielska it was 146,000, Demianowska Ice 103,000, Dobszyńska Ice 76,000, and Ważecka received 20,000 tourists. At total, between 2002 and 2008 the previously mentioned caves were visited by 520,000 people a year, a great number of whom were Polish. A breakdown in cave tourism occurred in 2009. The attendance to Slovak caves decreased of 34 % in comparison to previous years. It is assumed that besides introducing euro currency in Slovakia the main reason of the decline was the global economical crisis (refers to Slovak Caves Administration 2010). Despite their intensive use, Slovak caves did not undergo any transformations and distortions, unlike caves in Polish Tatra Mountains. All of the caves have well-preserved, often unique, dripstone structures. They are also an important archeological sites.

OPPORTUNITIES AND THREATS OF TRANSFRONTIER CAVE TOURISM

The analysis of cave tourism on the borderland inclines to draw several fundamental conclusions. The impact of Poland's and Slovakia's accession to European Union and Schengen Agreement on the development of transfrontier tourism should be considered absolutely positively. In recent years there was an increase in the number of communication connections, which run in the vicinity of Slovak caves. In Zakopane there are a few companies which run bus connections on the routes between Zakopane-Poprad and Zakopane-Liptowski Mikulasz. Both in summer and winter seasons the buses also run between Cracow and Demianowska Valley.

Since 2009 there is a possibility to fly with plane from Warsaw to Poprad. One-day trips around Tatra Mountains, which are offered by travel agencies, are also very popular among tourists.

Tourist attractions on both sides of the borderland are complementary to each others. Slovak caves, which are professionally prepared for mass tourist traffic, are large, with rich dripstone structures, and they are a great attraction for guests from Poland. On the other hand, there are Polish caves, which are "wild", undisturbed, unlit, and practically free, however, they could be an interesting sights for Slovak tourists. What is a great asset of Slovak caves is the institutional support. Tourist caves are managed by Slovak Caves Administration, located in Liptowski Mikulasz. This city also holds the seat of the Museum of Nature Protection and Speleology. These both institutions do not have their equivalent in Poland. All Polish caves in Tatras are subordinated to Tatra National Park Administration, but Malinowska Cave is under supervision of Vistula Forest Inspectorate.

However, there are some threats that stand in the way to cave tourism development. The main problem is the financial issue. Introducing euro currency in Slovakia seems to be a disputable question. Available analysis indicates that the new currency evoked the crisis in borderland's tourism. High price of euro caused a notable decrease in the number of Polish tourists visiting northern Slovakia in 2009. It also influenced on the lesser attendance in Slovak caves. This occurrence escalated due to the global economic crisis since 2008. As a consequence of price rise for tourist services in Slovakia, Polish tourist changed their visiting targets. Zakopane region became much more attractive for them instead of Slovakia's parts of Tatra Mountains. Simultaneously, the number of Slovaks, who visited Polish border cities for shopping, significantly increased. However, it is a typical trade tourism, which is connected with the price differences in those countries. The solution of that situation could be lowering of payments for visiting Slovak caves. Introducing some discounts for organized groups, bigger reductions for children, students and pensioners or family tickets should be considered as well. It is also worth reflecting on abolishing or at least introducing a huge lowering of the charges for photographing and filming in the caves, not to mention car park fees.

The second fundamental issue is the lack of sufficient promotion of the caves on the both sides of the borderland. In this case the situation in Slovakia looks much better. Slovak Caves Administration runs a professional website, where basic information about all of the tourist caves, such as the description, payments, visiting hours, are posted. The site is available in 5 languages, including English and Polish. Unfortunately, in Polish version the "current events" section is not updated. Small Staniszowska Cave also has its own website, which is available in 6 languages. The Administration provides a lot of promotional materials in several languages. In Poland information about the caves could be found on the website of Tatra National Park, as well as some tourist portals. In 1978 and 1989 there was a publication of a guidebook entitled *Jaskinie turystyczne Tatr* (*Tatras tourist caves*), which was written by Christian Parma and Apoloniusz Rajwa. Apart from the description of Polish caves Slovak ones were also included. So the guidebook in fact had a transfrontier character. Only 20 years later, in 2009 another speleological guidebook was published. It was *Jaskinie. Polska, Czechy, Słowacja* (*Caves. Poland, Czech, Slovakia*) by Izabela and Robert Szewczyk. It consisted of the descriptions of the most important show caves in those three countries. Despite the existence of guidebooks mentioned above, it is necessary to develop a new, common one, describing show caves of the borderland. It should be bilingual – both in Polish and Slovak. It could also have a multimedia character. The guidebook could be financed with the exploitation of European Union's funds within the framework of Polish-Slovak Transfrontier Cooperation Programme 2007 – 2013. At least 2 organization on both sides must submit a proposal of micro-project in the Tatra Euroregion Office for the program implementation.

The third and the last problem is the issue of reconciling cave tourism with the requirements of environmental protection. This difficulty occurs mainly on Polish side of the borderland. In the beginning of the 1990s Tatra National Park Administration undertook research of human's influence on the exact state of environmental condition of Tatras' caves. Obtained results confirmed the information about the progressive degradation, destruction and pollution of many caves. A good example of such negative processes provides Mroźna Cave, which today's actual conditions are far from the original state. Since the moment of its discovery, the cave's walls were covered with sediments nearly to their tops. Long-standing works for making Mroźna Cave available for visitors, during which a new entrance and hundreds of meters of new corridors were discovered, caused essential changes in the cave's original environment. Moreover, in 1958 precious dripstone decoration was destroyed by the tourists during the opening celebration of the cave. In the beginning of 1990s a fresh trace of digging an underground passage to the neighboring Naciekowa Cave was found. Today the main problem of visiting the cave is insufficient tourist infrastructure. In the vicinity of the cave there is shortage of litter bins and toilets. Some tourist handle with their physiological needs in the nearby of the entrance to the cave. The same thing refers to throwing out the litter. The absence of guides enables destructive behaviors inside the cave, for example signings on the walls or destruction of dripstone structures. Moreover, insufficient lighting is conducive for the development of lampenflora on the walls (Grodzicki *et al.* 1999: 1-46).

Slovak caves are preserved in much better conditions. But also in cases of them some unfortunate decisions were made. In the 1930s an experiment of artificial glaciations of Bielska Cave was undertaken. In the beginning a plentiful glaciation was received due to the process. Unfortunately, during the summer season the ice has melted and it resulted in total destruction of dripstone structures in this part of the cave. In 1920s a group of rough-mannered tourists destroyed dripstone structures in Demianowska Ice Cave. What is more, they took away all of the bones that were placed there as well. During explorative works that were conducted between 1950 and 1952 (among other, Cave of Peace was discovered then) the cave's thermal balance was disturbed, and as a result, significant parts of the ice cap has also melted. In subsequent years some works in aim of reviving the level of glaciation were conducted (Parma *et al.* 1989: 99-109).

For protecting the caves form further degradation there are some essential steps that should be taken. First, it is necessary to organize a constant program of cleaning the caves. Second, construction of suitable infrastructure, such as litter bins, toilets, security means, at the most attended places, is a must. Third, a control system of cleanness for all of the caves and their surroundings should be established. Fourth, it is necessary to hold research on the tourist influence on the caves and their environmental conditions (Grodzicki *et al.* 1999: 45). It is also important to rise ecological awareness of visitors through educational programs, as well as media campaigns. All of these activities could be conducted not only by representatives of state institutions, but also by members of NGOs and volunteers.

Conclusion

Polish-Slovak borderland is one of the most important karst regions both in Poland and Slovakia. Today, 13 caves are functioning there as tourist attractions. These caves are very diverse. The analysis made in this paper indicate significant differences in Polish and Slovak tourist caves. In this comparison, Slovak caves go much better. Specificity of Polish caves in Tatra Mountains shows a certain complementary of the studied region. Today the development of transfrontier cave tourism is dependent, to a high degree, on external conditionings, such as Schengen Agreement, euro currency in Slovakia, or global economic crisis. Despite a certain collapse in mutual relations, cave tourism is still a very profitable business. Tourist attractions very often wind up the economic situation in the whole region around the caves. However, the above analyse shows that nonetheless some problems occur on the borderland. On the Polish side they refer to the lack of sufficient infrastructure, inefficient environmental protection and bad promotion of tourist caves. In Slovakia too expanded commercialization of cave tourist is the biggest obstacles. The fees for visitors, as well as for other tourist services, are too expensive. It discourages Polish tourists to visit Slovak caves. To solve these problems it is necessary to take up common activities by institutions on both sides of the borderline. A good example of that type of initiative would be a preparation of a common, transfrontier tourist guidebook.

References

Barczyk G., Ładygin Z. 2007: Jaskinie dla turystów. Tatry, special edition, pp. 35-48.

Bella P. 2003: Jaskinie słowackie udostępnione dla zwiedzających, Liptowski Mikulasz, pp. 10-59.

[No author] 1933: Frekwencja turystów w jaskiniach słowackich, Przegląd Turystyczny, 2, p. 15.

Grodzicki J., Recielski K., Siarzewski W. 1999: Antropogeniczne zmiany w wybranych jaskiniach tatrzańskich cz. 1, Zakopane, pp. 1-46.

Lalkovič M. 1998: Poliaci a záujem o jaskyne na Slovensku. Čast I. – Do roku 1918. Slovenský Kras, 36, pp. 105-106.

Parma Ch., Rajwa A. 1989: Turystyczne jaskinie Tatr, Warszawa, pp. 50-109.

Pawlikowski J. G. 1887: Podziemne Kościeliska. Pamiętnik Towarzystwa Tatrzańskiego, 11, pp. 33-48.

Siarzewski W. 2002: Ochrona i udostępnianie jaskiń w Tatrzańskim Parku Narodowym. Materiały z X Międzynarodowej Szkoły Ochrony Przyrody i Obszarów Krasowych. Smoleń-Złoty Potok 25-27.09.2002, p. 4.

Siarzewski W. 2005: Z dziejów poznania jaskiń w Tatrach, Tatry, 11, pp. 54-57.

Slovak Caves Administration website, www.ssj.sk, [avalaible 01.10.2010].

Szewczyk I., Szewczyk R. 2009: Jaskinie. Polska, Czechy, Słowacja, Warszawa, pp. 93-94.

Wójcik W. 2005: Gdzie byś poszedł w góry? Słowacki obszar Euroregionu Tatry w polskiej literaturze przewodnikowej. Pogranicze Polsko-Słowackie, 2, pp. 68-71.

TOURIST CARRYING CAPACITY IN CAVES: MAIN TRENDS AND NEW METHODS IN BRAZIL[1]

Heros Augusto Santos Lobo[1], José Alexandre de Jesus Perinotto[2], Paulo César Boggiani[3]

[1] São Paulo State University (UNESP/Rio Claro-SP), Post-Graduation Program of Geosciences and Environment; heroslobo@hotmail.com
[2] São Paulo State University (UNESP/Rio Claro-SP), Applied Geology Department (DGA/IGCE); perinoto@rc.unesp.br
[3] University of São Paulo (USP/São Paulo-SP), Geosciences Institute (IGc); boggiani@usp.br

Abstract: The establishment of touristic carrying capacity is one of the greatest challenges facing environmental planners and managers. In relation to caves, the question is especially complicated due to the unique characteristics of the environment, such as spatial confinement, absence of light, and a lower dispersive flow of mass and energy. The present article presents the main tendencies in the limitation of the visitation of caves, with emphasis on Brazilian examples. Five conceptual trends were presented, including two new ones, developed recently in Brazil. It is concluded that any values obtained from any calculation of carrying capacity should be understood as a starting point for what must then be subjected to constant monitoring so that the causal network between variability in critical factors and human presence can be identified and more adequate solutions found. Thus the carrying capacity should be studied as a function of variation, intensity and frequency of demand, as well as of seasonal dynamics in the resilience of caves environment.

Keywords: carrying capacity, caves of Brazil, management of caves, environmental conservation, tourist caves

INTRODUCTION

Speleotourism is a segment of tourist activity which is widely exploited internationally. Cigna and Burri (2000) list more than 200 caves adapted for tourist visitation around the world, especially in Europe and Asia; only 20 of these are located in Brazil. However, this paper refers only to caves with institutionalized tourism. Lobo *et al.* (2008) present a list of some 200 caves in Brazil subject to some sort of tourist visitation, especially in regions such as the national parks (Serra da Bodoquena, Peruaçu, Ubajara, and Chapada Diamantina) and state parks (Touristic Park of the Upper Ribeira [PETAR], Intervales, Diabo Cave, Campinhos, Sumidouro and Terra Ronca) and natural monuments (Lago Azul cave, Maroaga cave, Peter Lund, and Rei do Mato cave), as well as other cavities in private lands.

In this universe, less than 40 caves maintain some sort of control of daily visitation (provisional or permanent); most of them, no specific management plan has yet been elaborated to regulate speleological tourism.

Moreover, a still small number of caves – less than 10 – are adapted for mass tourism – or large scale tourism, as it called in Brazil. The average of visitors in these caves is 20,000 – 50,000 per year (Lobo *et al.* 2010a).

One of the fundamental steps in the planning for the tourist use of a cave is the determination of the quantitative and qualitative limits for visitation, which must be based on physical, biological and social environmental factors. Reference studies on the subject on an international level have been made by Cigna and Forti (1988), Cigna (1993), Hoyos *et al.* (1998), Calaforra *et al.* (2003), and Fernández-

1 The presentation of this article is available at ttp://www.sbe.com.br/diversos/Loboetal_ISCA2010.pdf>.

Cortes *et al.* (2006a, b). In Brazil the main papers published were those of Boggiani *et al.* (2001, 2007) for the caves of the Natural Monument Lago Azul Cave in Bonito city, in the state of Mato Grosso do Sul, and of Lobo (2005, 2008) for the cave of Santana in Iporanga city, in the state of São Paulo.

In this scenario, and based on secondary studies and field work in Brazilian caves, the present article provides a synthesis of the methods for determining the carrying capacity of a cave, who was established on the basis of different environmental realities of caves and considering the possibilities and limitations of managing agencies.

CONCEPTS OF CARRYING CAPACITY IN CAVES

The carrying capacity is an idealized planning tool to permit managers of an area or tourist attraction to make decisions about the maximum intensity of visitation to be allowed in a given interval of time (Cifuentes 1992; Hoyos *et al.* 1998; Carranza *et al.* 2006). In relation to management, it is the maximum acceptable flow of visitors for a cave without causing irreversible alterations in the natural environmental dynamics (Mangin *et al.* 1999; Boggiani *et al.* 2007; Lobo 2008). In general, the carrying capacity is understood as a way

> of identifying the quality of recreational experience which is appropriate to a particular cave environment, and determining the environmental conditions consistent with that use. Thus the question has moved away from just simple numbers of people in caves to the social and environmental conditions which should prevail. Several complementary management tools have emerged. All of them involve the translation of qualitative management goals to quantitative management objectives using environmental indicators and standards (Gillieson 1996: 250–251).

Another more operational definition considers the fact that impact is inevitable and will be acceptable up to a given limit; the carrying capacity for speleotourism is thus defined as:

> The possibility of temporal-spatial limitation for the use of a cave so that environmental damages be avoided, with the resilience as key factor. Its origin derives from the possibilities for the management of an area so that the broader negative impacts of tourism on a larger scale could be mitigated or diluted, based on environmental fragility and in the possibilities of visitation (Lobo 2008: 383).

The determination of carrying capacity depends on the investigation of environmental parameters under natural conditions – including environmental seasonality –, as well as responses to monitored visits (Fernandez-Cortés *et al.* 2006a). These relationships of cause and effect may vary as a function of different levels of exchange of mass and energy in underground systems (Heaton 1986) and the inherent complexity of environmental systems (Bertalanffy 1972).

The methods of calculating carrying capacity tend to be centered on the theoretical modeling of the physical space, with rare exceptions based on the consideration of specific aspects of the biological aspects (Lobo 2008; Silva & Ferreira 2009). However, it is important that the determination of the carrying capacity of a cave be based on multidisciplinary studies, rather than merely on parameters of the physical aspects (Hoyos *et al.* 1998; Boggiani *et al.* 2007). In practice, the papers consulted (e.g. Cigna & Forti, 1989; Pulido-Boch *et al.* 1997; Hoyos *et al.* 1998; Cigna & Burri 2000; Cigna 2002; Calaforra *et al.* 2003; Fernández-Cortés *et al.* 2006a,b; Boggiani *et al.* 2007; Lobo 2008; Russell & McLean 2008) consider climatic monitoring as the minimal study for the identification of the carrying capacity in caves, since the alteration of atmospheric parameters such as temperature and relative humidity of the air can generate negative consequences throughout the environment.

Despite the clear theoretical understanding of the characteristics of carrying capacity, no standard procedure for its determination has been established (Lobo 2008), and various different methods are used on a local, regional, or continental scale; they depend on: a) the characteristics of the cave; b) the kind of visitation practiced; and c) the management capacity of the responsible environmental agency.

In the literature, three main tendencies for the determination of carrying capacity were found: control based on a coefficient of rotation; environmental parameters; or the Cifuentes method. The latter was, however, developed for the management of trails, but applicable with certain limitations for itineraries in caves. In addition to these well-known and widely applied models, other two possibilities can be added, both developed in Brazil: the confrontation of environmental fragility with projected scenarios and a time-based option.

VISITATION TURNOVER COEFFICIENT (VTC)

The VTC is the simplest form of controlling visitation for touristic itineraries and can also be utilized in caves. In essence, it calculates the number of people who could physically occupy a given surface area at a given unity of time, and then establishes the number of times that a visitation event could occur. It is thus a basic relationship between spatial and temporal feasibility.

An example of this kind of limitation, developed in Brazil, is quite useful for the management of vertical caves. In the case of the Anhumas pit (Figure 1a), located in Bonito city, in the state of Mato Grosso do Sul, Brazil, the limit for visitation is established as a function of the technical difficulty and the time necessary to traverse the 72 meters of vertical drop from the entrance, both for entering and for leaving, as well as the time spent in floating in the lake in the interior of the cave. In this case, visitation limits are very low – 18 persons per period of a day – although the cave is so large that if only environmental aspects were considered, many more people could visit it during any one day.

CONTROL OF ENVIRONMENTAL PARAMETERS

The determination of carrying capacity via the control of environmental parameters is necessary when some critical environmental factor of known fragility exists which should limit visitation. Moreover, it is useful when there is a linear relationship between cause and effect for the presence of visitors and variation in some identified critical factor. Its use is common in caves which shelter archeological remains, such as rupestrian paintings (e.g. Hoyos *et al.* 1998), or which contain rare minerals whose conservation depends on the stability of the atmospheric medium (e.g. Fernandez-Cortes *et al.* 2006b).

Hoyos *et al.* (1998) determined a numerical limit of 32 people at any one time in the Candamo cave in Spain, based on the impact of the temperature of the air. A similar principle was used by Calaforra *et al.* (2003) in the Cueva de Agua de Iznalloz in Spain. These authors arrived at a limit of 53 visitors at the same time in the cave, based on temperature alterations of 0.1°C. For the giant geode of Pulpi, also in Spain, Fernandez-Cortes *et al.* (2006b) explain the unfeasibility of visitation, not only due to the direct impact of trampling of the gypsite crystals, but also to the great probability of an increase in the rate of water condensation on the surface of the speleothems, which could lead to condensation corrosion. These authors point out that the presence of only three people in a period of less than 10 minutes was sufficient to trigger this mechanism of condensation. Moreover, the time required for normalization of atmospheric parameters exceeds 24 hours, making constant visitation unfeasible.

Another characteristic associated with these methods is the regular use of statistical procedures in the analysis of results, such as time series analysis based on descriptive statistics (Hoyos *et al.* 1998; Boggiani *et al.* 2007), Fourier transformations, and spectral analysis (Mangin *et al.* 1999; Calaforra *et al.* 2003; Fernández-Cortés *et al.* 2006a), trend surface analysis (Fernández-Cortés *et al.* 2006a; Lobo & Zago 2010) and correlation coefficients (Liñán *et al.* 2008; Lobo *et al.* 2009).

Such a means of obtaining the carrying capacity of a cave is linked to the identification of a maximum number of visitors per group, which does not necessarily reflect the accumulated total of daily visits possible.

CIFUENTES CARRYING CAPACITY

The carrying capacity of Miguel Cifuentes Arias is a method published in 1992 (Cifuentes 1992) and republished with slight adaptations in 1999 (Cifuentes-Arias *et al.* 1999). It was originally planned for the management of trails in tropical forested areas in Costa Rica and considered the limitations of human and material resources in countries or regions with few resources (Cifuentes 1992). The first adaptation known for use in caves was that adopted for the Lago Azul cave (Figure 1b) in Bonito city (Mato Grosso do Sul state, Brazil) in 1999 (Boggiani *et al.* 2001; 2007). Other examples are the cave of Terciopelo in Costa Rica (Carranza *et al.* 1996), the cave of Santana in Brazil (Lobo 2005, 2008), and the caves of Phong Nha and Tien Son, in Vietnam (Nghi *et al.* 2007).

This method consists of three stages. In the first stage, that of physical carrying capacity (CCR), a VTC is established for the itinerary of visitation. In the second, the Real Carrying Capacity (CCR) is established by the insertion of correction factors (reflecting problem situations such as the fragility of the environment and aspects which make visitation more difficult) which are used to reduce the CCR by a given percentage for each of the limiting aspects identified. In the final phase, the Effective carrying capacity (CCE) is determined. This either maintains the total number of visitors allowed by the CCR or reduces it as a function of the capacity for management (either existing or desired) of the managing agency responsible for the itinerary under study.

In the management plan of the Lago Azul cave, the main limiting aspects considered were those of an anthropic nature, such as the difficulty of access along the itinerary. Microclimatic studies were also conducted in the cave, but they were not actually utilized in the calculations due to the dynamics of the exchange of gases between the underground medium and the external environment. In the cave of Santana (Figure 1c), the used limiting aspects involved the comfort of the visitors and the energy flow level, using the concept of Heaton (1986) as a basis, as well as a practical application of the concept developed by Lobo and Zago (2007).

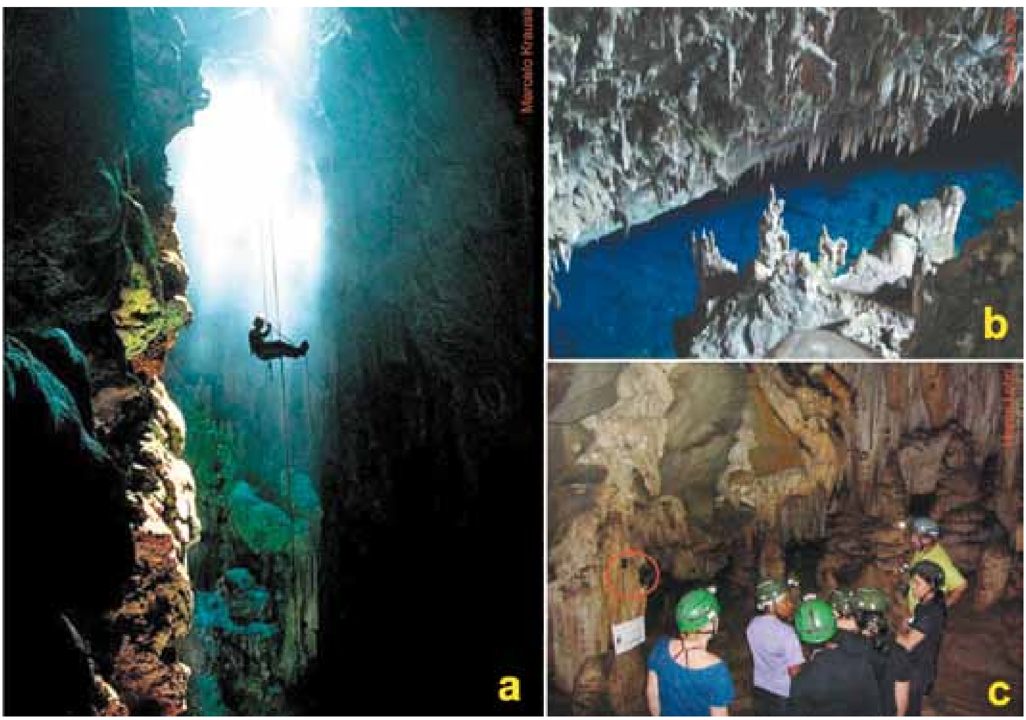


Fig. 1 a) Tourist entering by rappel in the Anhumas pit (city of Bonito, Brazil); b) Partial view of the lake and speleothems of Lago Azul cave (city of Bonito, Brazil); c) A tourist group with a tour guide in the Encontro hall, in the cave of Santana (Iporanga city, Brazil) – one of the monitored places of this cave (the red circle shows the datalogger, who is monitoring the relative humidity and the temperature of the air and the cave wall, with an external probe)

The difficulties in the application of the Cifuentes method are: a) the fact that it was originally designed for trails in tropical forests, and it loses much in its adaptation to cave environment; b) the system of calculation adopted juxtaposes factors and does not permit the identification of a single critical factor; and c) the lack of a causal nature between the limitations generated and the parameters analyzed.

NEW BRAZILIAN PERSPECTIVES IN SPELEOTOURISTIC CARRYING CAPACITY

In addition to these established methods used for determining the carrying capacity of caves which are widely utilized in the most diverse political-socioenvironmental contexts, two new approaches are under development in Brazil. These consider various realities of touristic-speleological management, such as the limited time available for the studies, the lack of human resources, and the unfeasibility of constant review of established standards.

SCENARIO PROJECTION AND LIMITATION BASED ON ENVIRONMENTAL FRAGILITY

The confrontation of an idealized scenario for the visitation of caves with the actual fragilities encountered in the environment has recently been proposed in Brazil (Lobo *et al.* 2010b). It requires the collaboration of a multidisciplinary team composed of professionals in tourism, geographers, geologists, biologists, and environmental managers, and was applied in 30 caves opened to visitation in State Parks of São Paulo, Brazil. The first step is a survey of the possibilities of what would be desirable for each cave, considering both the preferred scale of visitation (size of groups) and intensity of use (total number of visitors per day). This scale of visitation contemplates different kinds of visitation (school groups, ecotourists, adventurers etc), with this profile influencing the difficulty of the proposed itinerary, and the aspects of environmental conservation focused on.

This projected scenario is then submitted to an analysis of the fragilities of the environment, considering various aspects of the portion of the cave to be included in an itinerary, including morphology; the number, location, and composition of the speleothems; the presence of archeological or paleontological remnants; the stability of the microclimate; and the fauna found in the aquatic, terrestrial and aerial biotas. These factors of fragility are integrated using two criteria: maximum fragility (calculated for each portion of the cave) and weighted fragility (a weighted average for all of the fragilities analyzed). Fig. 2 and Table 1 provide some examples from Diabo cave, as well as values projected for the scenarios and the final carrying capacity established.

Lobo *et al.* (2010b) point out that the limits established are provisional and that the results must be monitored, with future modifications to be made as necessary based on the realities of each itinerary. The need for modification is to be identified via continuous reports of environmental conditions.

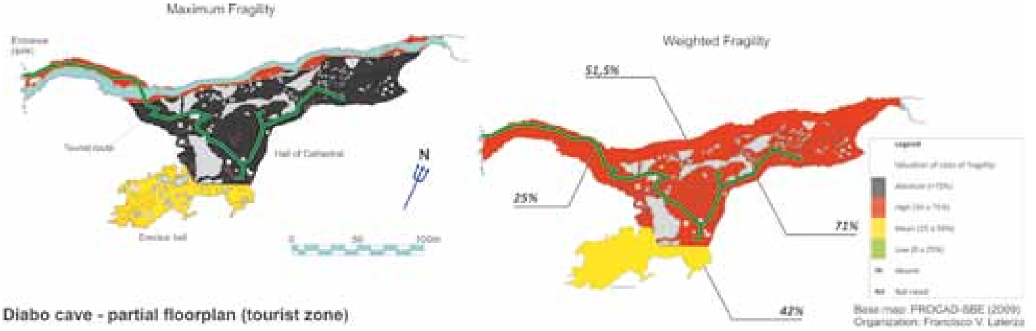


Fig. 2. Integrated maps of fragilities of the tourist zone of the Diabo cave – maximum and weighted (translated for Lobo et al. 2010b)

Table 1. Projected scenarios and provisional carrying capacity of the Diabo cave

Route	Projected scenario (visitors/day)	Visitors/ group	Provisional carrying capacity (visitors/day)	Recommendations for environmental monitoring
Tour route	1300	50	1100	air temperature and relative humidity
River route	100	10	80	aquatic fauna in the river
Erectus hall	30	6	18	physical damages in the speleothems; carbon dioxide concentration

CARRYING CAPACITY BASED ON LIMITATION OF VISITATION TIME ALLOWED

The final method for determining touristic carrying capacity in caves is also being developed in Brazil. Studies have been conducted in the cave of Santana, with atmospheric monitoring including parameters of temperature (of air, water and rock), relative humidity, CO_2, atmospheric pressure and wind (Lobo 2010). The operational logic of the method is based on control via limitation of visitation time based in the main environmental parameter – which can be changed for each cave. No attempt is made, however, to totally eliminate impacts, as is attempted in the case of most environmental control methods, but rather to limit them. The main characteristics of this new method are:

– delimitation of the path for visitation.
– simultaneous monitoring of the atmosphere in various points of the cave,
– the limits are based on the capacity of the environment to disperse the impacts generated so there will be no daily accumulations.

Considering this, correlation formulas between the visitors flow and their respective impacts are been developed, especially in caves where the dynamics of the environment do not permit identification of a linear relation of cause-effect between visitors and specific environmental impacts.

FINAL CONSIDERATIONS

Based on the examples in Brazil and abroad, it was concluded that each of the methods is useful in specific situations, since each reflects in some way a series of environmental fragilities that are related to the management of the relevant agencies.

For some situations, the VTC, the determination of a provisional carrying capacity (Lobo *et al.* 2010b) or the Cifuentes method (1992) are sufficient for the initial organization of speleotouristic use. Techniques such as these can be used to establish temporary limits, but these must be refined on the basis of more detailed technical-scientific studies.

In caves of greater morphophysiographic, microclimatic, and biotic complexity, or when specific aspects of extreme fragility require special protection, other methods are necessary for the establishment of public utilization. These should be based on critical environmental factors, and a carrying capacity based on the impact on these specific factors is called for, either based on linear correlations between stimulus and response or on seasonal variation.

The carrying capacity must be flexible and change as a function of the reaction of the cave to the differences in the planned visitation. The establishment of fixed quantities of visitors as a function of fluctuations of pressure or the profile of demand or based on temporal or environmental cycles is inefficient. It should be remembered that the natural environment changes everytime, renews itself constantly. Establishing a fixed criterion for the management of a natural resource implies the ignoring of this fundamental and universal principle.

ACKNOWLEDGEMENTS

We are enormously grateful to Linda Gentry El-Dash and the Brazilian Society of Speleology (SBE) for assistance into translate the article into English. And we also thank to the Unesp, for the partial financial support the first author participation on the ISCA congress.

References

Bertalanffy, L.V., 1972: *Teoria geral dos sistemas*.- Vozes, pp. 360, Rio de Janeiro.

Boggiani, P.C., Galati, E.A.B., Damasceno, G.A., Nunes, V.L.B., Shirakawa, M.A., Silva, O.J., Moracchioli, N., Gesicki, A.L.D., Ribas, M.M.E., Marra, R.J.C. & B.P.C. de Souza, 2001: Environmental diagnostics as a toll for the planning of tourist activity – the case of Lago Azul and Nossa Sra. Aparecida caves – Bonito/MS – Brazil.- In: Brazilian Society of Speleology (ed.) *Proceedings of International Congress of Speleology*, july 2001, Brasília. SBE/UIS, 299-300, Brasília.

Boggiani, P.C., Silva, O.J., Gesicki, A.L.D., Galati, E., Salles, L.O. & M.M.E.R. Lira, 2007: Definição de capacidade de carga turística das cavernas do Monumento Natural Gruta do Lago Azul (Bonito, MS).- Geociências, 26, 333-348.

Calaforra, J.M., Fernández-Cortés, A., Sánchez-Martos, F., Gisbert, J. & A. Pulido-Bosch, 2003: Environmental control for determining human impact and permanent visitor capacity in a potential show cave before tourist use.- Environmental Conservation, 30, 160-167.

Carranza, G.Q., Fernández, I.B., Porras, J.J., Casco, M.E., Arana, I.G., Mahecha, S.L. & J.V. Céspedes, 2006: *Estudio de capacidad de carga para la caverna Terciopelo em el Parque Nacional Barra Honda*.- UED, pp. 43, San José.

Cifuentes, M. C., 1992: *Determinación de capacidad de carga turística en áreas protegidas*.- CATIE, pp. 28, Turrialba.

Cifuentes-Arias, M., Mesquita, C.A.B., Méndez, J., Morales, M.E., Aguilar, N., Cancino, D., Gallo, M., Ramirez, C., Ribeiro, N., Sandoval, E. & M. Turcios, 1999: *Capacidad de carga turística de las áreas de uso público del Monumento Nacional Guayabo, Costa Rica*.- CATIE/WWF, pp. 99, Turrialba.

Cigna, A. A., 1993: Environmental management of tourist caves: the examples of Grotta di Castellana and Grotta Grande del Vento, Italy.- Environmental Geology, 21, 173-180.

Cigna, A. A., 2002: Modern trend in cave monitoring.- Acta Carsologica, 31, 35-54.

Cigna, A. A. & P. Forti, 1988: The environmental impact assessment of a tourist cave.- In: Kranjc, A. (ed.) *Cave Tourism International Symposium at-170 Anniversary of Postojnska Jama, Postojna (Yugoslavia)*, UIS, 29-38, Postojna.

Cigna, A. A. & E. Burri, 2000: Development, management and economy of show caves.- International Journal of Speleology, 29, 01-27.

Fernández-Cortés, A., Calaforra, J.M., Sánchez-Martos, F. & J. Gisbert, 2006a: Microclimate processes characterization of the giant geode of Pulpí (Almería, Spain): technical criteria for conservation.- International Journal of Climatology, 26, 691-706.

Fernández-Cortés, A., Calaforra, J. M. & F. Sánchez-Martos, 2006b: Spatiotemporal analysis of air condition as a tool for the environmental management of a show cave (Cueva del Agua, Spain).- Atmospheric Environment, 40, 7378-7394.

Gillieson, D., 1996: *Caves: processes, development and management*.- Blackwell, pp. 324, Cambridge.

Heaton, T., 1986: Caves: a tremendous range in energy environments on earth.- National Speleological Society News, 8, 301-304.

Hoyos, M., Soler, V., Cañaveras, J.C., Sánchez-Moral, S. & E. Sanz-Rubio, 1998: Microclimatic characterization of a karstic cave: human impact on microenvironmental parameters of a prehistoric rock art cave (Candamo cave, Northern Spain).- Environmental Geology, 33, 231-242.

Liñán, C., Vadillo, I. & F. Carrasco, 2008: Carbon dioxide concentration in air within the Nerja cave (Malaga, Andalusia, Spain).- International Journal of Speleology, 37, 99-106.

Lobo, H.A.S., 2005: Considerações preliminares para a reestruturação turística da caverna de Santana – PETAR, Iporanga, SP.- In: Sociedade Brasileira de Espeleologia (ed.) *Anais do Congresso Brasileiro de Espeleologia*, SBE, 77-87, Campinas.

Lobo, H.A.S., 2008: Capacidade de carga real (CCR) da caverna de Santana, PETAR-SP e indicações para o seu manejo turístico.- Geociências, 27, 369-385.

Lobo, H.A.S., 2010: *Dinâmica atmosférica subterrânea na determinação da capacidade de carga turística (Caverna de Santana, PETAR, Iporanga-SP)*.- PhD Thesis (preliminary version). Universidade Estadual Paulista, pp. 315.

Lobo, H.A.S. & S. Zago, 2007: Classificação dos níveis de circulação de energia no circuito turístico da Caverna de Santana – PETAR – Iporanga, SP.- In: Redespeleo (ed.) *Caderno de Resumos do Encontro Brasileiro de Estudos do Carste*, Redespeleo, 113-122, São Paulo.

Lobo, H.A.S. & S. Zago., 2010: Iluminação com carbureteiras e impactos ambientais no microclima de cavernas: estudo de caso da lapa do Penhasco, Buritinópolis-GO.- Geografia, 35, 183-196.

Lobo, H.A.S., Perinotto, J.A. de J. & P.C. Boggiani, 2008: Espeleoturismo no Brasil: panorama geral e perspectivas de sustentabilidade.- Revista Brasileira de Ecoturismo, 1, 62-83.

Lobo, H.A.S., Perinotto, J.A. de J. & S. Poudou, 2009: Análise de agrupamentos aplicada à variabilidade térmica da atmosfera subterrânea: contribuição ao zoneamento ambiental microclimático de cavernas.- Revista de Estudos Ambientais, 11, 22-35.

Lobo, H.A.S., Sallun Filho, W., Veríssimo, C.U.V., Travassos, L.E.P., Figueiredo, L.A.V. de & M.A. Rasteiro, 2010a: *Espeleoturismo: Oferta e demanda em crescente expansão e consolidação no Brasil*.- MTur, pp. 20, Brasília.

Lobo, H.A.S., Marinho, M. de A., Trajano, E., Scaleante, J.A.B., Rocha, B.N., Scaleante, O.A.F. & F.V. Laterza, 2010b: Planejamento ambiental integrado e participativo na determinação da capacidade de carga turística provisória em cavernas.- Turismo e Paisagens Cársticas, 3, 31-43.

Mangin, A., Bourges, F. & D'Hulst, 1999: La conservation des grottes ornées: um problème de stabilité d´un système naturel (l´e exemple de la grotte préhistorique de Gargas, Pyrénées françaises).- Earth and Planetary Sciences, 295-301.

Nghi, T., Lan, N.T., Thai, N.D., Mai, D. & D.X. Thanh, 2007: Tourism carrying capacity assessment for Phong Nha – Ke Bang and Dong Hoi, Quang Binh province.- VNU Journal of Science, Earth Sciences, 23, 80-87.

Pulido-Bosch, A., Martín-Rosales, W., López-Chicano, M., Rodríguez-Navarro, M. & A. Vallejos, 1997: Human impact in a tourist karstic cave (Aracena, Spain).- Environmental Geology, 31, 142-149.

Russell, M. J. & V.L. Maclean, 2007: Management issues in a Tasmanian tourist cave: potential microclimatic impacts of cave modifications.- Journal of Environmental Management, 87, 474-483.

Silva, M. S. & R.L. Ferreira, 2009: Caracterização ecológica de algumas cavernas do Parque Nacional de Ubajara (Ceará) com considerações sobre o turismo nestas cavidades.- Revista de Biologia e Ciências da Terra, 9, 59-71.

INTEGRATED CAVE ENVIRONMENTAL MONITORING SYSTEM (ICEMS)

Jana Marikovičová[1], Jozef Omelka[1], Dagmar Haviarová[2], Peter Gažík[2], Ján Zelinka[2]

[1] MicroStep-MIS, Čavojského 1, 841 04 Bratislava, Slovakia; omelka@microstep-mis.com, jana.marikovicova@microstep-mis.com
[2] State Nature Concervancy of the Slovak Republic, Slovak Caves Administration, Hodžova 11, 031 01 Liptovský Mikuláš, Slovakia; haviarova@ssj.sk, zelinka@ssj.sk, gazik@ssj.sk

Abstract: A specialized cave microclimate and hydrologic monitoring system was established in 5 show caves managed by Slovak Caves Administration in 2007. The basic goal was to set up a system which will be able to monitor selected parameters in caves continuously, with automatic data transfer to central database, remote access to data loggers in caves an with a possibility to use it also in caves without electric power supply.
ICEMS is a result of a joint research and development of two partners: Slovak Caves Administration and MicroStep-MIS. ICEMS belongs to key products of MicroStep-MIS. Cave monitoring system is a unique integrated system consisting of permanent and mobile data loggers, communication network, data collection and central database and management system. This system consists of sensors measuring different environmental parameters. At the same time the climatic conditions outside the cave are measured. Meteorological stations near cave entrances are included into monitoring system.
All the sensors are connected to the data logger which is specially designed for cave environment (high humidity, small size, watertight...). Measured values are stored locally on each logger's CF card. The system has two modes of measurement: Standard mode, Micro mode. Standard mode allows measurement every 10 or 60 minutes. Micro mode allows measurement every minute or every 10 seconds. The system further consists of sophisticated data collection, database, data processing and data presentation software. Data Collection application is designed for data collecting from datalogger network. Cave monitoring system is an open one, it can be extended or modified according to customers' requirements. The number of connected sensors can be modified too. One of the main system advantages is the ability of remote control and maintenance.

Keywords: cave microclimate, monitoring system, radon, cave environment, rock temperature, air flow, water sensors

THE PURPOSE OF MONITORING

A specialized cave microclimate and hydrologic monitoring system was established in 5 show caves managed by Slovak Caves Administration in 2007. The basic goal was to set up a system which will be able to monitor selected parameters in caves continuously, with automatic data transfer to central database, remote access to data loggers in caves and with a possibility to use it also in caves without electric power supply.

Cave microclimate monitoring is from the scientific point of view useful to have better knowledge of cave geo-systems, determination of anthropogenous influence on climate changes, on stability and regeneration possibilities of caves, especially show caves.

The main requirements on the functionality of the system were: sufficient capacity of own battery sources for at least 2 or 3 months, protection against over-voltage in case of power from the mains, protection against lightning, reliable functionality of probes in cave environment (high relative air humidity and low temperature in ice filled caves) and ranges of measurement important for caves.

SYSTEM

Integrated cave environmental monitoring system (ICEMS) is a result of a joint research and development of two partners: Slovak Caves Administration and MicroStep-MIS. ICEMS belongs to key products of MicroStep-MIS. Cave monitoring system is a unique integrated system consisting of sensors, permanent and mobile data loggers, communication network, data collection and central database and management system (Fig. 1).

System structure

- sensors
- data loggers
- communication network
- data collection and management system
- central database

System was developed, installed and is serviced by MicroStep-MIS and Slovak Caves Administration.

MicroStep-MIS develops software and hardware equipments as well as complex solution of monitoring systems, integration of environmental systems to unified networks.

SENSORS

This system consists of sensors measuring (Fig. 2):

- air temperature
- relative humidity – specially designed for high humidity in caves
- rock temperature
- wind speed and direction (2D, 3D)
- precipitation
- drip inlet
- evaporation
- global solar radiation
- CO_2
- radon Rn^{222} – designed for continous measurement of Rn^{222}
- water temperature
- water quality – conductivity, pH, NOx, Cl
- water quality – spectrometric measurement
- water level
- air pressure

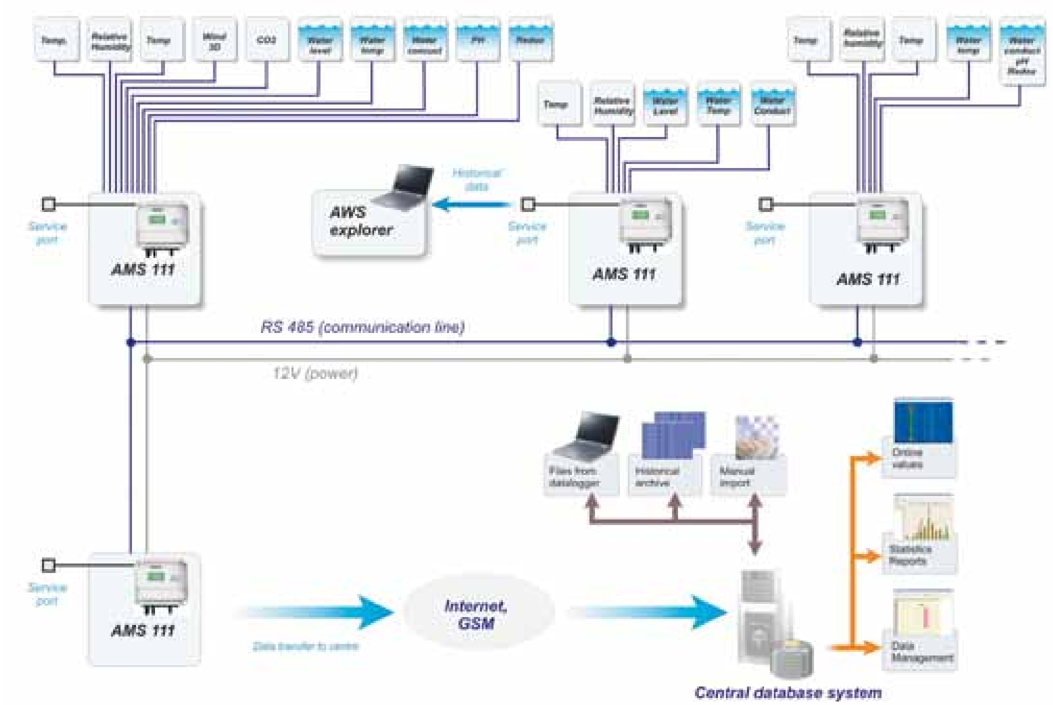


Fig. 1. Cave system overview

At the same time the climatic conditions outside the cave are measured. Meteorological stations near cave entrances are included into monitoring system (Fig. 3).

DATA LOGGER

All the sensors are connected to the data logger (Fig. 4) which is specially designed for cave environment (high humidity, small size, watertight...).

The logger is easy to maintain, with a very low consumption, flexible and easy to configure to any sets of sensors. Measured values are stored locally on each logger CF card. Storing is not limited by card capacity regarding to rich avalability of high capacity cards. Online data transmission is via RS485, WiFi, GSM / GPRS, etc. and is managed by the central system.

Cave monitoring system is equipped with effective overvoltage (lightning) protection. The system is scalable from one mobile station powered by a battery to a national monitoring for all the caves in the country with powerful central system.

Fig. 2. Different sensors and data logger in ice cave.Photo: J. Zelinka

Data logger has standard equipment as touch screen, battery, external/internal memory, communication interface (RS232, RS485, Bluetooth).

Other technical parameters of data logger used in caves:
- 22x precise differential, inputs resolution 24 bit,
- 12x digital inputs (0-20V),
- accuracy better than 1μV,
- 5 additional analog inputs.

The data logger has DC input, main battery and back-up battery for memory. Data logger contains integrated

Fig. 3. Meteorological station outside the cave. Photo: J. Zelinka

Fig. 4. Data logger. Photo: J. Zelinka

RS485 data communication line and RS232 service line. It can be equipped with optional GSM modem. Data logger can be connected with PDA for file browsing via portable Bluetooth. In PDA it is possible to check current data, configure logger parameters and download, upload configuration file as well as the data files.

The data loggers inside cave are operated on 230V power. In case of 230V power loss the data logger is equipped with main battery that provides backup power and high consumption sensors are switched off automatically. When the logger is operating with power from the main battery, sensors that require large amount of power are disconnected.

The data logger has build in compact flash memory with capacity up to number of GB (similar to USB keys). The measured data can be stored in this memory for several months.

The data logger has RS232 service port. User can download data and change settings using PDA or laptop computer.

Measurement modes

The system has two modes of measurement: Standard mode and Micro mode.

Standard mode allows measurement every 10 or 60 minutes. 10 minutes measurement interval is designed for static type of system. 60 minutes measurement interval is designed for mobile type of system.

Micro mode allows measurement every 10 or 60 seconds. 10 seconds measurement interval is designed for static type of system. 60 seconds measurement interval is designed for mobile type of system.

Each data logger can operate in both modes (also simultaneously), which can be switched from remote server. There is possibility to change measurement intervals too.

Communication network

Several data loggers are installed inside each cave. They are connected via two wire RS485 communication lines. Outside of the cave is installed external data logger which has GSM module.

External data logger is connected to GPRS network and establishes VPN connection with data centre. The external data logger routes communication between interior data loggers inside the cave and the data centre. The VPN connection is secured by telecommunication operator.

Operation and collection

The system further consists of sophisticated data collection, database, data processing and data presentation software.

Data Collection application is designed for data collecting from datalogger network. Main purpose of the central database (EnviDB) is to:

- automate procedures for the data management and processing,
- integrate data from collection system,
- provide data storage for environmental data and meta-data,
- perform quality control,
- single point of access for end-user services for data provision, distribution and publication.

Historical data from old devices and data from other measurement systems e.g. meteorological institutes can be imported to the central database. EnviDB is software designed for metadata management and collected data processing.

Cave monitoring system is open one, it can be extended or modified according to customers' requirements. The number of connected sensors can be modified too. One of the main system advantages is the ability of remote control and maintenance.

The measured data are collected automatically via GPRS VPN network. The collection software is installed in the HQ building. The data are collected automatically and on-line every 10 minutes.

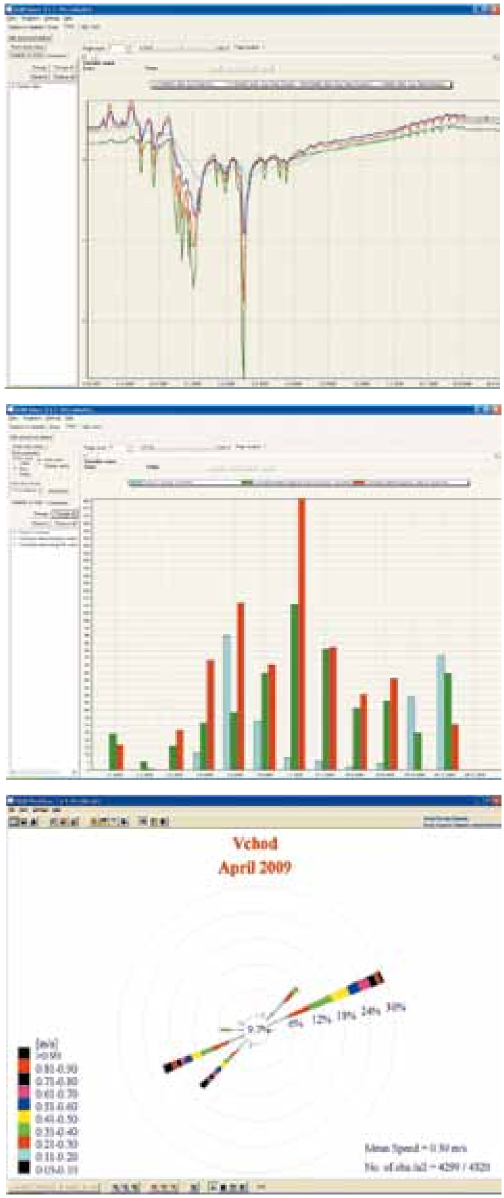
The downloaded data are stored in the central database.

The collection software allows view of all data loggers installed within the caves. User can see current status of communication (Fig. 5). In the messages browser user can view the latest data message downloaded from data logger and decoded values as well.

In the AWS details user can setup the micro regime and schedule automatic start and stop of micro regime (Fig. 6).

Fig. 5. Remote control status of communication

Fig. 6. Setting up the microregime measurement from the office



Figs. 7, 8 and 9.Various graphical interpretations of stored data

USER INTERFACE AND APPLICATIONS

Quality control

Before storing the data it is necessary to pre process the data – decode it from the original data logger records and modify it in into unified structure.

Data quality control is performed because it is crucial to ensure that only correct observations are submitted to database processing.

Wide variety of checks have been developed:

– Elimination of duplicates
– Internal consistency checks
– Comparison with global ranges
– Time line comparisons with other observations
– Manual monitoring and corrections

References

Cave monitoring systems are installed in the caves of Slovakia, Czech Republic and Slovenia.

• Five permanent and six mobile Cave Monitoring Systems are installed in Slovak Caves:

– Demänovská Ice Cave
– Demänovská Cave of Liberty
– Dobšinská Ice Cave (Fig. 10)
– Gombasecká Cave
– Domica Cave

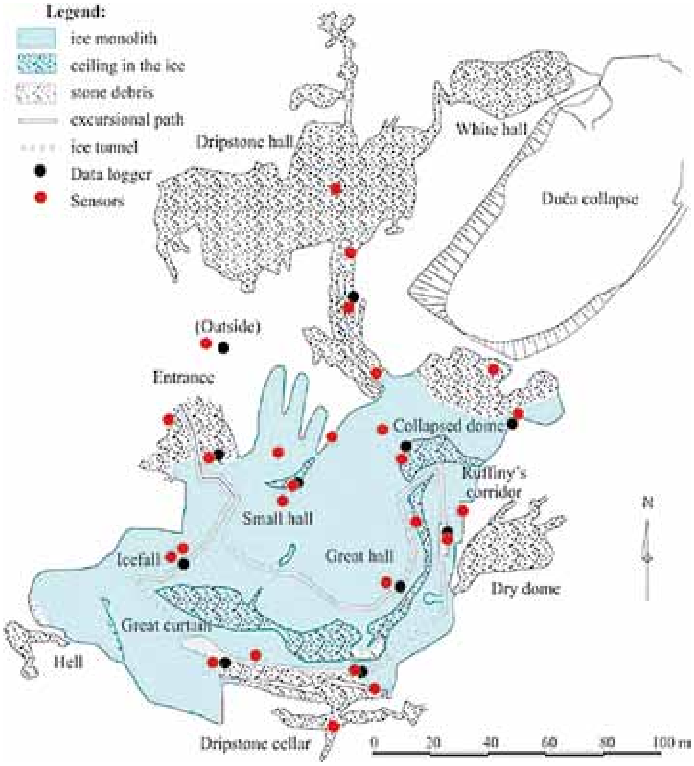


Fig. 10. Distribution of dataloggers and sensors in Dobšinská Ice Cave

Fig. 11. Radon sensor installed in Domica Cave. Photo. I. Smetanová

• One permanent and one mobile Cave Monitoring System is installed in Czech republic:
– Kateřinská Cave

• One permanent Cave Monitoring System is installed in Slovenia:
– Postojna Cave

Radon monitoring in Domica Cave

Continuous radon measurement in Domica Cave started in June 2010. This measurement is based on cooperation of four partners:

1. Slovak Caves Administration
2. Department of Nuclear Physics and Biophysics, Faculty of Mathematics, Physics and Informatics, Comenius University Bratislava
3. Geophysical Institute, Slovak Academy of Sciences
4. MicroStep-MIS, Monitoring and Information Systems

The radon sensor mobile head is measuring alpha decay of ^{222}Rn in measuring passage (Fig. 11). It was installed in Small Hall of Domica Cave. Periodic daily and non-periodic short term variations of ^{222}Rn activity concentration were registered during this short period of radon measurement. Daily average values were in range 0,8 – 2,65 kBq.m^{-3} (Fig. 12).

This measurement is a part of research of cave microclimate regime and research of impact on employees' health as well as the relationship between radon activity concentration changes and meteorological and cave microclimatic conditions study.

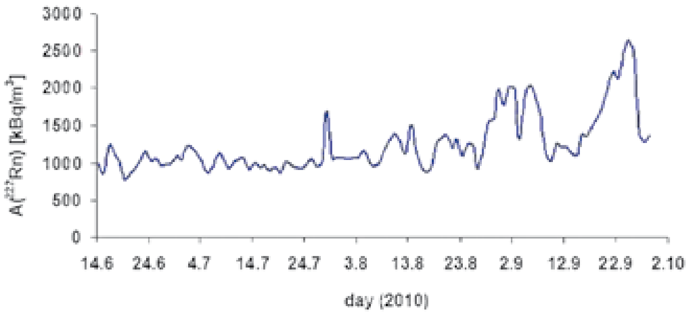


Fig. 12. ^{222}Rn-daily average values from Domica Cave. Author: I. Smetanová

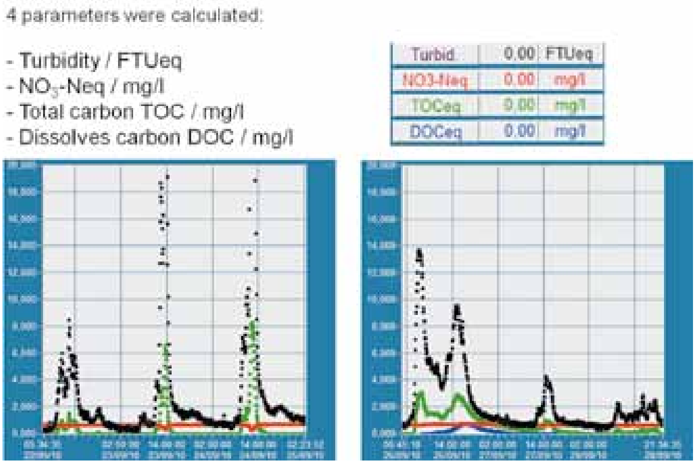


Fig. 13. Continuous water quality monitoring test in Demänovka River

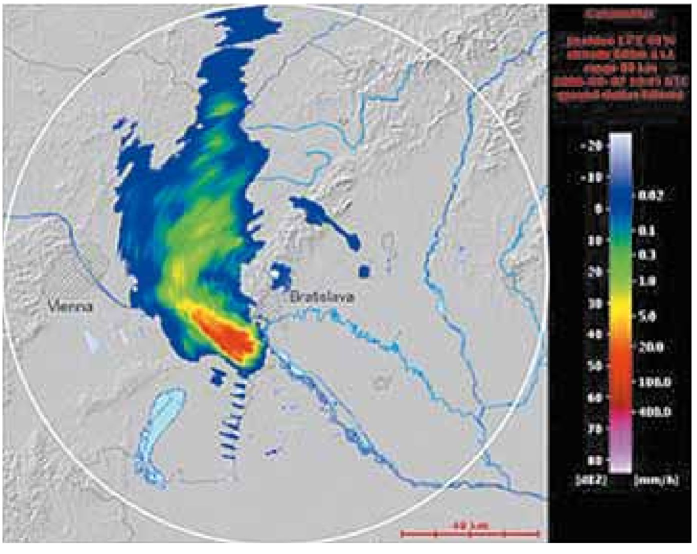


Fig. 14. Graph generated by radar

Water quality spectrometric measurement

Another part of research started in September 2010 – Continuous water quality monitoring of Demänovka River (Fig. 13). The new type of sensor – spectrometric analyser for this type of continuous monitoring was installed in Demänovská Cave of Liberty. Testing monitoring period started on September 17th 2010 and ended on October 1st 2010.

This testing proved the suitability of sensor installation in cave environment. Tested sensors were running without need of maintenance. Registered water quality was without significant changes during this period, the sample of water in Demänovka River was taken. Used type of global calibration method „RIVER" is suitable for water quality monitoring of surface water and four parameters were calculated.

Future

Further development and improvement of the ICEMS is going on. For example a new humidity sensor especially designed for humidity nearing 100 %, is under tests. Development and tests of a new drip sensor will start soon. Lightning and mini weather radar are ready to connect to ICEMS (Figs. 14 and 15). Optimization of spectrographic water quality measurement is under progress. New generation of data logger is ready for installation as well.

Fig. 15. Meteorological radar

Fig. 16. Countries with installed monitoring systems by MicroStep

Mini-portable meteorological radar is prepared for full integration to ICEMS. It is used for:

– detection of severe thunderstorms, intense rainfall, hail, down bursts, etc.
– nowcasting – prognosis from 30 up to 120 minutes
– monitoring and warning before local flash floods
– regional nowcasting with radar with respect on customer safety

Thunderstorm/lightning subsystem is used for detection of discharges by lightning sensor, integration with database of (hazardous) meteorological phenomena. Data displays, data archiving, operator alerts on significant changes/hazards, equipment status reporting and remote maintenance.

About MicroStep

MicroStep-MIS is specialized in development and manufacturing of environmental monitoring and information systems. The company‘s key activities cover: meteorology, seismology, gama radiation, air quality, marine systems, cave environment, crisis information systems. MicroStep-MIS operates worldwide (Fig. 16).

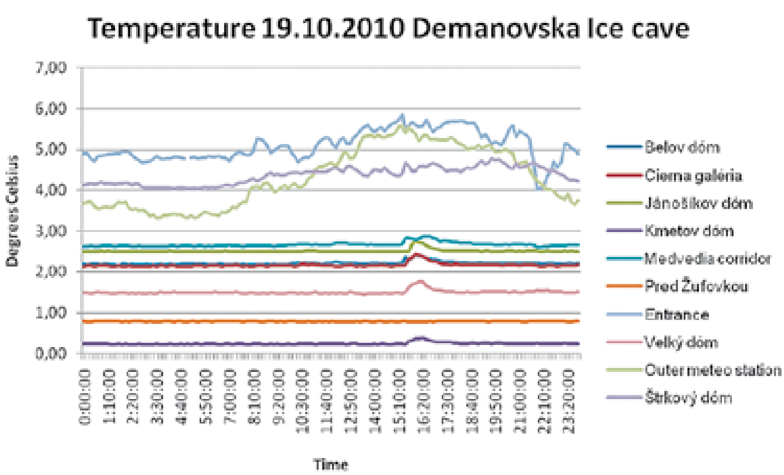


Fig. 17. Change of temperature in Demänovská Ice Cave during the visit of ISCA 6th Congress participants

At the end

Congress participants visited different Slovak caves. Here are the changes of air temperature measured during the visits to this caves (Fig. 17.)

IS WHITE-NOSE SYNDROME A THREAT FOR BATS IN EUROPEAN CAVES?

Natália Martínková[1,2]

[1] *Institute of Vertebrate Biology, Academy of Sciences of the Czech Republic, v.v.i., Květná 8, 60365 Brno, Czech Republic; e-mail: martinkova@ivb.cz*
[2] *Institute of Biostatistics and Analyses, Masaryk University, Kamenice 3, 62500 Brno, Czech Republic*

Abstract: White-nose syndrome is an emerging infectious disease that caused drastic die-offs in North American hibernating bats. It is associated with a fungal skin infection. The fungus, *Geomyces destructans*, grows in cold temperatures, and the body temperature of bats drops during hibernation to that ideal for *G. destructans* growth. In Europe, the fungus was first found in Germany in 2008. Since then it was also reported from France, Switzerland, the Czech Republic, Slovakia and Hungary. Affected bats sometimes have skin lesions, but no massive mortality has yet been observed. The fungus was probably present in Europe for an extended time period, as white growth similar to that of *G. destructans* was found on photographs and reported in literature. The occurrence of geomycosis increased in 2010 in the Czech Republic and Slovakia both in direct observation and on photographs of hibernating bats. Future research should aim to establish if geomycosis in Europe occurs also with the white-nose syndrome, and what effects it has on hibernating bat populations. In the meantime, cave visitors should try to reduce chances of accidental transmission over long distances by using new equipment for expeditions to other continents and thorough decontamination in known infected areas.

Keywords: white-nose syndrome, bats, *Geomyces destructans*, geomycosis, Europe, fungal disease

White-nose syndrome (WNS) is an infectious disease that affects hibernating bats (Blehert *et al.* 2009). In underground hibernacula, including caves, mines, cellars and other structures, infected bats have white fungal growth around their muzzles, on ears and wings. The fungal growth is most prominent towards the end of the hibernation period, and it consists of hyphae and spores of species *Geomyces destructans* (Gargas *et al.* 2009). In North America, the field signs of the WNS include the fungal infection, the geomycosis, aberrant behavior and high mortality (for term definitions, see Table 1; Meteyer *et al.* 2009, Martínková *et al.* 2010, Chaturvedi & Chaturvedi 2011). Winter mortality is often severe at affected sites, and population dynamics predictions show that even widespread species might become locally extinct within two decades (Frick *et al.* 2010).

WNS IN NORTH AMERICA

The spreading of WNS in North America shows signs typical of an emerging disease. The WNS was first identified in 2006 in the north-eastern United States, near Albany, New York (Blehert *et al.* 2009). Since then, the range affected by the disease increased yearly and nowadays includes also show caves. The predominant direction of the front movement is south-west, along the Appalachian Mountains, but it is also found with increasing frequency distant from the mountain range (see Foley *et al.* 2011 for a current map).

The bat species with high mortality associated with WNS include *Myotis lucifugus*, *M.*

Table 1. Definition of white-nose syndrome and geomycosis.

Term	Definition
White-nose syndrome	Specific histopathologic criteria for the disease, including confirmation of the geomycosis
Geomycosis	Fungal infection of *Geomyces destructans* without skin pathology indicative of the WNS

septentrionalis, *Eptesicus fuscus* and *Perimyotis sufblavus* (Blehert *et al.* 2009). *M. lucifugus* is the most affected species in North America. It hibernates in large clusters, amounting up to hundreds of thousands individuals in some hibernacula (Fenton & Barclay 1980), and seasonally the majority of animals in each site might die (Frick *et al.* 2010). In the north-eastern United Stated, *M. lucifugus* might become extinct in less than two decades as the direct consequence of the WNS (Frick *et al.* 2010).

Table 2. Bat species with the Geomyces destructans infection, the geomycosis, in Europe.

Species	Country	Year	Reference
Myotis myotis	France	2009	Puechmaille *et al.* 2010
	Germany	2009	Wibbelt *et al.* 2010
	Switzerland	2009	Wibbelt *et al.* 2010
	Czech Republic	2010	Martínková *et al.* 2010
	Slovakia	2010	Martínková *et al.* 2010
	Hungary	2009	Wibbelt *et al.* 2010
M. bechsteinii	Czech Republic	2010	Martínková *et al.* 2010
M. brandtii	Germany	2009	Wibbelt *et al.* 2010
M. dasycneme	Germany	2008, 2009	Wibbelt *et al.* 2010
M. daubentonii	Germany	2009	Wibbelt *et al.* 2010
M. mystacinus	Czech Republic	2010	Martínková *et al.* 2010
M. nattereri	Czech Republic	2010	Martínková *et al.* 2010
M. oxygnathus	Hungary	2009	Wibbelt *et al.* 2010

GEOMYCOSIS IN EUROPE

Shortly after the outbreak of the WNS in North America and identification of the fungus, *G. destructans* was found in France on a *Myotis myotis* individual (Table 2; Puechmaille *et al.* 2010). The bat had the white fungal growth on its muzzle that was identified genetically and in culture as *G. destructans*. Other than the fungal infection, the geomycosis, the bat appeared to be healthy (Puechmaille *et al.* 2010).

In the same year, additional infected bats were reported also from Germany, Switzerland and Hungary, and the geomycosis affected, except *M. myotis*, also *M. dasycneme*, *M. daubentonii*, *M. brandti* and *M. oxygnathus* (Table 2; Wibbelt *et al.* 2010), amounting in total to 22 bats infected with geomycosis (Puechmaille *et al.* 2010, Wibbelt *et al.* 2010). Wibbelt *et al.* (2010) were also able to confirm geomycosis in the pond bat from Germany collected the previous year, in 2008 (Table 2).

The third study in Europe summarised data from early spring 2009 and 2010 and it showed that clinical signs of geomycosis increased recently in the Czech Republic and Slovakia (Martínková *et al.* 2010). The trend was visible both on photographs of hibernating bats and in direct observation. The most often infected species was *M. myotis*, and the geomycosis was confirmed also in *M. bechsteinii*, *M. mystacinus* and *M. nattereri*, increasing the number of affected species in Europe to eight (Table 2; Martínková *et al.* 2010). In the Czech Republic, the geomycosis was found in a show cave first in 2010.

None of the European studies reported massive die-offs (Martínková *et al.* 2010, Puechmaille *et al.* 2010, Wibbelt *et al.* 2010). However, if the mortality was not as severe as in North America, it could remain undetected in Europe. The bats hibernate in smaller groups or individually in crevices. A small number of dead bats could remain undetected in such places. Alternatively, many hibernacula are accessible for small predators and those might scavenge the carcasses on some cave floors if carcasses are not too numerous. Mortality would be more readily noticeable in overall survey counts. Martínková *et al.* (2010) analysed long-term population size data for *M. myotis*, and they found that the population fluctuation in recent years is within the predicted trend interval. Therefore, it seems that geomycosis does not adversely affect bat populations in Europe at the moment.

CLINICAL FIELD SIGNS OF GEOMYCOSIS

While specific diagnostics of the WNS and associated geomycosis based on microscopic examination of tissues, fungal spores and DNA analyses can be proved only in specialized laboratories (Meteyer *et al.* 2010), the common field signs are easily discernible. Bats have white, puffy fungal growth patches on muzzle, ears or wings. They arouse from hibernation and fly in winter more frequently, and they often relocate close to the entrance to the hibernaculum.

The white growth is the spores and hyphae of the fungus. As *G. destructans* grows slowly (Blehert *et al.* 2009, Gargas *et al.* 2009, Chaturvedi *et al.* 2010, Martínková *et al.* 2010), it is usually observed later in the hibernation season and not on all infected bats. Bats without the visible white fungus on their bodies can still be infected with *G. destructans*, and the signs are subtle (Fig. 1). Infected bats wake up from hibernation due to physiological challenges of the infection (Cryan *et al.* 2010), and they groom the fungus off (I. Horáček, pers. comm.). Microscopic spores remain on and in the skin and they re-grow. Severe geomycosis directly damages skin in hibernating bats. On folded wings, this manifests as lightly colored skin in patches of different size and shape, as an area without sheen and as lesions (Fig. 1a). Infected bats arouse from hibernation and they increase their body temperature. If precipitation condensated on hair tips during hibernation, the water soaks into hair as the body temperature increases and the bat appears wet (Fig. 1b). While wet hair is not always an indication of increased body temperature, it often accompanies the process of arousal and would occur more often in hibernacula where geomycosis is present.

INFECTION TRANSMISSION AND PREVENTION

Bats can become infected by direct one-to-one transmission (D. Blehert *et al.*, cited in Foley *et al.* 2011), but the fungus was also found in soil in sites with confirmed WNS (Lindner *et al.* 2011). Spores from contaminated soil could adhere to clothing and equipment of cave visitors. Without thorough decontamination between visits, men can relocate the pathogen across distances larger than those accessible for infected bats. The disease front would expand faster. But the greatest danger from human-induced transmission is tourism between continents.

One of the hypotheses explaining the difference in manifestation of geomycosis between bats in Europe and North America is transfer by humans. Geomycosis appears to have been present in Europe prior to its first emergence in North America (Martínková *et al.* 2010, Wibbelt *et al.* 2010), and bats in Europe do not suffer massive die-offs that accompany the WNS across the Atlantic. If *G. destructans* was introduced to naïve bat populations and caused a catastrophe that nears to extinction, prevention of such events in the future is absolutely critical.

The U.S. Fish & Wildlife Service issues decontamination protocols that would make visiting underground safe for bats (http://www.fws.gov/whitenosesyndrome/), but some items cannot be decontaminated perfectly. Therefore, I would like to encourage cavers and cave visitors to invest in their expeditions. If people travel to a different continent and they expect to the visit underground there, a new set of clothing, shoes and gear that will be disposed of after the visit should be preferred. Alternatively, local cavers and cave manag-

Fig. 1. Hibernating Myotis myotis with Geomyces destructans infection. (A) Skin lesions on wings indicative of geomycosis. (B) Wet hair might accompany arousal in hibernating bats and occurs more often at infected sites.

ers could allocate necessary equipment to lend to visitors. These measures will increase costs of any underground explorations. But, hopefully, knowing that the costs help to protect the beautiful and interesting habitat will also increase personal satisfaction. The underground is a fragile and complex ecosystem, and bats are an important part of it that is currently in great danger from the white-nose syndrome in North America. And without further information, we have to assume that the danger is potentially worldwide.

References

Blehert, D. S., Hicks A. C., Behr M. J., Meteyer C. U., Berlowski-Zier B. M., Buckels E. L., Coleman J. T. H., Darling S. R., Gargas A., Niver R., Okoniewski J. C., Rudd R. J. & Stone W. B. 2009: Bat white-nose syndrome: An emerging fungal pathogen? Science, 323, 227. (DOI: 10.1126/science.1163874)

Chaturvedi V., Springer D. J., Behr M. J., Ramani R., Li X., Peck M. K., Ren P., Bopp D. J., Wood B., Samsonoff W. A., Butchkoski C. M., Hicks A. C., Stone W. B., Rudd R. J. & Chaturvedi S. 2010: Morphological and molecular characterizations of psychrophilic fungus *Geomyces destructans* from New York bats with white nose syndrome (WNS). PLoS ONE, 5, e10783. (DOI: 10.1371/journal.pone.0010783)

Chaturvedi V. & Chaturvedi S. 2011: Editorial: What is in a name? A proposal to use geomycosis instead of white nose syndrome (WNS) to describe bat infection caused by *Geomyces destructans*. Mycopathologia, online early. (DOI: 10.1007/s11046-010-9385-3)

Cryan P. M., Meteyer C. U., Boyles J. G., Blehert D. S. 2010: Wing pathology of white-nose syndrome in bats suggests life-threatening disruption of physiology. BMC Biology, 8, 135. (DOI:10.1186/1741-7007-8-135)

Fenton M. B. & Barclay R. M. R. 1980: *Myotis lucifugus*. Mammalian Species, 142, 1-8.

Foley J., Clifford D., Castle K., Cryan P. & Ostfeld R. S. 2011: Investigating and managing the rapid emergence of white-nose syndrome, a novel, fatal, infectious disease of hibernating bats. Conservation Biology, 25, 223-231. (DOI: 10.1111/j.1523-1739.2010.01638.x).

Frick W. F., Pollock J. F., Hicks A. C., Langwig K. E., Reynolds D. S., Turner G. G., Butchkoski C. M. & Kunz T. H. 2010: An emerging disease causes regional population collapse of a common North American bat species. Science, 329, 679-682. (DOI: 10.1126/science.1188594)

Gargas A., Trest M. T., Christensen M., Volk T. J. & Blehert D. S. 2009: *Geomyces destructans* sp nov associated with bat white-nose syndrome. Mycotaxon, 108, 147-154.

Lindner D. L., Gargas A., Lorch J. M., Banik M. T., Glaeser J., Kunz T. H., Blehert D. S. 2010: DNA-based detection of the fungal pathogen *Geomyces destructans* in soil from bat hibernacula. Mycologia, 103: 241-246. (DOI:10.3852/10-262)

Martínková N., Bačkor P., Bartonička T., Blažková P., Červený J., Falteisek L., Gaisler J., Hanzal V., Horáček D., Hubálek Z., Jahelková H., Kolařík M., Korytár Ľ., Kubátová A., Lehotská B., Lehotský R., Lučan R. K., Májek O., Matějů J., Řehák Z., Šafář J., Tájek P., Tkadlec E., Uhrin M., Wagner J., Weinfurtová D., Zima J., Zukal J. & Horáček I. 2010: Increasing incidence of *Geomyces destructans* fungus in bats from the Czech Republic and Slovakia. PLoS ONE, 5, e13853. (DOI:10.1371/journal.pone.0013853)

Meteyer C. U., Buckles E. L., Blehert D. S., Hicks A. C., Green D. E., Shearn-Bochsler V., Thomas N. J., Gargas A. & Behr M. J. 2009: Histopathologic criteria to confirm white-nose syndrome in bats. Journal of Veterinary Diagnostics and Investigation, 21, 411-414.

Puechmaille S. J., Verdeyroux P., Fuller H., Gouilh M. A., Bekaert M. & Teeling E. C. 2010: White-nose syndrome fungus (*Geomyces destructans*) in bat, France. Emerging Infectious Diseases, 16, 290-293. (DOI: 10.3201/eid1602.091391)

Wibbelt G., Kurth A., Hellmann D., Weishaar M., Barlow A., Veith M., Prüger J., Görföl T., Grosche L., Bontadina F., Zöphel U., Seidl H.-P., Cryan P. M. & Blehert D. S. 2010. White-nose syndrome fungus (*Geomyces destructans*) in bats, Europe. Emerging Infectious Diseases, 16, 1237-1243. (DOI: 10.3201/eid1608.100002)

FIRST RESULTS ON USE OF A HYDROGEN PEROXIDE SOLUTION IN POSTOJNSKA JAMA (SLOVENIA) TO REMOVE LAMPENFLORA

Janez Mulec[1], Stanislav Glažar[2]

[1] Karst Research Institute, Scientific Research Centre of the Slovenian Academy of Sciences and Arts, Titov trg 2, SI-6230 Postojna, Slovenia; janez.mulec@guest.arnes.si
[2] Postojnska jama, Jamska 30,SI-6230 Postojna, Slovenia; stanislav.glazar@turizem-kras.si

Abstract: To attract visitors in many show caves, artificial lighting is installed. As a result of artificial lighting in close and remote proximity of lights a community of phototrophic organisms develops. Lampenflora is a cause of biodeterioration of various types of substrata on which it is attached, especially for speleothems and other objects of natural and cultural value. Postojnska jama is a world-famous show cave with electric illumination first installed in 1884. Due to high number of visitors (around 500,000 per year) and a relatively long illumination period (average 1,000 hrs/sector/year) in the tourist part of the cave, lampenflora extensively colonizes some exposed parts. Before 2010 lampenflora was removed by spraying with solution containing active chlorine. 30 % of illuminated cave was treated in 2010 with an environmentally-friendly and odour-free 15 % solution of buffered hydrogen peroxide (pH 7.0-7.5). Solution was applied three times in one-month period. To increase the contact surfaces, biocidal effectiveness and to remove the unaesthetic appearance, taluses of mosses and ferns were removed before the application of hydrogen peroxide. When lampenflora is encrusted with calcium carbonate, the oxidizing effect of hydrogen peroxide is reduced.

Keywords: caves, Postojnska jama, lampenflora, growth control

INTRODUCTION OF CAVE LIGHTING IN POSTOJNSKA JAMA

Caves contain many important records of past geological periods and various cave formations. Many times these structures in caves are exposed to visitors. With an exception of areas near to cave entrances, these structures in show caves are artificially illuminated. In caves till the end of 19th century different sources of light were used, e.g. torches, oil lights, which emitted smoke and soot. In Postojnska jama, for example oil lamps were used for special "grand illuminations" for 12 various occasions between 1860 and 1885 (Shaw 2010).

To avoid smoke emissions and to keep step with development some caves were early equipped with electric illumination. The first cave equipped with permanent electric lighting in 1881 was Luray Caverns, (Virginia, USA), followed by Kraushöhle (Austria) in 1883 and Postojnska jama (Slovenia) in 1884. The entrance of Postojnska jama was known from the medieval age. In 1814 a team rediscovered Rov starih podpisov, a gallery near the mean entrance of the cave with a lot of inscriptions on cave walls. The oldest dated back to 1213 and is not visible today. According to Pierre Minvielle, the author of the signature from 1213 was the first speleologist (Minvielle 1967). The internal parts of Postojnska jama were discovered by Luka Čeč in April 1818. The cave was officially opened as a show cave on 17 August 1819. Like in other caves candles, torches, portable oil lamps and stationary lamps were used to lit the cave, but glass oil lamps are specific to Postojnska jama (Shaw & Čuk 2002, Shaw 2010). Limelight (also known as calcium light, discovered in the 1820's by Goldsworthy Gurney) was not adopted for the cave. As early as 1883 Postojnska jama was illuminated by electric lamps for the first time for a short visit of Emperor Franz Joseph of Austria. There were only three electric lamps. A year after a permanent electric lighting system was installed and put into operation (Table 1).

Table 1. Development of early electric lighting system in Postojnska jama.

Year	Lighting setup	Location
1833	3 electric lamps	Plesna dvorana
1884	12 arc lights	Kalvarija, Plesna dvorana,Veliki dom
1887	40 arc lights	Kalvarija, Plesna dvorana,Veliki dom
1901	12 arc lights, 977 low power bulbs	Kalvarija, Plesna dvorana,Veliki dom
1929	522 lamps from 40 to 2000 W	The whole tourist part of the cave

LAMPENFLORA

Lighting in caves changed human perception of underground, speleothems and space dimensions. On the other hand the introduction of light in light deprived environment enabled growth of phototrophic organisms. This complex community of organisms near artificial light sources is called lampenflora. The German term "Lampenflora" adopted also in the English vocabulary designates phenomenon – proliferation of phototrophic organisms near artificial light sources. Lampenflora grows at sites where under natural circumstances it would not appear. Various aerophytic cyanobacteria and algae, as well as some mosses and ferns dominate. In the early phase, cyanobacteria and eukaryotic algae usually play the most important role, while mosses and ferns appear later in succession. Vascular plants are sometimes found around lamps, but almost always only as germinating shoots (Mulec *et al.* 2008; Mulec & Kubešová 2010).

Lampenflora is a cause of biodeterioration of various types of substrata on which it is attached: speleothems, sediments, prehistoric paintings and historic signatures. Although in some caves lampenflora is presented to tourists as an attraction, for example in Natural Bridge Caverns (Texas, USA), it must be stressed that lampenflora is a consequence of light eutrophication in the underground. The occurrence of green patches deep in caves is interesting, but from the nature protection aspect unacceptable.

Lampenflora in caves represents a triple problem: (1) strange and unnatural greenish appearance of caves and other underground formations, (2) biodeterioration of solid surfaces on which it is attached due to its presence and biochemical activity, (3) effect on cave (troglobiotic) fauna. Effect on cave fauna is mainly indirect, because lampenflora represents huge amount of freshly introduced nutrients in the cave environment, which is normally poorer. Biomass of new formed lampenflora is available for cave-adapted animals and other occasional dwellers of caves. Along with easier available nutrients new comers become more competitive for a new ecological niche and a population of troglobiotic animals can be affected, both in diversity and abundance.

REMOVAL OF LAMPENFLORA

Lampenflora occurs in show caves as (active growing) green patches and encrusted with calcium carbonate. Lampenflora can become gradually encrusted because of its location under the oversaturated seeping water, or because of biologically enhanced carbonate deposition of some lampenflora organisms. Such an amorphous mix of dead phototrophs and carbonate irreversibly destroys speleothems or other objects of cultural value.

Many approaches to control lampenflora have already been tested, including physical, e.g. reduction of light intensity and lighting period, and chemical by applying various biocidal chemicals, such as formalin, bromine and cupric solutions, and solutions based on active chlorine (Mulec & Kosi 2009). Removing lampenflora by using brush might destroy fragile cave minerals. When planning the lighting setup it is important to define duration, intensity and appropriate sites to illuminate. A very promising recent approach is installation of LEDs (Light Emitting Diode) because of low energy consumption, long lasting LEDs and potential to tune the desirable emission spectrum (Toomey *et al.* 2009). In several caves around the world this new type of illumination is already in use.

CONTROL OF LAMPENFLORA IN POSTOJNSKA JAMA

Due to high number of visitors in Postojnska jama (around 500,000 annually) and a relatively long illumination period (average 1,000 hrs/sector/year) in the tourist part of the cave, lampenflora represents a serious problem for speleothems and other objects of cultural value, for example historic signatures and inscriptions in the gallery Rov novih podpisov.

Till 2010 regular removal of lampenflora in Postojnska jama included application of active chlorine (bleach) in working concentration of 100 mg/l. Every two years a team of professionals (Zavod za zdravstveno varstvo Maribor) applied active chlorine. They sprayed in the winter period for about a week, starting from the main entrance of Postojnska jama through the old cave along the railway to the railway terminus below Velika gora. Velika gora is the starting point of the tourist walk and also the biggest room in Postojnska jama with the dimensions: 40 m width, 100 m length and 32 m height. After lampenflora in Velika gora was sprayed, the application of the solution proceeded through the tourist part named Lepe jame to Črna jama and finally to Pivka jama. Spraying has been performed after daily tourist visits. On average 150 litres of solution were introduced into the cave during one application. Bad odour of chlorine was detected in cave air at least one month after application. Besides formation of unpleasant smell of chlorine, in nature chlorine compounds react with many different natural substances what results in formation of different toxic products. In addition chlorine compounds in water lower pH, what leads to corrosion of carbonate speleothems (Faimon *et al.* 2003). Such an aggressive chemical is not appropriate for sensitive cave environment.

USE OF HYDROGEN PEROXIDE SOLUTION

Based on literature (Faimon *et al.* 2003), laboratory tests and experiments from test sites in Postojnska jama, a novel procedure has been developed to remove lampenflora. In 2010, instead of chlorine solution an environmentally-friendly and odour-free 15 % solution of hydrogen peroxide was prepared with carbonate buffer (pH 7.0-7.5) and applied three times in a one-month period. Once hydrogen peroxide is buffered, it becomes unstable and losses its biocidal activity. To increase the biocidal activity and to remove the unaesthetic appearance, taluses of mosses and ferns have to be removed before application. Application of solution over speleothems covered with lampenflora has to be done as fast as possible. Prior application the treated surface area has to be estimated. On this base appropriate volume of solution has to be prepared in a cave where application will take place. Because hydrogen peroxide is an unspecific oxidant, proper protection measures have to be implemented during its application, such as protection gloves, masks, clothes and boots.

Approximately 30 % of lightened passages and the most exposed parts in Postojnska jama were treated in 2010 (Table 2). An average consumption of buffered hydrogen peroxide solution volume was 1050 ml per 10 m^2. Based on our experience maximum volume to apply at once was 2.0 l what corresponds to the surface of 60 m^2. For one application 20 minutes were needed on average. In a team of personnel which sprayed speleothems with hydrogen peroxide solutions there were always three persons: a leader, a person responsible for preparation of working solution and a person who did the application. In Lepe jame during the first application in April 2010 humidity was high due to heavy rains in that period, and optically the results of lampenflora removal were less effective compared to the second application in July 2010 which was done during the dry and hot period.

In Postojnska jama the hydrogen peroxide solution was efficient in killing lampenflora. In comparison with bleach, hydrogen peroxide solution is less effective and its application is more time consuming, but on the other hand it is odour-free, less hazardous for users and environmentally friendly with less toxic end products of oxidation reactions.

CONCLUSIONS

The buffered solution of hydrogen peroxide was effective when applied to active grow-

Table 2. Details on application of hydrogen peroxide solution in Postojnska jama for lampenflora removal.

Location	Period	Treated area	Volume of applied solution
	dd/mm/yy	m^2	l
Speleobiološka postaja	25/03 – 08/04/10	60	2.0
Lepe jame	01/04 – 16/04/10	400	14.0
Lepe jame	16/07 – 30/07/10	400	14.0

ing lampenflora. General guidelines for cave management based on this procedure will be prepared when no-, or negligible effects on carbonate substrata on micro level are proven and concentration of working solution and other parameters optimized. Once lampenflora is covered with flowstone, the oxidizing effect of hydrogen peroxide is reduced.

It has to be stressed that the above described procedure is not the ultimate solution for removal of lampenflora in show caves, because its growth is not stopped, but it is just slowed down. More sustainable approach in restricting lampenflora growth lies in the change of existing lighting to LEDs or other corresponding system. It is also important to change the concept of lighting in show caves: sometimes it is better not to present everything in the brightest light.

ACKNOWLEDGEMENTS

Authors are grateful for fieldwork and lab support to Janez Margon, Izidor Šantek, Jaka Rajmondi (Postojnska jama) and Mateja Zadel (Karst Research Institute ZRC SAZU).

References

Faimon, J., Štelcl, J., Kubešová, S., & Zimák, J. 2003: Environmentally acceptable effect of hydrogen peroxide on cave “lamp-flora”, calcite speleothems and limestones. Environmental Pollution, 122, 417-422.

Minvielle, P. 1967: *La conquête souterraine.* Arthaud, Paris, 258 p.

Mulec, J. & Kosi, G. 2009: Lampenflora algae and methods of growth control. Journal of Caves Karst and Studies, 71, 2, 109-115.

Mulec, J., Kosi, G. & Vrhovšek, D. 2008: Characterization of cave aerophytic algal communities and effects of irradiance levels on production of pigments. Journal of Caves Karst and Studies, 70, 1, 3-12.

Mulec, J. & Kubešová, S. 2010: Diversity of bryophytes in show caves in Slovenia and relation to light intensities. Acta Carsologica, 39, 3, 587-596.

Shaw, T. R 2010: *Aspects of the history of Slovene Karst 1545-2008*. ZRC Publishing, Ljubljana, 306 p.

Shaw, T. R. & Čuk, A. 2002: Technical developments for tourism in Postojnska jama, Slovenija 1852 – 2002. In Zupan Hajna, N. (ed): *4th International ISCA Congress Use of Modern Technologies in the Development of Caves for Tourism*, October 21 – 27, 2002, Postojna, Postojnska jama, turizem, Postojna, pp. 91-98.

Toomey, R. S. III, Olson, R. A., Kovar, S., Adams, M. & Ward, R. H. 2009: Relighting Mammoth Cave’s new entrance: improving visitor experience, reducing exotic plant growth, and easing maintenance. In White, W. B. (ed.): ICS 2009 15th International Congress of Speleology, Proceedings, Vol. 2, Greyhound Press, Kerrville, Texas, U. S. A., pp. 1223-1228.

FOUNDATIONS OF THE SLOVAK CAVES ADMINISTRATION MARKETING STRATEGY

Ľubica Nudziková

State Nature Conservancy of the Slovak Republic, Slovak Caves Administration, Hodžova 11, 031 01 Liptovský Mikuláš, Slovakia; nudzikova@ssj.sk

Abstract: The Slovak Caves Administration manages 12 show caves in Slovakia. Guiding services provide the main part of its own income. In this case, one of the main marketing strategy goals is providing income from services to cover organization mission, its development. The amount of revenues and of attendance rate depends on character of services and strong impact of vicinity. The years 1999 – 2008 may be an example of relative good impact of vicinity influence, the year 2009 may be an example in opposite way.

Keywords: Slovak Caves Administration, marketing strategy, attendance rate, guiding service character, income, impact of vicinity

The Slovak Caves Administration is the only caving professional organization in Slovakia (from 1st January 2008 merged with the State Nature Conservancy of the Slovak Republic). Since 1st January 2002 its mission had been extended by law. It administrates, protects, cares for all caves in Slovakia (to date of 31. 12. 2010 the number of caves is 6,020), manages 12 show caves including services for visitors, 6 show caves offer also other services (guiding service, culture, medical goals).

The decision, determining strategies started in 1995 and in 2005 Marketing Strategy was confirmed by Ministry of Environment of the Slovak Republic together with the Organization Development Strategy.

This strategy follows the main goals:

- to provide income from guiding and additional services to cover our organization mission, its development in up-to-date organizational and economic model;
- to respect cave carrying capacity and public expectations;
- to assign the same (similar) standard level in all 12 caves, regardless of their attendance;
- to provide price strategy, schedule list, conditions and organizing the services (regularly analyse and reassess, set separate, taking into consideration visitors' structure, impacts, price of other subjects etc.) to achieve good economic outcome.

From our management point of view in the guiding services in the Slovak show caves were based on following items:

1. Guiding service character:
   - strong dependence on vicinity;
   - minimal visit repetition in terms of percentage (exception e. g. visitors from surrounding area with their guests);
   - cave is not usually primary destination, it is only supplementary or alternative program;
   - maximal distance for visitors from accommodation to cave is 100 km, usually less, according to our experience;
   - average time, which visitors spend in the Slovak caves and their areas is 2 – 3 hours;
   - different attendance rate of each cave in one time, it has own line (in spite of the fact, that some of impact have a whole – area effect), etc.
2. Impacts on the amount of proceeds and attendance rate:
   - state and public policy of Slovakia and state and public policy of countries from which the most visitors arrive (tax policy, conditions according to law, purchasing power, rate of Slovak currency in comparison with exchange rate of other countries, situation in tourism in Slovakia, state promotion, "flows" of tourists, etc.);

- regional policy, geographical location in relation to regional situation in tourism (number of destinations, theirs reputation and attractiveness);
- traffic communications, ability to access, availability;
- weather;
- mass-media policy;
- cave capacity, operational and carrying capacity, reputation and attractiveness;
- safety conditions;
- interest form travel agencies or another subjects in tourism;
- decisions and activities of our organization (promotion, up-to-date schedule and price list, quality of service, technical infrastructure, additional services) etc.

The guiding service character is considered as the fact. Some of impacts should influence it according to the power, experience, financial options, effort, etc.

Admission, when set in market prices, mostly do not radically influence attendance rate. Three show caves in Liptov region in two selected months present an example (Table 1). They are located in mutual distances, each cave has own line of attendance, price is not so important for decision to visit cave, two of them have the same price, one 3 € less, year 2009.

MARKETING AND MANAGEMENT STRATEGY – RESULT, CHOICE OF ACTIVITIES 1999 – 2008

- total number of visitors for 10 years: 6,743,202;
- average annual attendance in this period: 674,000;
- the highest annual attendance in 2002: 726,597 (the highest in period after change political and economic system in 1989).
- revenues from services increased by 128 %;
- asset increased by more than 3,000,000 €;
- selling souvenirs and refreshment proceeds increased by 93 %;
- foreign exchange annual around 100,000 €;
- enough annual profit to have finance in amount necessary to start next tourist season;
- economic situation allows to create suitable and stable conditions for development of cave care, services, technical repairs and reconstructions and applying for European Structural Funds (in this period more than 330,000 €);
- from technical activities:
  a) building new visitors centres, technical infrastructure outside and underground;
  b) new central security system;
  c) new telephonic system in underground (based mobile network signal covering almost 100 %, safety, communicate underground – outside);
  d) new system for interpretation (various modifications, finally – wireless system, the Personal digital assistant PDA communicating via Bluetooth);
  e) technical repairs and reconstructions costs: 8,730,000 €.

CONSEQUENCE OF IMPACTS ON ATTENDANCE – YEAR 2009

Year 2009 may be an example of the consequences depending on strong dependence on vicinity and on the guiding service character:

- change of our currency to euro in time of economic crisis;
- time before government election;
- change of organizational and economic model of our organization;
- situation in Slovak tourism, interest of travel agencies;

Table 1. Attendance of three show caves in Liptov region in two selected months

Cave	Price (€)	Attendance in June 2009	Attendance in August 2009
Demänovská Cave of Liberty	7	13,234	23,197
Demänovská Ice Cave	7	8,160	25,828
Važecká Cave	4	2,794	4,582

Fig. 1. The attendance rate of 12 show caves in the management of Slovak Caves Administration in 1999 – 2008

Fig. 2. Entrance area of Belianska Cave. Photo: J. Bílek

Fig. 3. Entrance building of Harmanecká Cave. Photo: J. Hlaváč

- Slovak caves lost interest of travel agents, of foreign visitors, there were less tour organized trip;
- mass media policy (negative comments mainly to price increases, even that they could not be raised in the process of changing the currency).

For comparing with the statistics from the Ministry of Economy, Department of Tourism:
- individual tourism in Slovakia involved total foreign exchange earnings 96.50 %;
- number of accommodated foreign visitors compared with year 2008 fell by 28.80 % from Poland decreased by 49.50 %, from Czech 22.70 %, from Hungary 38.30 %, cave visitors – by 33.80 %, from Poland 59.50 %, from Czech 14.45 %, from Hungary 40.00 % (not everyone accommodated wants to visit cave, not everyone who is accommodated, visits the cave).

Another example should be Bystrianska Cave, it was the only one from all 12 caves, which had more visitors in 2009 compar-

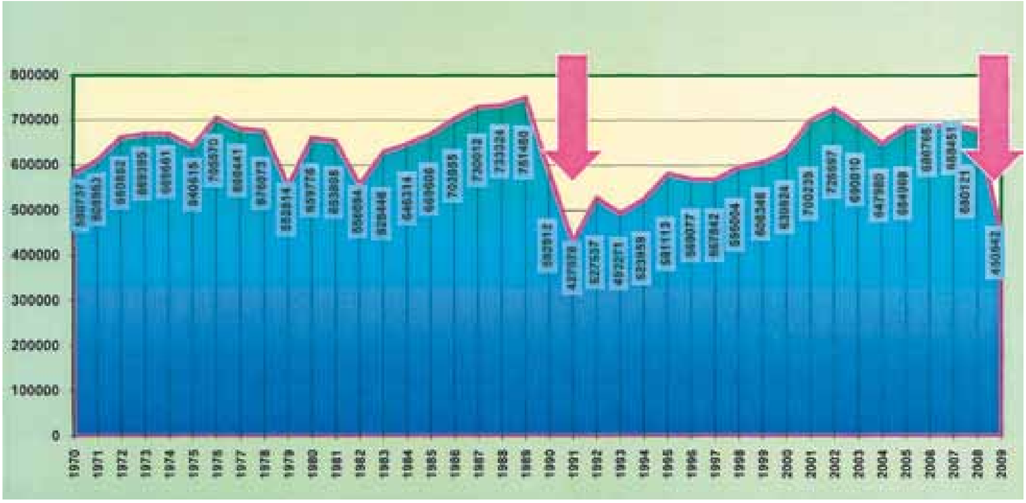


Fig. 4. Annual attendance 1970 – 2009 (1. 1. 1970 – establishment of Slovak Caves Administration)

ing with 2008 (in spite of that plus should be statistically insignificant). It is confirmed that each cave in one time has different attendance rate, that foreign people interest in this case is 5 % less (Slovak was +/- same number – table below), traffic communication was opened after reconstruction, etc., for comparing from the price policy – price 5 €).

Table 2. The foreign structure of attendance

Nationality	2008	2009	Difference
Polish	280,444	112,753	167,691
Slovak	241,121	240,730	391
Czech	74,819	47,931	26,888
Hungarian	22,938	13,749	9,189
Other	83,737	49,128	25,420
∑	680,121	450,452	229,579

Our organization uses its own software, which in addition to obligatory agenda, allows to collect information at the time of ticket purchase, and process statistics as a basis for decision making, software which is adapting to the requirements of legislation and our organization demand, tasks. For example monitoring the number of foreign visitors is implemented through a "hot keys" at the time of ticket purchase, in accordance with language, which they use.

CONCLUSIONS

Caves were the first tourism destination, historically, now it is important part, tourism strongly depends on vicinity, caves depend on tourism in country, in region etc. From our point of view it is important to know what "threats" and what "chances" in our specific conditions affect our outcome.

References

Statistics of Slovak Caves Administration

RADON MONITORING IN DOMICA CAVE, SLOVAKIA – A PRELIMINARY RESULTS

Iveta Smetanová[1], Karol Holý[2], Dalimír Jurčák[3], Jozef Omelka[3], Ján Zelinka[4]

[1] *Geophysical Institute, Slovak Academy of Sciences, Dúbravská cesta 9, 845 28 Bratislava, Slovakia; geofivas@savba.sk*
[2] *Department of Nuclear Physics and Biophysics, Faculty of Mathematics, Physics and Informatics, Comenius University, Mlynská dolina, 842 48 Bratislava, Slovakia; holy@fmph.uniba.sk*
[3] *MicroStep-MIS, Čavojského 1, 841 04 Bratislava, Slovakia; omelka@microstep-mis.com, dali@microstep-mis.com*
[4] *State Nature Conservancy of the Slovak Republic, Slovak Caves Administration, Hodžova 11, 031 01 Liptovský Mikuláš, Slovakia; zelinka@ssj.sk*

Abstract: Three stable monitoring stations equipped with an automatic measuring and registration instruments for continual microclimatic, hydrological and hydrochemical monitoring are installed in Domica Cave, southern Slovakia. In one of them (Virgin Corridor) the devices for continual monitoring of radon activity concentration in the cave atmosphere have been set up in June 2010. The external meteorological station situated nearby the cave includes sensors for measurements of air temperature, relative humidity, wind speed, wind direction, global radiation, rainfall amount and evaporation. From June to December the hourly radon activity concentration ranged 230 – 4,740 Bq/m^3. Periodic daily and non-periodic short term variations of ^{222}Rn activity concentration were registered. The research has been carried out with the regard to the possible health risk of people working in the cave, as well as the relationship between radon activity concentration changes and meteorological and cave microclimatic conditions have been investigated.

Keywords: radon, variations, cave, monitoring, meteorological conditions

INTRODUCTION

Radon (^{222}Rn), a product of ^{226}Ra decay in ^{238}U decay series, is a naturally occurring radioactive noble gas with half life of 3,82 days. Radon and its short-lived decay products are the most important contributors to the human exposure from natural sources (UNSCEAR 2000). Monitoring of ^{222}Rn activity concentration in the underground places such as mines (Veiga *et al.* 2004), tunnels (Lam, 1988), show caves (Thinova & Burian 2008) and underground monuments (Hafez & Hussein 2001) is performed mainly due to assess the radiological hazards to occupational workers. On the other hand, radon is used as a natural radioactive tracer of air movement in caves to enable better understanding of their microclimate (Fernandez-Cortes *et al.* 2009).

Radon activity concentration in underground environments is usually characterized by the large temporal variations (Eff-Darwich *et al.* 2002, Perrier *et al.* 2007, Barbosa *et al.* 2009, Perrier & Richon 2010).

After the decree by the Slovak government (345/2006) the action level for ^{222}Rn activity concentration in underground workplaces (tunnels, mines, caves) is 1,000 Bq/m^3 in average per one year. At sporadically used workplace this limit is related to an average radon activity concentration during the stay of working staff. In show caves the typical remedial action like forced ventilation cannot be used because it alters the internal microclimatic conditions which are important for the conservation of the cave decoration. The only way to reduce radon exposure to guides and other workers is to apply a radiation protection system based on restrictions in the amount of time spent in the cave.

In this paper the preliminary results of the continual ^{222}Rn activity concentration monitoring in the atmosphere of the show cave Domica are presented.

EXPERIMENTAL SITE

Domica Cave is situated on the south-western edge of the Silická Plateau in the Slovak Karst National Park (south-eastern Slovakia), close to the state border with Hungary. Cave is formed mainly in the Middle Triassic Wetterstein limestones of the Silica nappe by the corrosive and erosive activities of Styx River and Domica Brook and smaller underground tributaries draining waters mainly from the non-karst part of the basin. It is an upper part of the Domica-Baradla cave system with the total length of 25 km. Natural radioactivity of rocks (Triassic carbonates, sinters, fluvial sediments and cave soil) measured using gamma-ray spectrometry is relatively low (Štelcl *et al.* 2004).

METHODS

Three stable monitoring stations equipped with an automatic measuring and registration instruments for continual microclimatic, hydrological and hydrochemical monitoring are installed in this cave and operated by Microstep-MIS company (Gažík *et al.* 2009). In one of them (Virgin Corridor) continual monitoring of radon using an alpha detector Barasol have been set up in June 2010. The detector is placed 1,3 m above the cave floor and 1,5 m from the walls. Among others, the internal air temperature, CO_2 content and wind speed have been continually monitored there. The external meteorological station situated nearby the cave includes sensors for measurements of air temperature, relative humidity, wind speed, wind direction, global radiation, rainfall amount and evaporation. Data from all stations are recorded automatically every 10 minutes.

RESULTS AND DISCUSSION

Radon activity concentration in the atmosphere of Domica Cave exhibits daily and short-term variations. At this stage of the investigation the seasonal variation cannot be correctly evaluated. Hourly time series of ^{222}Rn activity concentration in the Domica Cave compared with hourly time series of

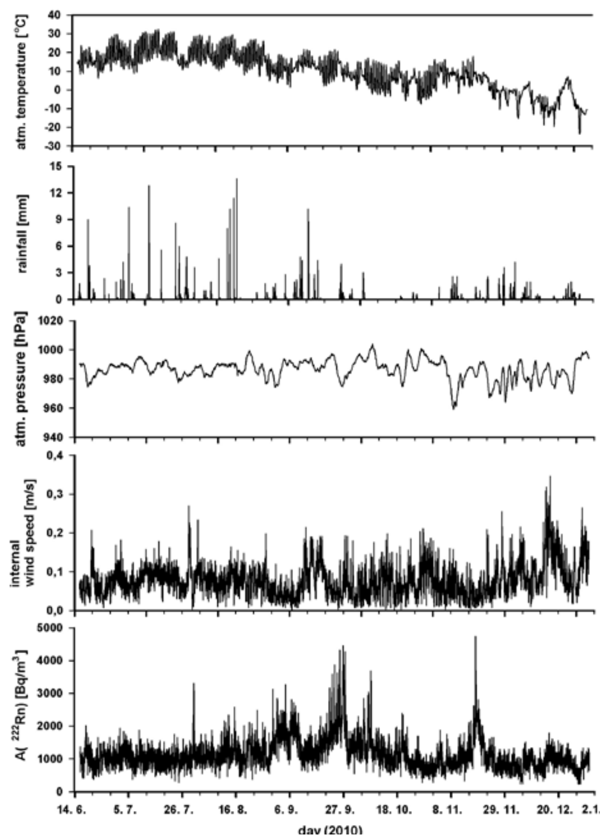


Fig. 1. Hourly time series of ^{222}Rn activity concentration and internal wind speed in the atmosphere of Domica Cave, atmospheric pressure, rainfall and atmospheric temperature.

Table 1. Monthly average and median values of ^{222}Rn activity concentration measured in the atmosphere of Virgin Corridor in Domica Cave.

A(^{222}Rn)[Bq/m^3]	July	August	September	October	November	December
average	1027,06	1180,88	1674,86	1146,40	1075,98	875,00
median	1008,17	1190,25	1644,50	1141,38	954,98	893,17

internal wind speed, atmospheric temperature, atmospheric pressure and rainfall are depicted in Fig. 1. The hourly averages of radon activity concentration ranged from 230 to 4,740 Bq/m^3, with median value 1,058 Bq/m^3. However, the values from 500 to 2,000 Bq/m^3 prevailed in the data set (Fig. 2). Daily averages of ^{222}Rn activity concentration lie in interval 480 – 2,700 Bq/m^3. Monthly averages and median values of ^{222}Rn activity concentration are displayed in Tab. 1. With exception of December, the action level for radon in underground workplaces was slightly exceeded.

Radon values measured in summer months as well as in the beginning of winter varied about 1,000 Bq/m^3. Short-term variations of ^{222}Rn activity concentration were registered mainly in autumn months. Their duration was from 4 to 10 days. The amplitudes of radon short-term variations ranged approximately from 600 to 2,000 Bq/m^3. No influence of atmospheric pressure, temperature and temperature gradient on short-term changes of radon activity concentration was observed. Short-term variations were also not associated with rainfall events.

From August to October the daily variations of ^{222}Rn activity concentration were observed. The internal wind speed measured in the Virgin corridor exhibits distinct daily variations that documented the changes of air flow in the cave during the day. Wind speed was small, typically less than 0,2 m/s, but occasionally reached up to 0,4 m/s. Radon daily variations were usually anticorrelated with the daily change of the internal wind speed (Fig. 3). The largest amplitudes of radon daily variations up to 2,300 Bq/m^3 were reg-

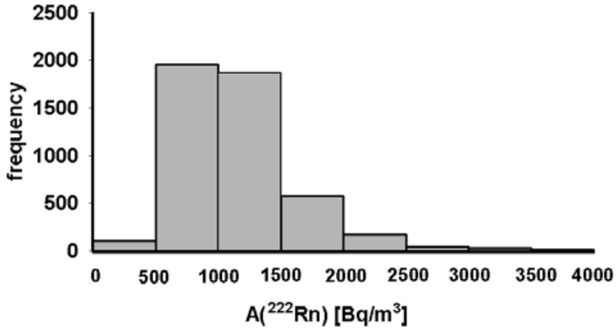


Fig. 2. Frequency distribution of ^{222}Rn activity concentration in the atmosphere of Domica Cave from June to December 2010.

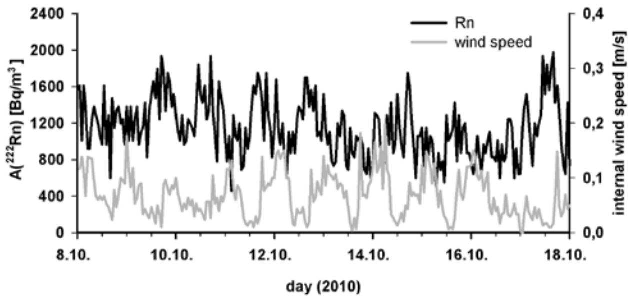


Fig. 3. Daily variations of ^{222}Rn activity concentration and internal wind speed.

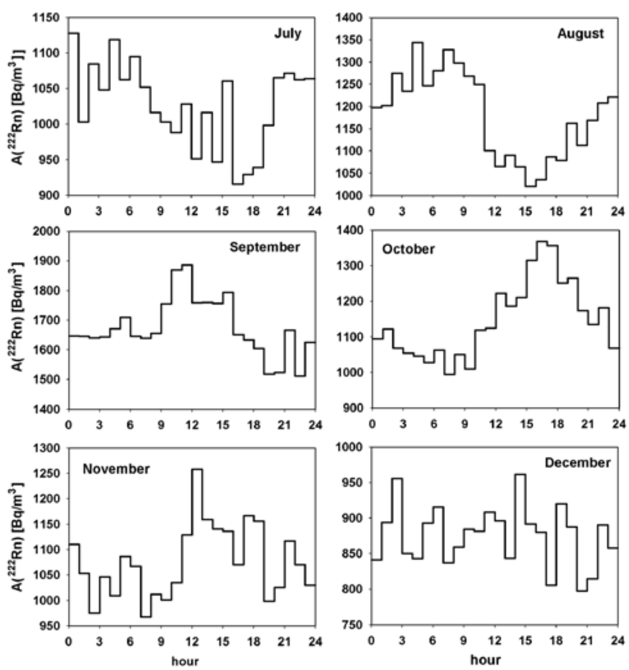


Fig 4. Daily waves of ^{222}Rn activity concentration in the atmosphere of Domica Cave.

istered in autumn months, from September to October; they were superimposed on radon short-term variations. Daily average wave of radon activity concentration clearly exhibits the shape and the amplitude of daily variation for a single month (Fig. 4). The position of radon maximum and minimum during the day was different for each month. In August the maximum was reached in the morning (7 – 9 a.m.), minimum at the afternoon (3 – 5 p.m.). In September, maximal values were measured at 10 – 12 a.m., minimum at 8 – 10 p.m. In October the reverse situation as in September was observed. The amplitudes of the average daily waves were at the level up to 25 % of ^{222}Rn activity concentration mean values.

Moreover, two distinct peaks were distinguished in radon time series. First one occurred at the end of July, lasting for one day with maximum of 3,310 Bq/m^3. At the same time also peak in CO_2 content of the cave atmosphere was registered. The presence of both peaks was accompanied with the decrease of the internal wind speed, while a significant increase of wind speed was measured approximately 36 hours before both peaks appeared. Internal temperature measured in Virgin Corridor over a period of our investigation was relatively stable, about 10 °C. After rainfall in summer months, as in this case, a sharp increase of water temperature in Styx River, as well as increase of air temperature in Virgin Corridor was observed, lasting approximately 2 days (Fig. 5). The change of internal air temperature can cause the change of air flow. However, not every significant increase of internal wind speed was accompanied by the rainfall event.

The second peak of ^{222}Rn activity concentration was recorded in the middle of November with duration of approximately 10 hours. Peak was superimposed on the radon short-term variation. At that time radon concentration reached its maximum level 4,738 Bq/m^3 for the period of the monitoring. Contrary to the previous event in summer, no significant change of CO_2 content was registered. A weak decrease of internal wind speed was measured, too. However, in the following days a similar decrease of internal wind speed was not resulted in any radon peaks. No rainfall or internal temperature changes preceded this radon peak.

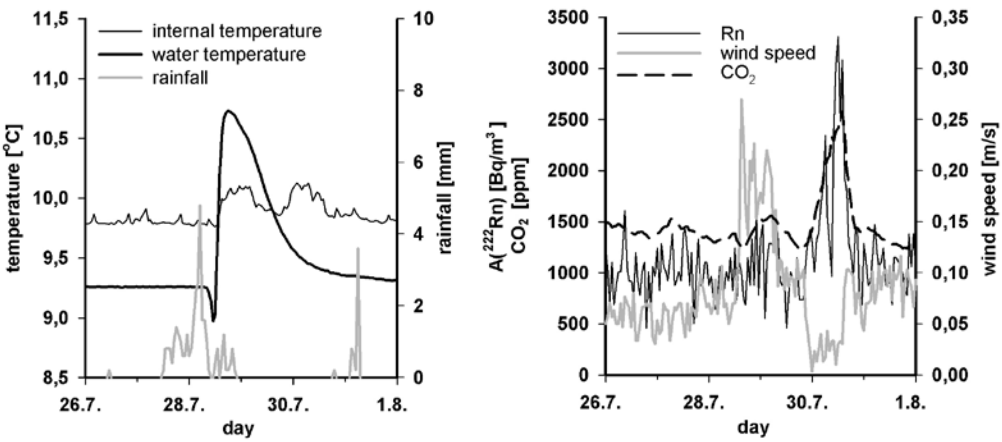


Fig. 5. Increase of internal temperature measured in the Virgin Corridor after the rainfall event (left). At the same time short-term increase of internal wind speed was measured. The decrease of internal wind speed was accompanied by the presence of ^{222}Rn activity concentration and CO_2 content peaks (right).

CONCLUSIONS

The preliminary results of ^{222}Rn activity concentration monitoring in the atmosphere of Domica show cave exhibit moderately high radon levels from 230 to 4,740 Bq/m^3, with median value 1,058 Bq/m^3. Daily and short-term variations of radon activity concentration were observed, as well as two radon peaks. The highest radon levels were registered in autumn months.

To explain the ^{222}Rn activity concentration behavior in cave in detail, a further monitoring is needed.

References

Barbosa, S. M., Zafrir, H., Malik, U. & Piatibratova, O. 2010: Multi-year to daily Radon variability from continuous monitoring at the Amram tunnel, southern Israel. Geophysical Journal International, 182, 2, 829-842.

Eff-Darwich, A., Martín-Luis, C., Quesada, M., de la Nuez, J. & Coello, J. 2002: Variations on the concentration of ^{222}Rn in the subsurface of the volcanic island of Tenerife, Canary Islands. Geophysical Research Letters, 29, 22, doi:10.1029/2002GL015387

Fernandez-Cortes, A., Sanchez-Moral, S., Cuezva, S., Cañaveras, J. C. & Abella, R. 2009: Annual and transient signatures of gas exchange and transport in the Castañar de Ibor cave (Spain). International Journal of Speleology, 38, 2, 153-162.

Gažík, P., Haviarová, D. & Zelinka, J. 2009: Integrovaný monitorovací systém jaskýň / Integrated monitoring system of caves. Aragonit, 14/2, 109-112. (in Slovak)

Hafez, A. F. & Hussein, A. S. 2001: Radon activity concentrations and effective doses in ancient Egyptian tombs of the Valley of the Kings. Applied Radiation and Isotopes, 55, 355-362.

Lam, W. K., Tsin, T. W. & Ng, T. P. 1988: Radon Hazard from Caisson and Tunnel Construction in Hong Kong. The Annals of Occupational Hygiene, 32, 3, 317-323.

Perrier, F., Richon, P., Gautam, U., Tiwari, D., R., Shrestha, P. & Sapkota, S. N. 2007: Seasonal variation of natural ventilation and radon-222 exhalation in a slightly rising dead-end tunnel. Journal of Environmental Radioactivity, 97, 220-235.

Perrier, F. & Richon, P. 2010: Spatiotemporal variation of radon and carbon dioxide concentrations in an underground quarry: coupled processes of natural ventilation, barometric pumping and internal mixing. Journal of Environmental Radioactivity, 101, 279-296.

Štelcl, J., Zimák, J. & Zelinka, J. 2004: Přirozená radioaktivita hornin v jeskynním systému Domica-Baradla. In Bella, P. (ed.): *Proceedings of the 4th conference Výskum, využívanie a ochrana jaskýň*, October 5-8, 2003, Tále, Slovakia, pp. 78-82. (in Czech)

Thinová, L. & Burian, I. 2008: Effective dose assessment for workers in caves in the Czech Republic: experiments with passive radon detectors. Radiation Protection Dosimetry, 130, 1, 48–51.

UNSCEAR Report 2000: *Sources and Effects of Ionizing Radiation*. United Nations Scientific Committee on the Effects of Atomic Radiation. Report to the General Assembly, New York.

Veiga, L., H., S., Melo, V., Koifman, S., Amaral, E., C., S., 2004: High radon exposure in a Brazilian underground coal mine. Journal of Radiological Protection, 24, 295–305.

Decree 345/2006, available at: http://www.zbierka.sk/zz/predpisy/default.aspx?PredpisCislo=345&Rocnik=2006 (last access: 20 January 2011) (in Slovak)

THE MOST IMPORTANT OPEN SPELEOARCHAEOLOGICAL SITES IN SLOVAKIA*

Marián Soják, Peter Fecko

Institute of Archeology, Slovak Academy of Sciences, Nitra,
Dept. Mlynská 6, 052 01 Spišská Nová Ves, Slovakia; sojak@ta3.sk, fecko@gmail.com

Abstract: In Slovakia there are many different types of presentation of the speleoarchaeological sites to the public. A shining example is the Domica Cave and its presentation of the life of its Neolithic inhabitants. The other example we want to mention is the Jasovská Cave, to which a nature trail with an education panel in the Oblúkova and Fajka Caves and in the old entrance of the Jasovská Cave may be added. Ideal conditions manifest themselves in the case of the Moldavská Cave where tourists may see the consequences of the Mongol-Tartar invasions to Slovakia in 1241. Many caves are situated next to marked hiking trails. Some of them are supplemented by the education panels of the palaeontological and archaeological information. Ideal conditions may be found in some caves situated in the Slovak Paradise, where evidence of coin counterfeiting from Late Middle Ages was discovered. Very interesting is the presentation of Neanderthal way of life in the Prepost Cave near Bojnice, where paleolithic findings were discovered in the castle moat. The presentation of archaeology in Slovak caves is comparable with foreign countries, although in many cases there is a lot to catch up on.

Key words: Slovakia, cave archaeological sites, open archaeological sites and their presentation to the public, speleoarchaeology, samples of archaeological findings, palaeontology, educational trails and boards, exhibitions, Paleolithic Age, Neolithic Age, Bronze Age, Roman Age, Middle Ages, Modern Age, coin forgery workshops

INTRODUCTION

About one third of more than 6,000 caves registered up to now in Slovakia were settled from prehistory to the modern age. Not all of them were suitable for long-term human habitation, definitely not the vertical caves, which were mostly used as the place of worship (the Majda-Hraškova Cave, Babská diera and many others). They also served as transient settlement, in particular underground spaces with a proper entrance position (oriented towards the sunny south), or with huge halls often repeatedly sought by ancient and medieval dwellers. A lot of caves in Slovakia provided remarkable archaeological findings of multi-cultural character. None of them were explored by means of methodical archaeological research. We would like to mention that many of the caves have already been investigated in the past (in the 17th – 19th century) and, therefore, we can hardly find places with intact sediments, cultural layers and objects with "in situ" findings. Dominant are non-methodically researched caves, which are often surprising by their rich findings but due to various reasons are not available to general public. The presented paper introduces those caves in Slovakia which are, on the contrary, open to public. Visitors may see there evidence of perished settlement, although in different forms, more or less appropriate (Soják, 2006). We will also highlight opportunities for further presentations of speleoarchaeology sites, particularly in the case of the easily approachable and from the archaeological point of view significant caves, often located on the outskirts of towns and villages or next to marked hiking trails.

* The contribution was created in a grant project VEGA, no. 1/0232/10

OPEN SPELEOARCHAEOLOGICAL SITES

Kečovo (Rožňava district) – Domica Cave, a "pearl" among speleoarchaeological sites in Slovakia

Perhaps there is no cave in Slovakia which would be comparable to the Domica Cave as far as importance and abundance of archaeological findings is concerned. The cave is located on the south-western edge of the Silická Plateau in the Slovak Karst National Park and is registered as a World Natural Heritage site (Hlaváč, 1997). Apart from countless paleontological findings and sporadic evidence of Late Paleolithic settlement (a silex spike of the Szeletian Culture), it is known as a Neolithic settlement of producers of the Gemer Linear Pottery and especially as a multi-phase settlement of the Bükk-Mountain Culture (Lichardus, 1968; Soják, 2005a).

The Domica Cave belongs among 12 caves in Slovakia which are opened to general public and operated by the State Nature Conservancy of the Slovak Republic – Slovak Caves Administration in Liptovský Mikuláš (other 4 caves are operated by a different entity). At the beginning the cave was not presented to visitors as a significant prehistoric human settlement, except for a modest archaeological exhibition situated at the foyer. It is, therefore, highly desirable to assess the activity of the aforementioned institution, which completed the Educational Centre within the Domica Cave site. Nowadays, the visitors may see a very nice exhibition including a video projection and an archaeological presentation in the cave. The Activity of the Archaeological Institute consisted in helping to implement the archaeological part in the newly-built exhibition, in the development of a scenario of an archaeological documentary as well as in the archaeological presentation directly in the cave (Gaál *et al.*, 2006; Soják, 2006; 2007a).

A model of an archaeological trench (1,5 × 2 m) was placed in a niche near the Hall of Eleven Fires. The trench was portioned into two parts, which explains a normal procedure of archaeological research. Both parts of the trench are divided by a control block where visitors may also see the soil profile. The south-eastern (researched) half of the trench remained exposed to the depth of 30 cm from the present ground level. It is divided into square sectors with installed fragments of ceramic and working tools (a trowel, a brush). The north-western half of the trench is explored at least to the depth of 90 cm to 100 cm in depth. The stratigraphical division of the layers in the profile was distinguished by three colours. The very bottom layer (1) represents the Pleistocene with bone findings of a cave bear and is outlined in yellow. Highlighted above this layer is the black cultural layer with the position of an imaginary fireplace represented by the red stripe (2). Situated at the top is the top layer symbolized by the brown colour (3). The profile is complemented by a scale bar and replicas of the findings. A decorated pot of the Bükk-Mountain Culture, a stone pad for corn growing and a bone-flattening tool were also placed into the trench. On the control block an original dish of the Bükk-Mountain Culture is placed, along with the north-marking method and some of the standard tools used by an archaeologist – a scraper and, on the edge of the trench, a graph paper with a pencil and a drawing of the trench (Fig. 1).

In the opposite Hall of Eleven Fires several minor stone fire pits were removed and replaced with a bigger one including firewood.

The daily life of Neolithic dwellers in the Domica Cave is suggested by the visual reconstruction in the Hall of Terraces, also called the Pottery Workshop. Produced at this place was evidence of work activity as for example mining clay, production of ceramics, fireplaces and artificially chiselled steps leading to the underground

Fig. 1. Model of the archaeological trench in the Domica Cave. Photo: M. Soják

River Styx. These activities were indicated by a model of an earth oven with unfired and fired vessels on a stone base. In the corridor leading to the River Styx a model of a fireplace with an electric "flame" was built. A life-sized neolithic woman is sitting at the fire. She is wearing sackcloth and a shell necklace. Next to her there is clay pottery, a stone pad with spilled grain, a grinder and a loom in the background (Fig. 2). The aforementioned reconstructions were later used in the shooting of the film about the life of Neolithic inhabitants in the Domica Cave. The documentary demonstrates scenes from everyday life where in addition to the production of ceramics skinning of deer, woven fabrics, sewing and processing of fur or other work activities round the fire are presented. Other scenes show children playing in the River Styx and ritual ceremonies in front of the Sacred Hall (body painting, drawing on the cave walls with charcoal and a shaman dance; Fig. 3). The film (along with other fields of caving, geology, history, discovery and research of the Domica Cave) is also shown during the exhibition, where visitors may view three-dimensional archaeological artifacts and education panels with texts and supplementary photos. The screening also takes place in the cave itself. In the distance on the cave wall animation of human's and dog's motion using programmed reflectors is shown. The sequence finishes with a view of three well-known charcoal drawings with a typical "crown", which are not physically available to regular visitors. In the Hall of Courage visitors may also see an "in-situ" sintered pot of the Bükk-Mountain Culture.

Fig. 2. A life-sized neolithic women with a loom in the background in the Hall of Terraces, Domica Cave. Photo: M. Soják

Fig. 3. The preparation of a shaman while shooting the documentary in the Domica Cave. Photo: M. Soják

Jasov (Košice-vicinity district), Jasovská Cave vs. Oblúková and Fajka Cave

Within the bilateral Slovak-Hungary project "The Caves of Slovak and Aggtelek Karst", the Jasovská Cave is a part of the World Natural Heritage since 1995. The importance of the cave is not only from the natural but also from the historic and archaeological point of view. Archaeological research in recent years documented evidence of settlement in the Upper Paleolithic, Neolithic Age, followed by the Bronze Age, Iron Age (Hallstatt and Laten), Roman Age, the 13^{th} – 15^{th} century and in the Modern Age. Thanks to the Slovak Caves Administration in cooperation with the Slovak Museum of Nature Protection and Speleology in Liptovský Mikuláš, a new exhibition within designing a new entrance to the cave was installed. The exhibition, open since 1997, presents natural conditions, protection, settlement and history of the cave and its inclusion in the World Heritage List (Bella, 1997a). Archaeological and historical presentation, including the famous inscription on the cave wall of the year 1452 in the Dining Hall, is a part of the third section of the permanent

Fig. 4. Jasov – the old entrance to the Jasovská Cave. The ground plan shows the location of the old archaeological trenches and the place of rescue research in 2004 – 2006 (according to J. Skutil, processed by F. Miháľ and M. Soják).

exhibition, as an attractive way to tour the cave. Visitors are given complete overview not only of its natural, but also social values.

In 2004 – 2006 rescue archaeological research was carried out in the old entrance to the Jasovská Cave (Fig. 4). In the exposed profile the stratigraphic position of the layers from Pleistocene to Holocene were discovered, with findings of the Neolithic, Bronze Age, Iron Age (Hallstatt, Laten), Middle Ages and Modern Times (Soják, 2008a). Thus, the aforementioned research picked up the threads of field activities by E. Nyary, A. Thallóczy in 1878, T. Kormos in 1916, later J. Eisner, J. Bárta and other researchers (Soják, 2007b, 50 nn.). The old entrance to the cave is ideal for a three-dimensional presentation of archaeological findings and partial reconstruction of the prehistoric way of life in the Middle Ages in the manner of the Domica Cave's presentation (3D models of people, work activities, etc.). It also shows the possibility of a panel presentation on the access path to the Jasovská Cave. The main stations with educational boards are suitably fit in the adjacent Oblúková Cave (Fig. 5) and Fajka Cave (Fig. 6). During research into the platform in front of the Fajka Cave led by J. Eisner in 1924, a part of a buried structure was uncovered. It was partially protected by a rock wall, with stones laid around a fireplace, animal bones, abundant ceramics, two massive iron axes with sockets and two pieces of iron bloom. J. Eisner interpreted this structure as a blacksmith's abode dated to the Hallstatt period of the Iron Age. Therefore, the reconstruction of the dwelling from the Iron Age could serve to diversify the educational tourist trail.

Fig. 5. Jasov – Oblúková Cave. The place for the appropriate archeological presentation in the form of education boards. Photo: M. Soják

Fig. 6. Jasov – Fajka Cave. After some reconstruction of the platform in front of the cave it could be a right place for an archaeological presentation through educational boards. Photo: M. Soják

Bojnice I. (Prievidza district), Prepost Cave

The cave is located in the Hornonitrianska Basin in the Prievidza district and the territory of the town of Bojnice, on the edge of a larger cascade called Parsonage Travertine Mound just below the historic centre of the town. The entrance is at the elevation of 242 m, 11 m above the present small lake in the patronage garden. It has a character of a rocky overhang, which is about 12 m wide and 4.5 to 8 m high. Its internal space reaches only 6 m with a narrow, 8m-long passage on the north-eastern side. The Museum of Prehistoric Slovakia was established on the grounds of the Prepost Cave in 2007 with the help of the Slovak Caves Administration in Liptovský Mikuláš with active cooperation of the Institute of Archaeology SAV Nitra (Ľ. Kaminská, M. Soják) and the Upper Nitra Museum in Prievidza (I. Géczyová). The exhibition (HAUFO Bratislava, design by F. Hauskrecht, dummies by F. Finta), through a series of sculptures of Neanderthals clad in furs, gets a closer view of life at the end of the Middle Paleolithic in the cave's vicinity. Visitors may see a different work activity round the fireplaces, production and usage of chipped stone tools and hunting weapons (a wooden spear), childcare, worship of the cave bear (the skull in the wall niche) and supposed appearance of a leather screen leaning on abri (rock overhangs) (Fig. 7). The whole area is fenced off with wooden poles and supplemented by bilingual educational boards (besides Slovak also in English language) with the theme of travertine rock (a geological map of the vicinity, a text explaining the origin of the hot solution and formation of travertine), formation of the Prepost Cave (stages of the cave formation with drawings, a text, a map marked with other travertine caves in Slovakia) and information about other caves open to public. Primary is the archaeological educational board developed in collaboration with the Institute of Archaeology SAV Nitra (M. Soják; Fig. 8). According to the manager Emil Medera, the aim of the Museum of Prehistoric Slovakia is to connect the past with present by means of supporting today's young and talented artists in an attractive way (displaying their works of art). But the main emphasis is placed on interactive cooperation with pupils, i.e. their active involvement in the program content – solving various practical "prehistoric" tasks, work in a small group – "a Neanderthal clan" – and so on. Except for the educational program for elementary and secondary schools, a day and night guided tour, the museum also features a small souvenir shop (www.muzeumpraveku.sk). If one considers that in the Bojnice vicinity there are several positions with documented settlement in the Middle Paleolithic, the presentation here is in right place (Bárta, 1972). This kind of interactive museum does not have any match in Slovakia and serves certainly in favour of tourism development and extending the horizon of the ancient history of our territory. Similar evidences of Middle Paleolithic settlement were obtained for example from the territory of Poland (Jaskinia Ciemna –

Fig. 7. Bojnice I. – Prepost Cave. Sculpture of a Neanderthal child underneath the portal of the cave. Photo: M. Soják

Fig. 8. Bojnice I. – Prepost Cave. Educational board in front of the cave. Photo: M. Soják

the Dark Cave) in Ojców. Its presentation of a Neanderthal man strikingly resembles the Prepost Cave in the form of educational boards at the edge of a viewing platform and several Neanderthals sculptures in the so-called South Tunnel. Sculptures of Neanderthals in the Jaskinia Ciemna are visible from quite afar but they are not nearly as "alive" as in the Prepost Cave (Soják, 2008b).

Važec (Liptovský Mikuláš district), Važecká Cave

It is one of the best-known caves in Northern Slovakia (Fig. 9). Though in terms of length it belongs among short show caves, it is known by occurrence of rich dripstone decoration, remarkable findings of cave bear bones, as well as by rare cave fauna. Archaeologists have not found any evidence of settlement so far. However, we have several archaeological artifacts from the Upper Paleolithic which were found in the Liptov region (Valde-Nowak, Soják and Struhár, 2008). Therefore, we can imagine an exhibition of archaeological artifacts in the cave (especially chipped stone tools) in conjunction with the cave bear, which was very desirable game for prehistoric hunters of the Liptovská Basin. Nevertheless, a permanent zoo-palaeontological exposition is a part of the show path for cave visitors. It is aimed at popular-educational presentation of the cave bear (*Ursus spelaeus*) as one of the biggest extinct predators which ever lived on the European continent. The appearance of the bear is depicted by a skeleton reconstruction and a sculpture of the animal, both situated in the cave's interior (Fig. 10). They extended the original collection of bones, teeth, claws and skulls by then exhibited in the small palaeontological showcase in the cave space in Kostnica and other underground spaces. Outside the cave there are two educational boards of the cave bear that provide general information on its body size and weight, origin and distribution, habitat, reproduction, age and food supplemented with concrete data from local findings in the Važecká Cave (Višňovská, 2006). The cave bear sculpture is made of artificial stone (the actual size of an adult) created by the sculptor Daniel Tatarka and undoubtedly has an impact on visitors' imagination and deepens the experience of the underground space. The experience from abroad (e.g. Hermannshöhle in Germany, the entrance hall of the Niedźwiedzia Cave located near Kletno in Poland) points rather to presentation of reconstructed skeletons and findings "in situ" in the interiors of caves (e.g.

Fig. 9. Važec – Važecká Cave. Entrance portal. One of the educational boards in the background. Photo: M. Soják

Fig. 10. Važec – Važecká Cave. Sculpture of a cave bear in the Entrance Hall. Photo: M. Soják

Peştera Urşilor in Romania, Teufelshöhle in Germany, Grotta di Bossea in Italy and others) than whole sculptures of cave bears. Therefore, the Važecká Cave is unique, even though not the only one (Bernadovič, 2001, 38; Višňovská, 2006, 61).

Lipovce (Prešov district), Bad Hole Cave (Zlá diera)

It is the only cave in the Prešov district open to public, namely as of 2006. Cave guiding activities are performed by R. Košč with a group of enthusiasts. The cave is located in the geomorphological unit Bachureň. Visitors experience a unique descent to the cave's mysterious depths. Accompanied with a guide, they are equipped with protective helmets and traditional cavern carbide lamps or their own torches as the cave has no electricity (Gaál, 2006). In the archaeological research in the late 19th century (Roth, 1881) and during works making the cave accessible, tangible evidence of prehistoric settlement was found, such as fireplaces with animal bones and pottery dated to the Prehistoric Age (Bronze Age?), Middle Ages and Modern Times. In the cave anthropological findings and evidence of the cave utilization at the end of the Second World War were also discovered (Bárta, 1984). The paleonthological and archaeological "presentation" in the interior of the cave is inconvenient, as it is limited only to osteological and shards findings freely placed on the clay surface in the Great Hall (Fig. 11). After complex processing of all archaeological findings from the cave, it would by desirable to make a nice exhibition in the cave itself with educational boards where visitors could see samples of the findings together with texts and drawings. The reconstructed pottery could be placed into glass showcases in the chronological order. A part of this kind of presentation could be located in the area above the cave, where there are objects for the staff and guests, and at the rest area for tourists. In the dim places of the cave's underground without electric lighting, only presentation of larger exhibits is appropriate, e.g. bones, reconstructed pottery, or sculptures of prehistoric humans or hunting animals.

Fig. 11. Lipovce – Bad Hole Cave. Example of the paleonthological presentation in the cave. Photo: M. Soják

ARCHAEOLOGICAL PRESENTATION OF CAVES ON HIKING TRAILS

Driečany (Rimavská Sobota district), Veľká and Malá Driečanská Caves

The educational trail in the Drienčany Karst was built in 1989 to 1992 and restored in 2002. The nature trail begins from the Centre for Environmental Education SAŽP Drienok and has fifteen stops. In front of both caves there are educational boards with texts (in Slovak and English language), pictures and information about settlement of the cave. In the Malá Drienčanská Cave, through which a short passage for visitors is made (Gaál, 2000), evidence of the settlement in the Early, Late Bronze Age (the Kyjatice Culture) and in the Late Middle Ages (15th century) was found. Inside the cave there is a replica of a vessel improperly fastened to a rock (risk of stumbling). We believe that it would be preferable to place it under the exhibition panel or to attach a photo directly to the panel. In the Veľká Drienčanská Cave the best evidence of Pleistocene bones (*Ursus spelaeus*) was found, as well as Neolithic and Bronze Age findings. On the education board, situated in front of the entrance, there is an illustration of a cave bear and its life-sized tooth and on the layout of the cave an archaeological trench from the research of J. Bárta in

1955 is marked (Bárta, 1963). It would be also preferable to close the cave using iron bars in order to protect bat colonies and to prevent amateur excavati

Poráč (Spišská Nová Ves district), Šarkanová diera and Chyža Caves

The caves are situated next to each other. In both caves evidence of rich settlement of the Neolithic Age (Linear Ceramic Culture, Želiezovská Culture, Bükk-Mountain Culture), the Middle Ages and Modern Age was found (Bárta, 1956; Soják, 2001). Based on the municipality's initiative, the idea emerged to make the Šarkanová diera Cave partially accessible within the nature trail the Nature Attractions near Poráč (2000). A part of the cave with decoration remains, which was not destroyed by vandals yet, was closed by iron bars. In front of the entrance an educational board was fixed, initially with information that is outdated from the archaeological point of view (Soják, 2006), but later, in 2008, thanks to the cooperation with the Archaeological Institute SAV Nitra and upon I. Balciar's own initiative, new knowledge based on current speleo-archaeological research in the Šarkanová diera and Chyža Caves were added (e.g. evidence of a coin forgery activity in the 15th century).

OTHER OPTIONS FOR PRESENTATION OF SPELEO-ARCHAEOLOGICAL SITES

Bojnice III. – the Castle Moat vs. Bojnická Castle Cave and other potential presented caves

On the premises of the Bojnice Castle on the site called Bojnice III. – Castle Moat, numerous split stone tools from up to 11 positions were acquired but also evidence of ruined fireplaces and animal bones. We can follow up here an almost uninterrupted sequence of travertine layers from the last interglacial (R/W) to the early last glacial period (W). Since 1965, the Bojnická Castle Cave is also a part of the Bojnice Castle. Its original entrance is represented by the well on the current courtyard No. IV. Ideal conditions for an exhibition of Paleolithic cave dwellers in Bojnice may be found in the underground spaces of the cave. It would make the permanent exhibition at the castle more attractive, promote an important Paleolithic site in the Castle Moat and would also direct tourists to the Museum of Prehistoric Slovakia in the nearby Prepost Cave. The exhibition in the Bojnická Castle Cave would also be appropriate in the view of its attested Paleolithic settlement. It is testified by the black belts of soot ingrown in dripstones on the cave's walls and the cultural layers with charcoal, fossil bones and artifacts of quartz and andesite tuff. All the evidence was discovered in 1965 by drilling of a horizontal tunnel leading to the cave (Lalkovič, 2005, 39, 41).

Of course in Slovakia there are more caves with evidence of Paleolithic settlement, however there is none which has been explored systematically. In almost all of them, settlement from the younger period of Prehistoric Ages was also discovered. Making caves available to general public comes into consideration in the case of more accessible caves, situated near main roads or nature trails. Within this frame of reference the following ones come in consideration: Dzeravá skala near Plavecký Mikuláš, Čertova pec near Radošina, the caves No. 1 and 2 near Lučivná and the like (Farkaš, 2007; Kaminská, Kołowski and Svoboda, 2005; Soják, 2007c, 35nn). Many of these and other caves have provided interesting paleontological materials, chipped stone tools and remarkable artifacts of Paleolithic Art (Kaminská, 2009). But, if we take wealth and especially attraction into consideration, we can't compare them to findings from foreign prehistoric caves, where visitors may see accessible anthropological remains, or fascinating galleries of cave paintings (Bella, 1997b; Lehotský, 2000).

Slovak caves are also promising, having provided evidence of settlement from the younger section of Prehistory to the Middle Ages and Modern Age. Some of them are situated along the busy nature trails or not far from restaurants and cottages, whose owners or operators could direct tourists to the open caves. We can also mention the Homološová diera Cave in Slovinky, situated above the restaurant Čierny bocian (Black Stork) in the Galmus Mountains (settled in the Eneolithic, Bronze

Age, Middle Ages, and during the 2nd World War), or the Netopierská Cave (with the findings from the Roman Age) in the Nemce cadastral territory in Starohorské Hills, situated near the nature trail (Bárta, 1995; 1984, 249). The Liskovská Cave deserves to be made accessible and archaeologically presented on a professional level. The Temná Cave near the village of Žehra has great conditions for an exhibition. It is situated in the travertine massif under the famous Spiš Castle. Since the cave is only accessible to experienced cavers, entry for ordinary tourists is not possible. From among archaeological findings, human skeletal remains with two leather moneybags filled with Roman coins (dated from the 1st to 2nd century A.D.) are unique. This remarkable finding could be used as an excellent specimen in the permanent exhibition at the Spiš Castle (Soják, 2005b). The same is true for over more than 40 adjacent caves situated in the Dreveník Hill vicinity between Žehra and Spišské Podhradie. Many of the caves in the aforementioned hill are important archaeological sites, which deserve attention in terms of presentation, at least by educational boards on hiking trails or in the parking lot below the Spiš Castle (here the educational board invites visitors to the Bad Hole Cave in Lipovce). They are partially substituted by information boards placed in the lower courtyard of the Spiš Castle. However, they would deserve more comprehensive attention in the form of an exhibition at the Spiš Castle.

Moldava nad Bodvou (Košice–vicinity district), Moldavská Cave and Mníchová diera

The Moldavská Cave is located in Moldava nad Bodvou's vicinity west of the hospital site, above local garages. It represents more than a 3km-long and spread labyrinth, interlinked with bigger and smaller spaces suitable for settlement. It has been known from time immemorial as a cave with numerous human bones. Only systematic archaeological research in 2004 – 2006 pointed to its special rarity in connection with the Mongol-Tartar Invasion on the territory of Slovakia in 1241 – 1242. We can also find there archaeological findings from Prehistory and Early History. All this prompted P. Dvořák to write his next work cycle, the book *Stopy dávnej minulosti*, which also suggests the importance of the cave for medieval history of Slovakia (Dvořák, 2009, 179-193). The book is based on the results of speleo-archaeological research, which were described in a separate monograph in 2007 (Soják and Terray, 2007). Considering the aforementioned knowledge of the cave and its appropriate position near the town centre, opening the cave for an archaeological exhibition is fitting. Relatively good conditions for presentation are offered by the Entrance Hall. The exhibition itself requires active collaboration with archaeologists, cavers, other experts and of course with the municipality. It would also require such arrangements as for example closing the corridors leading from the Entrance Hall by iron bars, performing landscaping in the accessible part as well as in front of the entrance to the cave, sensitive handling of the local fauna (presence of bats) or a guided tour. Connectivity of the historical-archaeological exhibition in the Local Information Centre and the Moldavská Cave by a natural trail would be obvious. In addition, one of the trail branches located next to the cave could lead to the adjacent Mníchová diera Cave, where evidence of settlement was also found (late Middle Ages and Modern Times) and which also has appropriate conditions for at least a panel presentation (Soják and Terray, 2007, 58, 59).

"THE CAVE AS THE COIN FORGERY WORKSHOP" AND BREEDING GROUND FOR PRESENTATION

Thanks to intensive speleo-archaeological research in recent years, several caves with evidence of coin forgery activities from the end of the Middle Ages were discovered. The research was carried out especially in the Spiš region and in the south and east of Slovakia. Advisable conditions for the presentation of the aforementioned illegal activities may be found especially in the Spiš region in the caves of the Kozie chrbty Hills, the Spiš-Gemer Karst (Slovak Paradise) and the Volovské Hills (Galmus). Even though many of these caves are located in the hard-to-access terrain of mountains and rocky gorges (for the reason of confidentiality), almost all of them are near marked hiking trails (see the most recent: Soják, 2010). Particularly the Chvalovská Cave and several caves of the National Park Slovak Paradise deserve the presentation of poly-cultural settlement, including coins forgery activities. Another ideal cave is the Kláštorná Cave located below the medieval Carthusian monastery built on the Rock of Refuge (*Lapis refugii*) near the village of Letanovce (Soják – Hunka, 2001). The premises of monastery, frequently visited in the summer tourist season, could be used as a place for presentation of coin forgery activities. Similar conditions of accessibility are also offered by the Ružová Cave (located near the Kláštorná Cave), where evidence of settlement was also found (Soják, 2007c). From the archaeological point of view, the Suchá diera Cave (also called the Nízka Cave) located in Spišská Teplica, in the Kozie chrbty Hills, is also very attractive. After science-popularization processing of findings from the cave in the book about history of the village (Soják at al., 2002), efforts by local people emerged to realize education excursions (especially for schools), leading from the village across the Vápenica Valley to this cave. It is necessary to mention that, due to continuous damaging of the cave's sediments, rescue archaeological research was implemented, which demonstrated settlement of the Upper Paleolithic and presence of a coin forgery workshop from the Late Middle Ages (Soják and Hunka, 2003).

On the territory of the Czech Karst, the Koněpruské Caves (also called the Caves of the Zlatý kůň Hill) are the most important ones. On the upper floor remains of a coin forgery workshop from the second half of the 15th century were examined; the workshop is open to public (Fig. 12). Visitors walk along a footpath where coin forgers also used to walk, they have the opportunity to see their workshop and buy a copy of fake coins at a local souvenir shop. In the same period, coin forgers used to work in the Babí pec Cave in Kozákov (national park the Czech Paradise) and in the Čertova díra Cave on the Kotouč Hill near Štramberk. Originating from Moravia's territory are modern fake coins from the Výpustek Cave located near the villages Křtiny and Dagmar near the village Lipovec. In Poland a coin forgery workshop was found in the Zbojnícka Cave located near Źywca and in Austria in the Kleines Zwerglloch Cave near Bad Fischau (Matoušek and Dufková, 1998, 141; Matoušek, Jenč and Peša, 2005, 72, 116, 162). But appropriate archaeological presentation of the aforementioned caves is also absent.

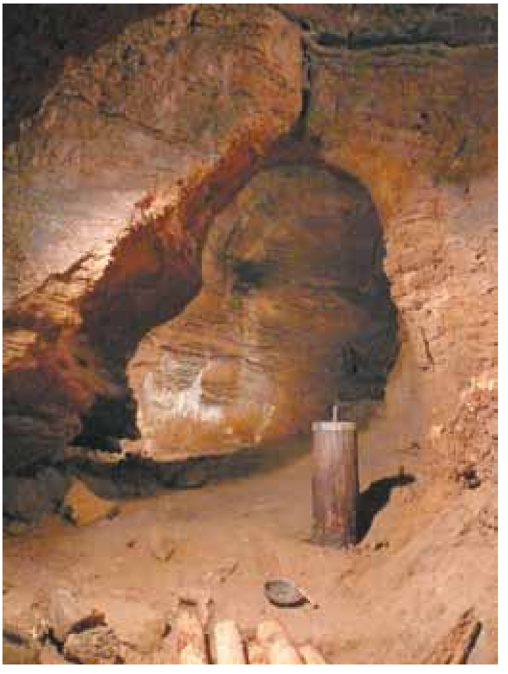


Fig. 12. Koněprusy – Koněpruské Caves. Monetagium with the presentation of the coin forgery workshop. Archive of the Archaeological Institute SAV Nitra

CONCLUSION

A relatively small area of Slovakia is abundant in occurrence of karst forms, of which a considerable part is also notable for archaeological sites. Among the modest number of the open caves only the Domica Cave is a representative site in terms of archaeology and its presentation. Even though we cannot compare the Domica Cave with Franco-Cantabrian caves and their beautiful underground galleries of Palaeolithic Art, Domica keeps up with foreign speleo-archaeological sites. In Slovakia there are numerous poly-cultural cave settlements where failure to make them visible in favour of tourism development and national awareness is noticeable. After all, which country can boast of such treasures as the Moldavská Cave, the Temná Cave below the Spiš Castle or the number of caves mentioned above with evidence of coin forgery activity at the end of the Middle Ages? Therefore, we should seek, in collaboration with interested institutions and experts from various related disciplines, to promote these phenomena and open more caves to general public in the form of exhibitions, fixed educational boards near hiking trials and, last but not least, in the form of popular educational films and publications. In doing so, substantial funds are not always needed. In Slovakia several prospective speleo-archaeological sites have come into view in recent years, deserving presentation understood in this manner. All considered, to implement the above mentioned presentations of the caves, cooperation with local municipalities, cultural institutions (as for example museums) or with the private sector (entrepreneurs) is needed, and in particular full cooperation with the State Nature Conservancy of the Slovak Republic – Slovak Caves Administration in Liptovský Mikuláš and the Slovak Museum of Nature Protection and Speleology in Liptovský Mikuláš.

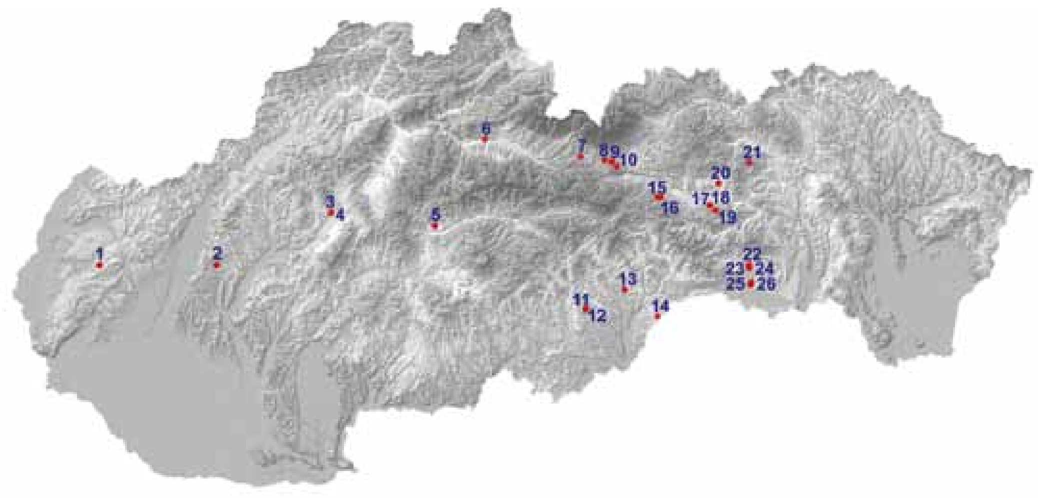


Fig. 13. The map of the most important speleoarcheological sites in Slovakia: 1 – Dzeravá skala Cave, 2 – Čertova pec Cave, 3 – Prepost Cave, 4 – Bojnická Castle Cave, 5 – Netopierská Cave, 6 – Liskovská Cave, 7 – Važecká Cave, 8 – Lučivianska Cave no. 2, 9 – Lučivianska Cave no. 1, 10 – Suchá diera Cave, 11 – Malá Drienčanská Cave, 12 – Veľká Drienčanská Cave, 13 – Chvalovská Cave, 14 – Domica Cave, 15 – Ružová Cave, 16 – Kláštorná Cave, 17 – Chyža Cave, 18 – Šarkanova diera Cave, 19 – Homološová diera Cave, 20 – Temná Cave, 21 – Bad Hole Cave, 22 – Oblúková Cave, 23 – Fajka Cave, 24 – Jasovská Cave, 25 – Moldavská Cave, 26 – Mníchová diera Cave

Bibliography

Bárta, J. (1955). Jaskyne Netopierska a Kaplnka v Nízkych Tatrách a ich rímske osídlenie s antropologickými nálezmi. Slovenská archeológia, 3, 286-301.

Bárta, J. (1956). Neolitické osídlenie jaskýň pri Poráči na Slovensku. Archeologické rozhledy 8, 633-639.

Bárta, J. (1963). Desať rokov speleoarcheologickej činnosti Archeologického ústavu SAV. Slovenský kras, 4, 1961-1962, 87-97.

Bárta, J. (1972). Pravek Bojníc. Od staršej doby kamennej po dobu slovanskú. Bratislava, 40 s.

Bárta, J. (1984). Tretie desaťročie speleoarcheologickej činnosti Archeologického ústavu SAV v Nitre (1972-1982). Slovenský kras, 22, 245-265.

Bella, B. (1997a). Stála výstava vo vstupnom areáli Jasovskej jaskyne. Aragonit, 2, 21-22.

Bella, B. (1997b). Poznatky zo študijnej cesty po sprístupnených jaskyniach Francúzska. Aragonit, 2, 27-29.
Bernadovič, F. (2001). Študijná cesta po sprístupnených jaskyniach Nemecka. Aragonit, 6, 37-39.
Dvořák, P. (2009). Stopy dávnej minulosti, 5. Slovensko v stredoveku. Druhé kráľovstvo a jeho koniec. Budmerice, 255 s.
Farkaš, Z. (2007). Dzeravá skala – osídlenie v neskorej kamennej dobe. Pamiatky a múzeá, 56, 1, 2-5.
Gaál, Ľ. (2000). Kras a jaskyne Drienčanského krasu. In Kliment, J. (ed.): Príroda Drienčanského krasu. Banská Bystrica, 29-96.
Gaál, Ľ. (2006). Zlá diera – nová sprístupnená jaskyňa na Slovensku. Aragonit, 11, 64-65.
Gaál, Ľ. – Gažík, P. – Soják, M. (2006). Nové náučné centrum v Domici. Aragonit, 11, 57-59.
Hlaváč, J. (1997). Vyhlásenie jaskýň Slovenského a Aggtelekského krasu za svetové dedičstvo. Aragonit, 2, 34-35.
http://www.muzeumpraveku.sk/
Kaminská, Ľ. (2009). Paläolithische Kunst in der Slowakei. Anthropologie, 47, 2, 125-130.
Kaminská, Ľ. – Kozłowski, J. K. – Svoboda, J. A. (2005). Paleolitické osídlenie jaskyne Dzeravá skala pri Plaveckom Mikuláši. Výsledky výskumu v rokoch 2002-2003. Slovenská archeológia, 53, 1-26.
Lalkovič, M. (2005). Z histórie Bojnickej hradnej jaskyne. Aragonit, 10, 38-41.
Lehotský, R. (2000). Jaskyňa Petralona – významná grécka archeologická a paleontologická lokalita. Aragonit, 5, 42-43.
Lichardus, J. (1968). Jaskyňa Domica najvýznačnejšie sídlisko ľudu bukovohorskej kultúry. Bratislava, 124 s.
Matoušek, V. – Dufková, M. (1998). Jeskyně a lidé. Praha, 165 s.
Matoušek, V. – Jenč, P. – Peša, V. (2005). Jeskyně Čech, Moravy a Slezska s archeologickými nálezy. Praha, 279 s.
Soják, M. (2001). Neolitické osídlenie Spiša. Slovenská Archeológia 48-2, 2000, 185-314.
Soják, M. a kol. (2002): Dejiny obce Spišská Teplica. Spišská Teplica, 271 s.
Soják, M. (2005a). Osídlenie jaskýň. In J. Jakál (ed.): Jaskyne svetového dedičstva na Slovensku. Liptovský Mikuláš, 101-112.
Soják, M. (2005b). Osídlenie Temnej jaskyne pod Spišským hradom. Východoslovenský pravek, 7, 83-100.
Sják, M. (2006). Stav a perspektíva prezentácie jaskynných lokalít na Slovensku. Študijné zvesti AÚ SAV, 40, 177-192.
Soják, M. (2007a). Výskumy na východnom Slovensku. AVANS v roku 2005. Nitra, 177-183.
Soják, M. (2007b). Osídlenie blízkeho okolia Moldavy nad Bodvou. In Soják, M. – Terray, M. (eds.). Moldavská jaskyňa v zrkadle dejín. A Szepsi-barlang a történelum tükrében. Moldava nad Bodvou, 50-72.
Soják, M. (2007c). Osídlenie spišských jaskýň od praveku po novovek. Nitra, 184 s.
Soják, M. (2008a). Jaskyne Slovenského krasu a okolia vo svetle nových archeologických objavov. Slovenský kras, 46, 2, 419-438.
Soják, M. (2008b): Archeologický výskum dvoch poľských jaskýň. Spravodaj SSS 3, 39, 37-39.
Soják, M. (2010). Výpoveď archeologických prameňov v obci a jej okolí. In I. Chalupecký (ed.). Dejiny Betlanoviec. Levoča, 17-40.
Soják, M. – Hunka, J. (2001). Prekvapujúci objav z Kláštornej jaskyne. Spravodaj SSS, 4, 25-27.
Soják, M. – Hunka, J. (2003) Paleolitické sídlisko a neskorostredoveká peňazokazecká dielňa v Spišskej Teplici v jaskyni Suchá diera. Slovenská archeológia, 51, 2, 341-365.
Soják, M. – Terray, M. (eds.) (2007). Moldavská jaskyňa v zrkadle dejín. A Szepsi-barlang a történelum tükrében. Moldava nad Bodvou, 137 s.
Valde-Nowak, P. – Soják, M. – Struhár, V. (2008). Prvé doklady epipaleolitického osídlenia na území Liptova. Študijné zvesti AÚ SAV, 43, 139-146.
Višňovská, Z. (2006). Paleontologická expozícia medveďa jaskynného (*Ursus spelaeus*) vo Važeckej jaskyni. Aragonit, 11, 60-64.

THE AUSTRALASIAN CAVE AND KARST MANAGEMENT ASSOCIATION INC: A TRANS-NATIONAL ORGANIZATION OF SHOW CAVES, MANAGERS, GUIDES, SCIENTISTS AND CAVERS

Andy Spate[1], Kent Henderson[2], Dan Cove[3] and Greg Martin[4]

[1] International Relations Officer, ACKMA
[2] Publications Officer, ACKMA
[3] Interpretations Officer, ACKMA
[4] Former President & New Zealand Vice-President, ACKMA

Abstract: The Australasian Cave and Karst Management Association Inc (ACKMA) was founded in 1987 arising from a previous series of six biennial cave tourism and management conferences under the auspices of the Australian Speleological Federation (ASF) and agencies of various governments. Before 1987 the impetus for the cave and tourism conferences was largely from interested individuals but increasingly management agencies, and more importantly their staff, realized that cave and karst management needed a separate voice – away from recreational cavers. ACKMA has become a very effective and active organization.

Whilst its membership of about 300 is largely drawn from Australia and New Zealand, it also has members in Britain, Europe, Canada, the United States, South Korea, Malaysia, South Africa, and the Middle East. It convenes formal conferences every two years. In intervening years well-attended Annual General (business) Meetings are held, normally in Australia, although the latest (April 2010) was held at Mulu Caves in Sarawak, Malaysia. Nearly one third of the membership attended this meeting!

The Association publishes a well illustrated and informative journal four times a year. This normally runs to about 48 pages and includes scientific articles, educational material as well as news and events from its members and their institutions illustrated with black and white and colour images.

ACKMA also supports biennial cave guide workshops, which usually run for 3–5 days. These are opportunities for cave guides to meet and exchange ideas about guiding, interact with cave scientists and to promote one another's products so that the show cave environment of Australia, New Zealand and beyond are co-promoted. ACKMA and its members are involved in consultancies providing assistance on advice in fields such as cave lighting, show cave development, cave and karst interpretation, landscape rehabilitation on karst terrains and on karst groundwater issues in Australasia, Asia, the USA and Europe.

ACKMA's support for proper karst management has even been incorporated in the parliamentary record of the Canadian province of British Columbia in legislating for their recent, and innovative, karst management legislation!

We believe that the interdisciplinary and international links and the fact that ACKMA successfully involves cave guides, national park rangers, recreational cavers, scientists, cave managers, educators and others from across the world in better managing caves and karst makes it a remarkably unusual – and effective – trans-national organization.

INTRODUCTION

Conferences on Cave and Karst Management have been held in this region since 1973. From then until 1983, they were organized under the auspices of (but not organised by) the Australian Speleological Federation, the first five being termed Australian Conferences on Cave Management and Tourism. The 6th Conference was held at Waitomo Caves, New Zealand in 1985. On 16 May 1987 the *Australasian Cave Management Association* (ACMA) was formed at a meeting held at Yarrangobilly Caves during the 7th Conference in New South Wales. All conferences since have been referred to as Australasian Conferences on Cave & Karst Management.

The Association re-named itself the *Australasian Cave & Karst Management Association* (ACKMA) at the subsequent biennial General Meeting associated with the 8th Conference held at Punakaiki, New Zealand, in 1989. At the 1995 biennial General Meeting at Derwent Bridge, Tasmania, during the 11th Conference, the Association became incorporated as the *Australasian Cave & Karst Management Association Inc*[1]. Prior to that date Officers of the Association were elected to two-year terms. The tenure of officers is now twelve months. The ACKMA's Aims are set out in the box below.

AIMS of the Australasian Cave and Karst Management Association Inc.
To develop improved standards in the management of the cave and karst heritage of the Australasian region.
To provide for liaison between services to, and joint action by, those interested in cave and karst management.
To carry out or cause to be carried out any scientific research which may further the improvement of standards in cave and karst management.
To formulate and promote policies and initiatives in cave and karst management.
To do any other things which are conducive or incidental to the attainment of the above.

Significant events in the life of ACKMA are set out in Appendix 1 below.

MEMBERSHIP

The membership of ACKMA is made up of a diverse range of individuals and organizations scattered across the globe. We have even had members in Antarctica! There are individual cave guides, national park rangers, cavers, scientists, engineers, adventure tour operators, scientists, farmers, teachers and a former government minister as well as show cave operations and government departments.

The following three figures indicate the occupations and distribution of ACKMA members as of January 2011. The category 'cave interested people' includes anyone who does not readily fit into another category. It also includes organizations with whom ACKMA is cross-affiliated or otherwise associated, which are listed as ACKMA members but who do not pay an annual fee.

All Australian and many New Zealand show cave operators are linked with ACKMA in some way as are many of the cave adventure tour operators as is shown in Tables 1 and 2. The distribution of the sites is show in Maps 1 and 2. With one exception all 23 Australian show cave sites are government owned with eight run by concessionaires under lease from state or local government. Jenolan and Margaret River are perhaps the most important show cave destinations but in a country as large as this the local economic importance of small show cave operations cannot be understated. For example, in the tiny village of Wee Jasper in New South Wales the only economic operation other than farming and holiday accommodation is the small, but delightful, Careys Cave. We estimate that more than 750,000 people visit Australian show caves annually.

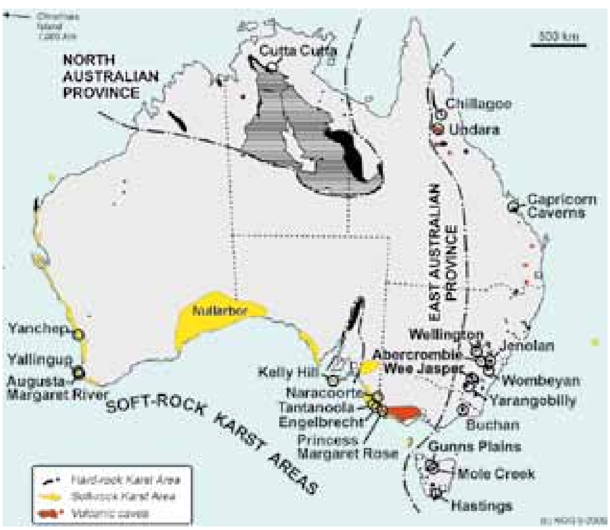
There are a number of other sites in Australia where government owned lands possess significant karst features that are open to the public with tours through the sites. The chief among these are The Pinnacles in Nambung National Park, and Windjana and Geike Gorges in the Kimberley – these are all in Western Australia.

[1] Inc = Incorporated. Formal incorporation provides ACKMA Inc with a legal identity.

Table 1. Australian show caves affiliated with ACKMA.

PLACE	CAVES	TOURS	COMMENTS
Abercrombie, New South Wales*	4	3	Government run
Buchan, Victoria*	3	3	Government run
Calgardup, Western Australia	2	2	Government run
Capricorn Caverns, Queensland*	1	3	Private land
Chillagoe, Queensland*	3	4	Government run
Cutta Cutta, Northern Territory*	1	1	Leased from government
Engelbrecht, South Australia	1	1	Leased from local government
Gunns Plains, Tasmania	1	1	Leased from government
Hasting, Tasmania	1	1	Government run
Jenolan, New South Wales*	10	20	Government run
Kelly Hill, South Australia	1	1	Government run
Margaret River, Western Australia	3	3	Leased from government
Mole Creek, Tasmania	2	3	Government run
Mount Buffalo, Victoria	1	1	Adventure caving in boulder cave. Concession in national park
Naracoorte, South Australia*	5	4	Government run
Ngilgi, Western Australia	1	2	Leased from government
Princess Margaret Rose, Victoria*	1	1	Leased from government
Tantanoola, South Australia*	1	1	Government run
Undara, Queensland*	several	several	Leased from government
Wee Jasper, New South Wales	1	2	Leased from government
Wellington, New South Wales*	3	3	Operated by local government
Wombeyan, New South Wales*	6	6	Government run
Yanchep, Western Australia*	1	1	Government run
Yarrangobilly, New South Wales*	6	4	Government run

*Notes on Table 1. Caves = number of caves used. Tours = the number of tours or tour types conducted in those caves (e.g. at Jenolan there are many themed tours such as historical, photographic or ghost tours). An asterisk * denotes the presence of specialized karst or other nature walks at the site.*



Map 1. Distribution of Australian show caves (shown as circles). 'Soft rock' refers to Limestones of Tertiary to Quaternary age. 'Hard rock' refers to limestones and dolomites that are Palaeozoic age or older.

There is also a tourism operation in the Dismal Swamp polje in north-western Tasmania. There are also significant tourist operations in a number of the sandstone karst areas across northern Australia such as in the World Heritage listed Purnululu National Park in the Kimberley of Western Australia.

The situation is somewhat different in New Zealand with a greater proportion of privately owned operations and far more adventure, and adventurous, tours including several "black-water rafting" operations. Again, cave visits are an important feature of local economies. An estimate of 675,000 people visit a show and adventure cave annually in New Zealand.

Table 2. New Zealand show caves.

PLACE	CAVES	TOURS	COMMENTS
Cathedral Cave, SI*	1	1	Private land, self-guided in complex sea cave
Honeycomb Hill, Karamea, SI*	1	1	Government owned – leased adventure tour,
Kawiti, Whangarei, NI	1	1	Leased operation on Maori land
Maori Leap, Kaikoura, SI*	1	1	Private land
Ngarua, Nelson, SI*	1	1	Private land
Nikau, Waikaretu, NI	1	1	Private land, adventure tour
Norwest Adventures, Westport, SI	2	2	*Blackwater rafting* in government owned Metro Cave
Te Anaroa, Nelson, SI	3	3	Private land
Te Anau Glowworm Cave, SI	1	1	Leased from government
Waitomo, NI	5	5	See Table 3
Wild West Adventures, Greymouth, SI*	1	1	*Blackwater rafting* in government owned Dragon Cave

*Notes on Table 2. SI = South Island – NI = North Island. An asterisk * denotes that the operation is not an ACKMA member.*

Map 2. Distribution of New Zealand show and adventure caves.

The far greater proportion of privately owned caves and adventure activities in New Zealand caves is due to the legal situation in that country which provides for such activities without the litigation mentality, and actuality, so evident in Australia. The Waitomo area has a very large number of adventure caving activities as well as the five conventional show caves. Waitomo Glowworm Cave is a significant part of New Zealand's economy.

Table 3 shows the variety of cave-related opportunities at the economically important Waitomo region.

AFFILIATIONS

ACKMA is affiliated or linked with a variety or organizations around the world. These include the:

American Cave Conservation Association

- American Caves Association
- Association of British and Irish Show Caves
- Australasian Bat Society
- Australian Speleological Federation Inc
- Bat Conservation International
- Cave Divers Association of Australia
- French National Show Caves Association (ANECAT)
- Guiding Organisations Australia
- International Network on Cave Protection and Management (under the IUCN Commission on National Parks and Protected Areas)

Table 3. Caving opportunities at Waitomo.

OPERATION	CAVES	TOURS	COMMENTS
Waitomo Glowworm Cave	1	1	¼ Government; ¾ Maori land. Leased to commercial operator
Aranui Cave	1	1	Government owned leased to commercial operator
Ruakiri Cave	1	3	Part Government, part privately owned – 2 separate commercial leases
Spellbound	2	2	Private land – leased to operator
Rap Raft Rock/Waitomo Wilderness Tours	1	1	Private land
Waitomo Adventures	4	4	Private land
GreenGlow	1	1	Private land
Cave World	1	1	Private land

- International Show Caves Association
- International Union of Speleology
- Italian Show Caves Association (ACTI)
- Malaysian Karst Society
- National Speleological Society (of the USA), Cave Management and Conservation Section.
- New Zealand Speleological Society

We welcome affiliation with any other group or institution around the world.

MEETINGS

ACKMA conducts or is involved with a variety of meetings as detailed below. These yearly or more frequent meetings keep the Association fresh and rejuvenated. The Australasian region – Australia, New Zealand and nearby islands is huge as can be seen from Map 3. Australia is about 4,000 km from east to west and New Zealand is about 1,500 km from north to south. The two are separated by about 2,000 km. The meetings and the ACKMA Journal, of which more detail is below, are the 'glue' that holds the organisation together in spite of the distances that separate us.

Map 3. Australia and New Zealand at their correct size and latitudinal relationship to the rest of the world.

Conferences

An ACKMA Conference is held every two years. The Conferences are a blend of business meeting (a formal Annual General Meeting (AGM) of a half day or less), papers dealing with science, management, infrastructure and interpretation amongst other issues, and visits to show caves, wild caves and karst landscapes. Often there are associated workshops dealing with such things as cave lighting and interpretation a Conference. This biennial event is held around May each year and lasts for 5 – 6 days. It rotates around Australia and New Zealand show cave sites. There are six Australian States and for ACKMA purposes the North and South Island of New Zealand are counted as "states". There are thus 8 "states", and each can therefore expect to host a Conference every 16 years. These Conferences are normally attended by 100 or so attendees – usually with around 5 – 10 from far beyond the Australasian region.

Business meetings

Each alternate year ACKMA conducts its AGM – again normally at a show cave site or a place of special karst interest. Increasingly these meetings are taking on the role of a 'mini-conference' with papers and workshops. These are normally attended by about

60 members although the most recent one at Gunung Mulu in the Malaysia sate of Sarawak attracted about one-third of the total membership! The yearly AGM meeting must be held to satisfy the legal aspects of our incorporation – the establishment of our legal identity – and include the reports of office bearers, inspections of the accounts and budgets and the all-important election of the office bearers.

Guides gatherings

ACKMA encouraged show cave guide interchange from its inception and developed the concept of guide's gatherings – known by a variety of names over the years. These events were initially held annually, by are now biennial. They allow guides to exchange ideas and technologies and permit them to meet with scientists and other experts in cave and karst science and management. National park rangers and other management personnel increasingly attend these meetings to increase their knowledge of caves and karst.

Scientific seminars

ACKMA has, in the past, been a facilitator (with various academics and their institutions) of Karst Studies Seminars. Five of these events were held, largely at two year intervals, at various cave locations in Australia. Their primary purpose was to enable university students in karst studies and related fields to present their research to their peers and to ACKMA members generally. Regrettably, a diminution of the number of students in Australia and New Zealand studying in karst-related fields have meant these seminars are presently in abeyance.

PUBLICATIONS

Conference proceedings

The *Proceedings* of the first sixteen Conferences thus far held have been published on paper, and are also available on CD Rom. The 17th and 18th Conference *Proceedings* are only available on CD Rom. As well as the Conference proceedings these CDs have selected important papers from the Journal and the ANDYSEZ columns (these are described in more detail below).

The ACKMA Journal

The first edition of the ACMA (later ACKMA) Newsletter was published in June 1988 – a mere 12 pages. It was thereafter published half-yearly until 1993. For the subsequent 18 months, it was published quarterly, with two full "Journal Editions", and two (minor) "Newsletter Editions". The publication was permanently renamed the ACKMA Journal from Edition 16 issued in September 1994, and from Edition 19 (June 1995) it was been issued quarterly as a full Journal. The most recent edition is number 81 published in December 2010 with the next to appear in March 2011. Edition number 81 ran to 56 pages, had a colour cover and some colour images inside – as well as many black and white photographs. The emphasis on this edition was on cave lighting.

The Journal contains a President's report, non-peer reviewed scientific papers, news from Australasia and further abroad, social notes, reviews on conferences attended by ACKMA members, travelogues, opinion pieces, book reviews, and news on up coming conferences and events. It includes an irregular series – the ANDYSEZ columns – of which some 55 have appeared over the years. These are discussions of things of interest to cave guides and others – putting science into layman's language – and have covered issues such as helictite formation, radon in caves, carbon dioxide in caves, dating of caves, modes of speleogenesis and much else. These are usually compiled by Andy Spate but there have been a number of guest authors of the column.

The ACKMA CD

As mentioned above ACKMA produces a CD Rom every two years following the biennial conferences. This contains the proceedings of all previous conferences – including those that were held before ACKMA's formation in 1987. Also included on the CD are selected important papers from the ACKMA Journal that are judged to be significant for the management of caves and karst. The ANDYSEZ columns are also included.

The ACKMA Website

ACKMA has a regularly updated website – http://ackma.org. The home page is displayed below (Figure 4). The website map can also be found below. The website has public face and a members-only area. The latter area has expanded access to papers from the Journal and the rules, minutes and other official papers of the organisation.

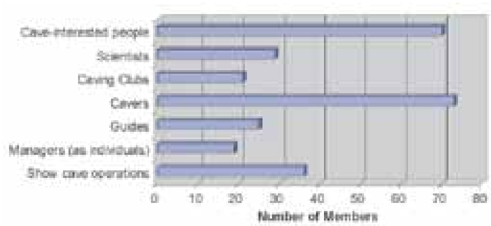


Fig. 1. ACKMA members by occupation.

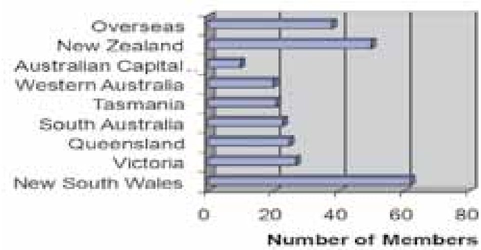


Fig. 2. ACKMA members by location.

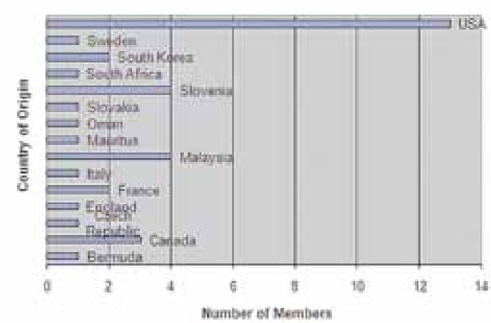


Fig. 3. Overseas ACKMA members by country of origin.

Fig. 4. ACKMA Website homepage.

The website map includes the following pages:

- About ACKMA
- ACKMA Conferences Pages
- ACKMA History
- ACKMA home page (as above)
- ACKMA Journal Articles Pages
- ACKMA's Aims
- Australian Caves Pages
- Cave Decoration Pages
- Cave Science External Links Page
- Description Page
- Employment Advertisements
- External Links Page
- Forthcoming Conference Pages
- Join ACKMA Page
- Members Only Pages
- New Zealand Caves
- Scientific Papers
- Travel External Links Page

Miscellaneous publications

ACKMA has produced a variety of publications over the years including the now outdated Directory of Australian and New Zealand Caves. Probably the most useful of ACKMA's publications other than the Journal and the CD Rom has been the Conference Handbook. This lists the attendees, abstracts of the papers to be presented, brief biographies of attendees and their contact details and much on the history of ACKMA. It is an invaluable reference document for the membership. Most conferences also have a field guidebook which outlines the geology, geomorphology and cultural setting of the conference venue.

CONCLUDING REMARKS

We believe that ACKMA has been a very successful organisation in bringing together cave and karst managers, interpreters, scientists, academic institutions and others into an effective multi-national organisation to promote the better management of the world's cave and karst resources. Membership from many countries has helped the Association to become more relevant and exciting. ACKMA has effective communication avenues including its biennial conferences, annual business meetings, the Journal and other mechanisms to produce an active and effective organisation.

APPENDIX 1

Chronology of significant events since the founding of ACKMA Inc[2]

1987 May	**7th Australasian Conference on Cave & Karst Management**, NSW
May	ACMA Founded, Yarrangobilly Caves, NSW
1988 June	Edition 1 of the ACMA Newsletter published
1989 Apr	**8th Australasian Conference on Cave & Karst Management**, Punakaiki, NZ
Apr	ACMA becomes ACKMA – Annual General Meeting, Punakaiki, NZ
Aug	ACKMA team prepares a Report on Cutta Cutta Caves, NT
Sept	New Zealand ACKMA team advises on cave management in Tonga
1990 May	1st Cave Guides *Gabfest*, Yarrangobilly Caves, NSW
1991 Mar	2nd Cave Guides *Gabfest*, Wombeyan Caves, NSW
Sept	**9th Australasian Conference on Cave & Karst Management**, Margaret River, WA
Dec	National Parks and Wildlife (Karst Conservation) Bill and the Wilderness (Karst Conservation) Amendment Bill pass through the New South Wales Parliament following considerable representations by ACKMA members. The Government's proponent, the then Minister for the Environment, the Honourable Tim Moore is himself an ACKMA member
1992 Feb	1st Australian Karst Studies Seminar/Workshop, Buchan, Vic
Mar	3rd Cave Guides *Gabfest*, Naracoorte Caves, SA
Feb	International Network on Cave Protection and Management established under the Commission on National Parks & Protected Areas (CNPPA) with significant ACKMA involvement. The three chairmen of the Network have all been ACKMA members
Aug	ACKMA Fellow Neil Kell awarded Churchill Fellowship to study cave lighting in the USA & elsewhere
Sept	ACKMA Committee meets in Melbourne, Vic
1993 Mar	4th Cave Guides *Gabfest*, Buchan Caves, Vic
May	**10th Australasian Conference on Cave & Karst Management,** Rockhampton, Qld

[2] Note that this table includes events not specifically organized by ACKMA but which were organized by ACKMA members, or attended by many ACKMA members or where ACKMA members presented a number of papers. ACT = Australian Capital Territory, NSW = New South Wales, NT = Northern Territory, NZ = New Zealand, Qld = Queensland, SA= South Australia, Tas = Tasmania, Vic = Victoria, WA = Western Australia

May	Post Conference Study Tour to Undara and Chillagoe Caves, Qld
Nov	2nd Karst Studies Seminar/Workshop, Wombeyan Caves, NSW
1994 Mar	5th Cave Guides *Gabfest*, Jenolan Caves, NSW
May	ACKMA Committee meets in Sydney, NSW
May	Joint ACKMA – ASF Executive Meeting in Sydney, NSW
July	2nd Australian Seminar on Spelean History, Sydney University, NSW
Aug	New Zealand ACKMA members from North and South Islands meet at Waitomo, NZ
Dec	Naracoorte Caves, together with Riversleigh, inscribed on the Word Heritage List as the *Australian Fossil Mammal Sites*
1995 Apr–May	**11th Australasian Conference on Cave & Karst Management**, Tas
May	ACKMA Incorporated inaugurated
Aug	ACKMA officially incorporated (in Victoria)
Oct	ACKMA's *South East Karst Province of South Australia* report published
1996 Feb	ACKMA-supported 'multilateral' Cave Guide exchanges held
Feb	3rd Australian Karst Studies Seminar/Workshop, Naracoorte Caves, SA
Mar	6th Cave Guides *Gabfest*, Kelly Hill Caves, Kangaroo Island, SA
June	ACKMA Annual General Meeting weekend, Taralga, NSW
Aug	*Directory of Caves in Australia & New Zealand* published
1997	*IUCN Guidelines for Cave and Karst Protection*, compiled and edited by an ACKMA team, is published (with input from experts around the world)
Apr–May	**12th Australasian Conference on Cave & Karst Management**, Waitomo Caves, New Zealand
May	Post Conference Study Tour – Takaka Karst, South Island, New Zealand
1998 Feb	4th Australian Karst Studies Seminar/Workshop, Mole Creek Caves, Tas
Mar	7th Cave Guides *Gabfest*, Augusta/Margaret River Caves, WA
Mar	ACKMA Report on Cape Range karst released by the WA Government
Mar–Apr	ACKMA team undertakes management study on Christmas Island
June	10th Anniversary Edition of the ACKMA Journal published (No. 31)
June	ACKMA Annual General Meeting weekend, Jenolan Caves, NSW

1999 Apr	**13th Australasian Conference on Cave & Karst Management**, Mt. Gambier, SA
Apr	Post Conference Study Tour to Karst & Volcanics of Western Vic
Apr	ACKMA Life Member's Fund inaugurated
Apr	CD Rom series – *ACKMA Insights* – launched
Oct	ACKMA & ASF Joint Executive Meeting, Canberra, ACT
2000 Feb	5th Australian Karst Studies Seminar, Wellington Caves, NSW
Feb–Mar	8th Cave Guides *Gabfest*, Wombeyan Caves, NSW
June	ACKMA Annual General Meeting weekend, Buchan Caves, Vic
Oct	Australian Geological Survey Organisation and ACKMA *Discover Australian Caves* education kit is launched, Yarrangobilly Caves, NSW
Nov	Limestone Quarrying and Conservation Workshop, Bathurst, New South Wales
2001 Jan	Professor Elery Hamilton-Smith awarded Membership of the Order of Australia (AM) in Australia Day Honours List.
Apr–May	14th Australasian Conference on Cave & Karst Management, Wombeyan Caves, NSW
May	Post Conference Study Tours to Yarrangobilly Caves & Cooleman Plains, and to Abercrombie & Jenolan Caves, NSW
May	Asia Pacific Forum of Karst Eco-systems and World Heritage, Gunung Mulu National Park, Sarawak, Malaysia
2002 Feb	9th *Cave & Karst Presenters Workshop* (formerly *Gabfest*), Naracoorte Caves, SA
May	ACKMA Annual General Meeting, Yarrangobilly Caves, NSW
July–Aug	ACKMA has a stand at the Samcheok City International Cave Expo, South Korea
2003 May	**15th Australasian Conference on Cave & Karst Management**, Chillagoe Caves and Undara Lava Tubes, Qld
Dec	Memorial Dedication Ceremony to the late ACKMA President Peter Dimond, Waitomo Museum of Caves, New Zealand
2004 May	10th Cave Guides Workshop, Mole Creek, Tas
May	ACKMA Annual General Meeting Weekend, Mole Creek, Tas
Nov	New Book: *Caves & Karst of Wombeyan* launched, Wombeyan Caves, NSW
Dec	Caves and Caving Exhibit opened at Tasmanian Museum & Art Gallery, Hobart

2005 Mar–Apr	10th Conference on Australasian Palaeontology (CAVEPS), Naracoorte Caves, SA
Apr	ACKMA Pre-Conference Study Tour, South Island, New Zealand
Apr	**16th Australasian Conference on Cave & Karst Management**, Westport, South Island, New Zealand
Apr	ACKMA Post-Conference Study Tour, South Island, New Zealand
2006 Feb–Mar	*11th Cave & Karst Presenters Workshop*, Margaret River, WA
May	ACKMA Annual General Meeting Weekend, Kangaroo Island, SA
Oct	ACKMA represented at the 6th International Show Caves Association Congress, Bermuda
2007 Apr–May	**17th Australasian Conference on Cave & Karst Management**, Buchan Caves, Vic
2008 Feb	12th *Cave & Karst Presenters Workshop*, Jenolan Caves
May	ACKMA Annual General Meeting Weekend, Capricorn Caves, Qld
Sept	13th International Symposium of Vulcanospeleology, Jeju Island, South Korea
Sept	19th International Symposium of Subterranean Biology, Fremantle, WA
2009 May	One day *Cave Guides Interpretation Workshop* held prior to the 18th Conference
May	**18th Australasian Conference on Cave & Karst Management, Margaret River, WA**
June	21st Birthday Edition of the ACKMA Journal (No 75) published
2010 Apr	ACKMA Annual General 'Week', Gunung Mulu National Park, Sarawak, Malaysia
July	13th *Cave & Karst Presenters Workshop*, Wellington Caves, NSW
Oct	7th ISCA Congress, Slovakia, attended by four ACKMA members

KEY SUCCESS FACTORS OF POSTOJNA SHOW CAVE DEVELOPMENT IN ITS 192-YEAR-LONG HISTORY OF TOURISM

Peter Štefin, Ksenija Dvorščak

Postojnska jama d. d., Jamska cesta 30, SI-6230 Postojna, Slovenia;
peter.stefin@postojnska-jama.si, ksenija.dvorscak@postojnska-jama.si

Abstract: The Postojna Cave is an interesting case study example of a show cave which has gone through numerous changes during its 192-year-long history of tourism. The right approach to its development – with the key success factors – has brought excellent results. Its success is the result of a well thought out development strategy combined with the well used natural resources.

The advantageous geostrategic and historical position of Postojna contributed to the development of the necessary traffic infrastructure of the area. The Cave was well-known and well-visited even prior to becoming a major tourist Slovenian attraction, however, with the implementation of the basic infrastructure inside the Cave and introduction of visitor friendly technologies, the number of visitors increased rapidly. Moreover, the pleasant microclimate and accessibility of the Cave also contributed to its growing popularity. The tourist guide service was organized very early and great emphasis was put on the training of the guides and foreign language knowledge. The Cave management was aware of the importance of publicity. They advertised the Cave worldwide in guidebooks of the 19th century. The management knew how to adapt quickly to visitors' needs and requirements and, thus, promoted the development of tourist infrastructure inside the Cave, outside it, in the town and, finally, in the whole region. An important factor in promoting the Cave was associating with different tourist agencies, trade unions and joining other international organizations. A significant role in this was played out by the Karst Research Institute as well. During the long history of tourism of the Postojna Cave, different models of cooperation with the local community have been developed, and this has shown that the Cave cannot be operated separately from its local environment.

Keywords: show cave, tourism, key success factors

1. GEOSTRATEGIC POSITION OF POSTOJNA

Postojna is located nearly in the centre of the Republic of Slovenia, which covers an area of 20,273 km^2 and has a population of 2 million people. 46 % of the area is covered by karst and 62 % by forests. Not surprisingly, last year, a ten thousandth cave was discovered in Slovenia. Among the ten thousand, 26 caves and 3 mines (Lead Mine Mežica, Coal Mine Velenje and Mercury Mine Idrija) are open to public.

The town of Postojna is located on a strategically very important crossroad of traffic links connecting Eastern and Central Europe

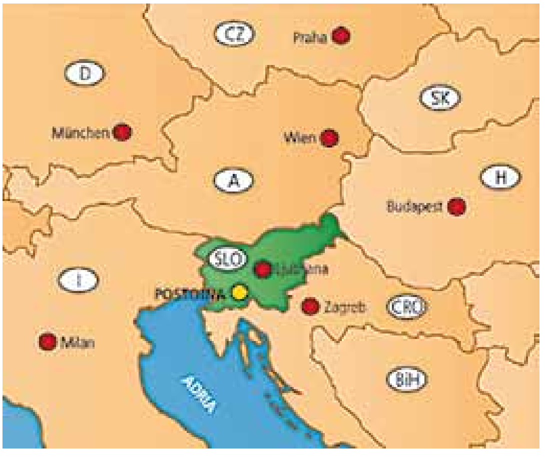


Fig. 1. Location of Slovenia in Europe.

Fig. 2. Location of Postojna in Slovenia.

and the Adriatic and Western Europe, respectively. It is situated in the Pivka Valley, which opens into the neighbouring regions. In the north, between Hruščica and Javorniki, 612 m above sea level, there is a ridge with Postojnska vrata (Postojna Gate), a passage leading towards the Ljubljana Basin, Munich and Vienna into Eastern and Central Europe. The second passage is in the north-eastern part, near Razdrto, 580 m above sea level, connecting Postojna with Trieste, Koper and Slovenian and Croatian Istria, and through the Vipava Valley and Gorica with Western Europe. In the southwest and the south, there are several passages leading from Pivka towards the Rijeka Valley, Istria and the Kvarner Gulf; most typical of those are the ones near Šembije and Hrastje.

The routes and paths crossing the Pivka Basin were used in the prehistoric times already. The first roads were built by the Romans. The remains of a Roman road can be seen near Razdrto. There was another one between Primož and Šilentaber pri Pivki in the Košanska Valley. There were Roman settlements on Sovič nad Postojna. The Predjama Castle and the ruins of Sovič date from the feudalism period. Most villages were mentioned as early as the 15th century, when Postojna was mentioned as a square. Postojna was proclaimed a town in 1909 (Kovačič 2004:13).

Due to its extremely important geographical location, the area belonged to the Austro-Hungarian Empire before the World War I. In the period between the WWI and WWII it belonged to Italy and after the WWII it became part of former Yugoslavia. On 25th June 1991, when Slovenia declared its independence, the area became part of the Republic of Slovenia.

In the areas north and south of Postojna, several different defence lines and numerous military establishments were built under the rule of different countries and governments.

2. DEVELOPMENT OF ADEQUATE TRAFFIC INFRASTRUCTURE IN THE REGION

During the Austro-Hungarian rule, the empress Maria Theresa assigned Postojna a role of the regional centre due to its geographical and strategic position. One of the factors which made Postojna's location so advantageous were the good regional roads from Ljubljana to Postojna, and through Razdrto to Trieste. In the 18th century, many people earned a living by transporting goods by horses and carts (so called 'furmanstvo'). 'Carters' inns, which offered looking after the 'carters' and their beasts of burden, were established along the roads in the direction of two major ports, Trieste and Rijeka. A significant postal connection between Trieste and Vienna also ran through Postojna, where there were inns which specialized in maintenance of postal carriage horses. These services are considered to be the beginnings of tourist services for travellers.

In 1857, the railway line connecting Vienna and Trieste, which ran through Postojna, was completed and this caused the disappearance of services such as horse and carriage transportation (furmanstvo), which were finally abandoned after WWII when the border between the zones A and B (dividing Italy and Yugoslavia) were set. During this period, the numerous inns started to lose business and closed down. At the same time, however, the number of visitors of the Postojna Cave started to increase with the so-called resort tourists, who came to the area in the summer looking for rest and fresh air. The air owns its freshness mainly to the local wind called 'burja', which begins to blow above Postojnska vrata and blows southwards over all Karst region, the Vipava Valley and all the way across the Gulf of Trieste to Grado.

The third landmark in the history of the Cave, was the completion of the motorway from Ljubljana, through Postojnska vrata to Razdrto, in the 1970s. Recently, the motorway has been connected to the Italian motorway A4 in the west, with Austria and Hungary in the north and northwest, and in the southwest, through Croatia and Serbia towards Romania, Bulgaria, Greece and Turkey. For these countries, Postojnska vrata represents virtually the only passage via landtransport towards the Western Europe. There were streams of tourists from Central Europe towards the Kvarner Gulf and the Dalmatian islands and Istria, Grado and Venice in Italy and, thus, the number of potential visitors of the Cave grew. By now, the double track railway, modern motorway and three local roads run through Postojnska vrata. The amount of traffic on these roads and railway in both directions importantly influences the number of visitors of the Postojna Cave.

After the completion of motorway through the Kanal Valley connecting Germany and Austria through Klagenfurt, Villach, Arnoldstein, Udine and Venice in 1985 and the completion of motorway connecting Vienna, Prague, Bratislava and Budapest through Croatia in the directions of Čakovec, Varaždin, Zagreb and Karlovac, through Plitvice towards the Adriatic coast, the Kvarner gulf and Istria, there was a slight decrease in number of visitors of the Cave. The number of tourists travelling through the area dropped significantly after the Ten Day War in 1991.

It took about 15 years for the numbers to start increasing again, while the freight transport increased a bit more rapidly, mostly in the directions of the port of Koper, Trieste, and Gorizia, towards Italy, Switzerland, France and Spain.

We can see just how important good traffic connections are in relation to the number of visitors of a certain tourist attraction, by comparing the Postojna Cave and the Plitvice Lakes National Park. Prior to year 1991, the number of visitors of the Cave used to be higher and amounted to almost a million visitors per year. Nowadays, when the motorway to the Dalmatian coast runs through Plitvice, the numbers have changed. The Plitvice National Park is visited by almost a million people a year, while the Postojna Cave is now visited by half a million tourists a year.

3. ACCESSIBILITY OF THE CAVE AND BENEFICIAL MICROCLIMATE

A cave is usually defined as an underground cavity or a hole with a more or less vertical entrance. The entrance into the Postojna Cave, however, is different. The position of the Cave is almost horizontal and the system includes five caves, namely, the Postojna Cave, the Otok Cave, the Magdalena Cave and the Black Cave which make for 20 kilometres of underground passages. Add the subterranean Pivka River and the Mountain Cave (Calvary), and the length of underground passages amounts to almost 27 kilometres. The experts explain that these passages, today admired by visitors, are old riverbeds of the Pivka River, which later submerged 25 metres further underground, approximately 3 million years ago. The passages have been flooded at least once or twice since, the results of which can be seen as special calcite formations and the so-called rings around the cave pillars. These additional layers are easily visible next to the entrance into the Biospeleological station. It is due to the horizontal position of the cave system that people had discovered it so early, which can be seen from the visitors' signatures on the walls of the cave near the entrance, dating back to 1213. And let us just mention that the Pivka River, on its 6,500 kilometre long way to the Black sea, has several different names.

4. EARLY DEVELOPMENT OF VISITOR FRIENDLY INFRASTRUCTURE AND APPLICATION OF MODERN TECHNOLOGIES IN MANAGING THE CAVES

People came to visit the Postojna Cave in the 13th century already, when it was open, but unprotected, non-illuminated and there were no guides employed. In anticipation of a visit from the Emperor Francis I of Austria, in 1818, some local men, among them Luka Čeč, were ordered to have the section of the Cave illuminated. At some point, Čeč moved away from the group and climbed a wall leading to a passage which had previously been unknown. When he reappeared, he called out to his friends: "There is a new world here, here is Paradise!" This discovery opened the door to new underground discoveries, gradually all the way through to the Great Mountain. The following year, the Cave was already open to general public as a show cave, paths across the passages were made, the wooden bridge over the river was built, the visitors' book was introduced and visitors taken around by the guides who also took care of illuminating the cave (Borjančič 1992).

Walking through the cave was tiring. Therefore, prior to the visit by the Emperor and Empress in 1857, three sedan chairs were ordered and later carried by the porters accompanied by guides. The sedan chairs were used until 1872, when the first railway line was constructed and the tracks laid down all the way to the Great Mountain.

Anton Globočnik, who was the chairman of the Cave Board until 1885, was responsible for many innovations and improvements inside the Cave: lighting was installed in 1883, the paths to the Great Mountain improved, the cave signposting in three languages was introduced, a tree-lined avenue leading to the Cave was planted, the right side entrance was arranged and the door put up. At that time, there were carriages on the rails inside the cave which were pushed by cave guides when the cave was visited by some distinguished guests. Horses and donkeys were used for pushing the carriages with material for constructing the paths inside the caves.

In 1924, the manually operated carriages were replaced by a Montania petrol locomotive which pulled five 4-seat carriages – wagons, but that was not enough to accommodate the number of visitors. The following year, another Montania locomotive was introduced and the year after that the third one. Thus, there were three trains, with 31 carriages altogether, which operated up to 8 times a day (Borjančič 1992).

There were a lot of improvements and developments in the Cave in the period between the two wars. Many paths inside the cave were built or reconstructed, such as artificial tunnels (1926-1927) between the Postojna Cave and Black and Pivka Caves. The works were financed by the state – Italy. The tunnels had primarily been built for the purposes of Italian army, which used them as secret passages from Italian into the Yugoslavian territory and back. The border between Italy and Yugoslavia was approximately 1 kilometre north of the entrance into the Black Cave. Besides serving the aforementioned purposes, these tunnels provided ventilation of the caves as well. Until the dissolution of Italy in 1943, the director of the Postojna Cave was professor Agnelli, who had discovered the Castellana Cave in Puglia in 1938. Later that same year, he founded the Karst Research Institute in Postojna, within the Scientific Research Centre of the Slovenian Academy of Sciences and Arts. A lot of the financial resources were provided by the state and were used for the improvements in the cave, such as renovation of the railway and installing of lighting. In 1928, the magnificent Jamski Dvorec Mansion and Restaurant were built right next to the entrance to the Postojna Cave.

After WWII, there were less visitors to the cave. However, the numbers soon started to increase again, so it was necessary to replace the old technology: the last petrol locomotive was in use no later than 1956 when it was replaced by the environment-friendly, battery powered locomotive EMAM from Milan. As the number of visitors grew, so did the number of new locomotives. In the years 1964 and 1968 The Cave Board had the 3,700metre long two-track loop railway built, which could accommodate more and more visitors. By 1978, the Cave was equipped with 12 battery powered locomotives pulling six trains which were able to seat 720 visitors and take them into the Cave every 30 minutes. Its horizontal position, the excellent footpaths covered in slip-free cement and quartz sand, without any stairs and great lighting system are all factors contributing to the fact that the Postojna show cave had become the most visited tourist attraction in the former Yugoslavia and later in Slovenia, too. Those factors make the Cave accessible to visitors of all ages as well as visitors with special needs. It is possible to visit the cave in a wheelchair which is an exception among the show caves in the world.

5. EXCEPTIONAL MICROCLIMATE AND CAPACITIES OF THE CAVE

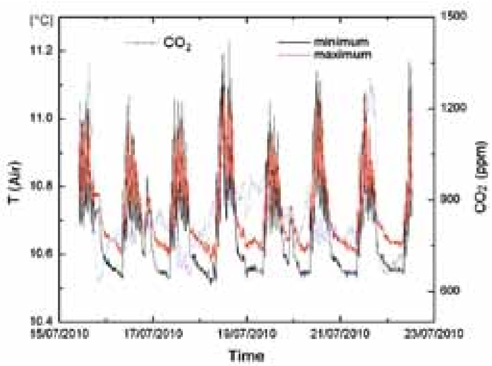


Fig. 3. Example of the increase in temperature and exhaled CO_2 during a tourist visit. Source: The Karst Research Institute, F. Gabrovšek

The third comparative advantage of the Postojna cave system is, besides its size, natural ventilation of the caves. The cave consists of three levels and is very well ventilated, thus, allowing for large numbers of visitors. The system itself has five main entrances or exits, natural airing system and ventilation through the subterranean stream of the Pivka River during the periods of relatively low level of water. When the outside air pressure is falling, the air from the cave blows out of the five exits and when the outside pressure is rising, the fresh air blows into the cave, which makes it possible for 6,000, 8,000 and even 10,000 visitors to enter the cave daily.

This exchange of pressure does not really affect the temperature inside the Postojna Cave, about 9 °C, the same as the average annual temperature of Postojna, which is situated 550 m above sea level. The relative humidity in the cave depends on the season and the amount of rainfall, and ranges between 60 % and 100 %. And it is the level of humidity that has such a beneficial effect on people with respiratory problems.

6. PROFESSIONAL GUIDE SERVICE

In order to guide and manage such high numbers of tourists, it is necessary to employ plenty of educated and trained guides. At the moment, there are 23 guides employed on a permanent basis. During high season, however, we hire over 70 guides, most of whom are students or temporary workers. The cave trains are operated by 6 to 8 train drivers, who also do maintenance and repair works during low season.

Each spring there is a compulsory training organized for the new cave guides.

Before the training, however, there is a selection process during which the candidates are tested in functional knowledge, foreign language knowledge and public speaking skills. All future cave guides need to have at least secondary school diploma, speak at least two foreign languages and have extensive knowledge of Karst, karst landforms and the Postojna Cave. As it is sometimes required of the guides to move in unsecured cave areas, they need to be acquainted with the cave etiquette and basic speleology skills.

The Postojna Cave is open to public throughout the year and there are at least three guided visits per day, at 10.00, 12.00 and 15.00, from May to September every hour between 9.00 and 17.00, and an additional guided visit at 18.00 in July and August. Out-of-hour visits are possible by prior arrangement at any time. The guided tours are available in Slovene, English, German, Italian and French and by prior arrangement in Spanish, Dutch, Russian, Croatian and Serbian as well. The guided visit lasts one and a half hours.

7. PUBLICITY AND MARKETING OF THE POSTOJNA SHOW CAVE

In the beginning of the 19th century, when the travellers started to express interest in the Postojna Cave, descriptions of the Cave were published in several international guidebooks, which was very important in terms of publicity and advertising. The descriptions included information on guided visits, entrance fees, timetables, illumination in the caves, the recommended clothing etc. In terms of promotion, the management took part in the World Fairs (Expos) in Paris, 1867, and Vienna, 1873, where they presented the proteus (the blind amphibian, endemic to the caves). In the 20^{th} century, many specimens of the proteus were sent to European zoos and natural science museums around the world (Savnik 1960, 107).

As long ago as in 1868, an Englishman, Thomas Cook, the pioneer of organized tourism, included the visit of the Postojna Cave in his first organized tour around Europe.

However, it was not enough to publish texts in guidebooks only, the cave management decided to advertise the Cave in popular books of that time, which were read widely, such as *The Hundred Wonders of the World (1818)* or *The Wonders of Nature and Art (1803),* where one could read about different natural phenomena around the world. (Shaw 2010: 292)

For the purposes of promotion, the Cave Board members decided to organize an annual Whitsuntide festivity, which took place every year on Whitsun Monday in the Congress Hall (The Ballroom) of the Postojna Cave, starting in 1821.

The Cave was luxuriously illuminated for the occasion and the people danced to the sounds of several military and civilian brass bands. Special low-cost trains took people to Postojna. The trains were named Vergnügunszuge (which could be translated as Merry Trains) in 1913. There were German, Italian and Slovene people at the festivity. The cave management with Ivan Andrej Perko as manager advertised the town of Postojna and negotiated the low fares with the railway. They also offered cheap entrance fees to the Cave, for the Whitsun and the Feast of Assumption on 15^{th} August especially, so that the less wealthy people could afford to visit it (Fikfak 2009).

In order to make the Cave even more interesting for the public, different concerts are organized in the Concert Hall of the Cave, and one of the most famous ones was the concert preformed by La Scala Milano Orchestra in the Concert Hall in September 1929, conducted by the composer and conductor, Pietro Mascagni.

8. LARGE NUMBERS OF VISITORS AND GUESTS

After the Postojna Cave had been opened to public in 1819, the number of visitors kept increasing. In 1845 it had more than 2,000 visitors and in 1919 there were more than 10,000.

The person, whose vision of Postojna as a tourist destination was perhaps the most clear and high flying, was a Swiss man, Franz Progler. He was the one who built the first luxurious hotel – Grandhotel Adelsberghof – in 1874.

Grandhotel Adelsberghof, or Postojnski Dvor as named by the locals, was a luxurious and comfortable hotel with 65 rooms, cricket and tennis courts, electricity lighting, bathrooms with showers and a car park. The hotel, which was surrounded by the beautiful English garden, organized transfer to and from the railway station for its guests.

Postojna was famous for its climate and it was a popular summer destination for people who wanted to escape the summer heat. There were a lot of visitors from Trieste and there was even a special train connection from Vienna to Postojna. A visit to the Postojna Cave became a matter of prestige and social status. It was a golden era for restaurant and hotel owners. In 1894, Postojna was visited by 7 times more tourists than Bled, more than Lake Gardo, Bad Aussee or Villach.

However, just after the WWII, the visitors were scarce until 1960 when the number of visitors started to increase rapidly again. Two hotels in Postojna, Javornik and Tiha Dolina, which had been built before the war, were open again and there were a couple of restaurants (Jamska and Jadran) and a few inns in town.

The Kras Hotel was the first hotel built after the war and its opening in 1963 marked a new stage in the history of tourism in Postojna.

The influx of foreign currency, together with municipal funds, provided for the development and construction of municipal and tourist infrastructure.

The Postojnska Jama company funded between 70 % and 85 % of the local budget from its investments.

The growing number of cave visitors after 1974 and the increase in the number of tourists travelling through Postojna towards the seaside and back all called for development of tourist infrastructure: there had to be more parking spaces, more restaurants and accommodation capacities.

The former tourist and hotel organization POSTOJNSKA JAMA was made up of three organizational units: the Postojna Cave, Gostinstvo (Hotels and restaurants) Postojna and Skupne službe (commercial, financial and accounting service). Until the dissolution of Yugoslavia, it had 550 employees, and it was in charge of management of the Postojna Show Cave, Predjama Castle, the Cave under the Predjama Castle, Hotel Jama (A part built in 1971, B part in 1982, the swimming pool area in 1984), Hotel Kras, Hotel Šport, Motel Proteus (first pavillions built in 1958, renovated in 1984), Boarding house Erazem, Pivka Jama Camping (renovated in 1985), restaurant Jamski dvorec mansion (1928) and several canteens in Postojna. The company managed 1,260 beds and 5,500 seats in several restaurants.

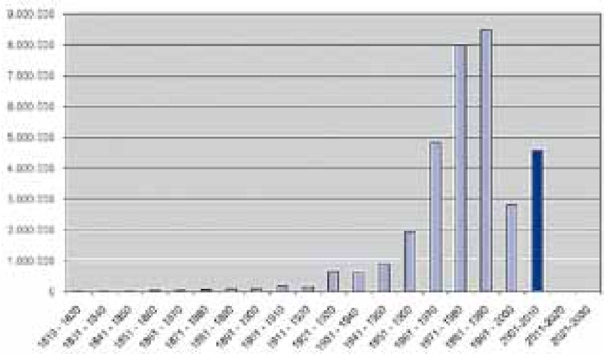


Fig. 4. Number of visitors of the Postojna Cave through decades.

The period between the years 1977 and 1990 was the period of flourishing tourism for the Postojna Cave. It was visited by 900,000 tourists per year. The largest number of tourists was recorded in 1985, when the Cave was visited by 942,256 people. The largest number of visitors in a single day was recorded on 8th July 1978, when the cave guides took care of as many as 12,025 visitors. It coincided with the spell of rainy weather in the Kvarner Gulf, Istria, Italian coast between Grado and Venice, the lakes Bled and Bohinj as well as the lakes in Austria. It means that on that day we received over 12,500 visitors who came either on their own or as guests of different tourist agencies.

In the period until the independence in 1991, THO Postojnska jama was the key element in the development of tourism in municipality of Postojna. After the independence was declared, as in the period before it, there appeared many who wanted to have their say and share in the management of the Postojna show cave. The company was converted into a public limited company in 1996. The major share holders were its employees and national funds. In 2003, POSTOJNSKA JAMA, turizem, d.d. was awarded a five year concession for managing the Postojna Show Cave and Predjama Cave System. The company had to pay 1,418,000 EUR of concession fee. In 2008, the company Istrabenz turizem, d.d., became the 100 % owner. Istrabenz renamed POSTOJNSKA JAMA into TURIZEM KRAS, destination management, ltd. In the same year, it was awarded the 20 year concession for managing the Postojna Show Cave and Predjama Cave System. In August 2010, BATAGEL & CO from Postojna became the owner of 74.90 % of the company, while the Municipality of Postojna has the 25.10 % share.

9. ADVERTISING AND SALES OF PRODUCTS OF THE TURIZEM KRAS D.D. (POSTOJNA CAVE)

The Postojna Cave has been one of the most visited attractions in the area for years, but now one out of five visitors decides to visit the Predjama Castle, too. There are more and more people who decide to spend the night in Postojna and eat in local restaurants. The sales of souvenirs have been increasing. The above mentioned is the result of clever investments in advertising. As part of publicity and promotional activities, the company has been organizing different events, meetings and concerts. Promotional leaflets, posters, price lists and other printed material are available in 29 languages and distributed all over the world by different services.

The Postojna Cave is showcased at all important fairs and exhibitions for general public, workshops for people working in tourism and other promotional events around Europe. It is present on the world tourism market and sales networks of different tour operators and tourist agencies. The Cave is advertised in all available media around the world. We collaborate with over 3,000 agencies around the world. The promotional material is delivered to over 2,500 places in the 300 km radius as we pay visits to different tourist agencies, hotels, camping sites, border crossings, tourist information centres etc. before the start of high season. We advertise on billboards, posters and banners in many tourist places. We have a well managed and attractive website with many links to other sites. We do our best in keeping the Postojna Cave the most attractive tourist destination in Slovenia.

10. FUTURE CHALLENGES

TURIZEM KRAS d.d. will soon assume the name it used to have, namely POSTOJNSKA JAMA d.d. (it was on 08. 04. 2011), as the Postojna Cave is a trademark, a landmark in Slovene tourism. The company will work towards the 10 % annual increase in the number of visitors. Great emphasis will be put on improving the quality of the services and the customer satisfaction. One of the challenges to be met in the future is the renovation of Hotel Jama, which is located in front of the entrance into the Cave. By offering more services, the company will try to transform Postojna from the transit point into a destination point.

The company will continue to invest into the cave infrastructure of the Postojna and Predjama cave systems. The priorities include the replacement of the old lighting system with the new environment friendly light system, modernisation of the transport inside the caves, repairs of footpaths and the installation of the first purification facility inside the show cave. The guidance in the cave and marketing will be upgraded with modern interpretation techniques and tools. The goal of the company is to ensure the balance between conserving the natural characteristics of the Cave and its marketing. All activities of the Postojna Cave are subject to efficient and profitable business conducting.

The company will continue to work closely with the Karst Research Institute, which functions as a guardian of both cave systems. Their opinions and recommendations are always taken into account before making any decisions in regard with the caves. The company will continue to cooperate with international institutions such as UIS and ISCA. We will exchange opinions, expert solutions and participate in their commissions and meetings. POSTOJNSKA JAMA will cooperate with tourist agencies, tour operators, tourist organizations and institutions and work towards attracting more and more visitors, while always keeping customer satisfaction in mind.

References

Borjančič, A. (1992): *120 let železnice v Postojnski jami,* Notranjski kompleksni muzej: Postojna

Fikfak, J., ed. (2009): *Postojna, upravno in gospodarsko središče*. Galerija 2: Postojna; Inštitut za novejšo zgodovino: Ljubljana

In Postojna je mesto postala, (1999), Notranjski muzej: Postojna

Kovačič, N. (2004): *Zemljepisni oris Pivške kotline v Ljudje in kraji ob Pivki*, ed. Fatur S., Občina Postojna, Galerija 2: Vrhnika

Postojnska jama – nova spoznanja, (1998) Postojnska jama, turizem d. d.: Postojna

Savnik, R. (1960): *Iz zgodovine Postojnske jame II*., Kronika, leto VIII, št. 2, Ljubljana, p. 107

Schmidl, A. (1854): *Die Grotten und Höhlen von Adelsberg, Lueg, Planina und Laas*. Dunaj, p. 101

Shaw, T. (1999): *Proteus for sale and for science in the 19th century. Močeril v 19. stoletju za prodajo in za znanost.* Acta Carsologica 28/1, 15, Inštitut za raziskovanje krasa ZRC SAZU: Ljubljana

Shaw, T. (2010): *Aspects of the History of Slovene Karst 1545 – 2008,* Inštitut za raziskovanje krasa ZRC SAZU: Ljubljana

Šorn, M. (1996): *O izletniških navadah Ljubljančanov*, Način preživljanja prostega časa meščanov Dunaja in Ljubljane od druge polovice 19. Stoletja do 30-ih let 20. Stoletja. V Razvoj turizma v Sloveniji. Ljubljana: ZZZS 1996, pp. 105-121.

Tuma, H. (1997): *Iz mojega življenja: spomini, misli in izpovedi*. Založba Tuma: Ljubljana, p. 86

INTERPRETATION IN CAVE TOURISM – A LITTLE UTILISED MANAGEMENT TOOL

Zsuzsa Tolnay

Head of Ecotourism and Environmental Education Department, Aggtelek National Park Directorate, 3758 Jósvafő, Tengerszem oldal 1, Hungary; tolnayzs@yahoo.com

Abstract: Show caves are tourist attractions, thus host visitors. But are guided tours only a business activity, an opportunity for visitors to spend their free time, or can it be considered a management tool building on management–visitor interaction? While this paper does not deny the previous characteristics, it argues that through interpretation site mangers can, in fact, influence their audiences and work towards their management goals. A case study research carried out at the World Heritage caves of the Aggtelek Karst gives factual evidence to support this theory.

Key words: interpretation, management, knowledge, attitude, visitor, heritage, cave

THE THEORETICAL BACKGROUND TO INTERPRETATION AT SHOW CAVES

The central service at each show cave is the cave tour (guided or self-guided) by nature, often paired with further interpretive efforts, such as visitor centre, print or electronic publications, lectures. But, in fact, some of the memorabilia sold in the souvenir shops and the built environment can reflect the given place (Carter 2001), too. The motivations of managers can vary to some extent, but by conscious interpretive activities they are likely to achieve those management goals that are related to visitors.

Before actually talking about the management nature of guided tours (and other interpretive activities) at show caves, it is quite necessary to ask some fundamental questions.

Why interpret?

What is interpretation?

To answer the first question, remember a site you visited for the very first time. Besides the first impression, maybe aesthetic experience and some fragmented information, you were unlikely to know the real story of the place, its relevance and broader context. And most cave visitors are first time visitors to a particular cave.

But to answer this question it is also necessary to examine the participants of the situation. Beyond the obvious, the cave itself, there are two major players, i.e. the visitor and the interpreter. Visitors, however, are quite diverse, and they all bring their knowledge, personality, agendas, mood, etc. to an interpretive situation and they have different motivations for visiting the cave (Beck & Cable 1998).

The interpreter, on the other hand wants to educate the public, and communicate a message. Also different management objectives are meant to be achieved by providing interpretive services. (In this context to enhance conservation ethic should be one at show caves.)

This leads us to the question: "What is interpretation?" There are several established definitions (Tilden 1967, Interpretation Canada n.d. cited in Capital Regional District Parks 2003, Association for Heritage Interpretation n.d., National Association of Interpretation n.d., Scottish Interpretation Network n.d.) for that, but they all have something in common. They all state that it is a communication process between visitors and interpreters, and that it reveals meaning of and enhances appreciation towards the site (Beck & Cable 1998). When asking "What is interpretation?" it should also be clear what it is not. As already Tilden (1967) stated, it is definitely not only facts and figures, but rather to tell a story. Some might not think of it as a kind of science, but to do it at its best, interpreters should obey some basic rules, in which some academic principles are well worth considering.

The communication/interaction quality of interpretation is the key why it is also a management tool. Managers/interpreters may consider visitors merely sources and causes of problems (such as whose physiological needs have to be satisfied, who potentially damage the site, etc.), but taking a different view point one should realize that they are in fact free choice learners (Ham 1992) who come to the cave voluntarily and usually are quite open to hear something new and interesting, while experiencing something unique, and if they are satisfied with the service they receive, they spread the word. Managers, in fact have different tools to manage the public, and while legal leverages and physical barriers are necessary, as Beaumont (2001) argues it is interpretation through which a win-win situation can be achieved.

Fig. 1. The Interpretation Cycle should be considered a mutual process in the visitor-manager relationship.

THE LEARNING CYCLE

While we take our visitors on a guided tour or provide a book or DVD on the cave, we actually take our audience on an intellectual journey. In the theory of reasoned action by Fishbein and Ajzen (1975) attitude is argued to be a key to behaviour. Thus it is commonly accepted today that to achieve favourable, even pro-active behaviour of the audience we need to shape their attitude, and as a prerequisite, their knowledge. In practice, by tapping into visitors' belief systems and knowledge structures interpreters can create a situation of cognitive dissonance that can be a powerful tool to shape people's thinking and attitude (Orams 1995: 88) therefore their behaviour. In Moscardo's (Moscardo *et al.* 1996, Moscardo 2004) opinion we should transform our visitors into 'mindful' visitors. Figure 1 expresses the above theories with the addition that from the linear knowledge-attitude-behaviour process, by adding learning a cycle can be formed.

However, it is equally important to understand this figure not only from the visitor-manager, but also from the manger-visitor perspective. By that it is meant that if managers are willing to learn about their visitors it can greatly influence their attitude towards the public and their management behaviour. This again supports the communication nature of interpretation.

CASE STUDY

As a pragmatic example for the above theories, the results concerning the knowledge-attitude relationship of a specific research project is presented here. The interpretive practices at the World Heritage caves of the Aggtelek Karst Hungary were appraised in a study (2009-2010) (Tolnay 2010), which included the investigation of various aspects from planning to implementation, from the analysis of interpretive management to visitor studies. In order to gain the best insight in the complex issues, different methods were used, among them a visitor questionnaire survey.

The visitor questionnaire survey

The questionnaire was structured around five issues, i.e. (a) visitor profile and audience groups segmentation in terms of demographic and social characteristics, (b) prior knowledge, motivation (Graefe et al. 2000; Packer & Ballantyne 2002; Black 2005; Briseño-Garzón et al. 2007) and interest (Black 2005), (c) visitor opinion and satisfaction outside the cave visit (Puczkó & Rátz 2000), (d) visitor opinion and satisfaction during the cave visit phase and other interpretive provisions (Puczkó & Rátz 2000), (e) visitors' perception on the 'sense of the place' (Stewart & Kirby 1998; Carter 2001), as a complex of cognitive and attitude issues.

Although the questionnaire was based on closed questions, visitors were offered the opportunity to express their opinions in their own words, as they were asked in sections (c) and (d) what their best and worst experiences were. The closed questions resulted in nominal and scale variables. The scale variables were derived from a 5-grade Likert-scale, where value 1 stood for fully disagree/fully dissatisfied, and value 5 for fully agree/fully satisfied.

Questionnaires were filled out pre- and post cave visit, by different participants to eliminate research bias in this respect (Tubb 2003). This also allowed for analyses of the effectiveness of the cave tour guiding from three aspects, knowledge, attitude and sense of the place. Sense of place is a new quality formed by a combination of the knowledge and attitude.

The 'typical visitor'

Although there is no such thing as a 'typical visitor' (Carter 2001, Black 2005) the survey result showed that overwhelmingly the visitors were Hungarians i.e. domestic (90 %) visiting for the first (36 %) or at most the second (38 %) time, and travelled from a considerable distance (71 %) from over 200 kilometres, despite the fact that they spent less than one day at the site or in the area (81 %). They were in their active years (between 18 and 55) (84 %), and had a minimum of a secondary level education qualification (90 %). There were different motivations for visiting the site but recreational activity paired with an interest in nature was the prime motive (78 %). The occasion was a family excursion (74 %) using the family car as the principle mode of transportation (95 %). Visitors use more than one source of information to prepare for their visit and the internet was the most important resource (54 %). A relatively high proportion of visitors did not search for any preliminary information (24 %). This can partly be explained by the repeat visits and by some awareness of the site within society.

Testing knowledge gain

There are different aspects of knowledge. It can mean familiarity with and knowing about the existence of something. In this respect 77 % of visitors thought it was a well-known place.

However, lexical knowledge and its increase is a different dimension and can indicate how successfully the message is delivered. One question asked the visitors if they were aware of the World Heritage designation of the caves, as this fact is clearly communicated during the guided tours, without any explanation on the significance of the designation. However, sixty percent of visitors were aware of this fact.

Applying Chi-square statistical test method to study whether cave visits had any influence on knowledge, it was found, that although people, who had already visited the cave tended to be aware of the WH designation more, in fact cave visits did not influence this knowledge significantly (X^2=2.377; df=1; p>0.01). It means that message delivery is not very successful during the cave tour.

Testing the 'sense of the place'

Some questions/statements were selected and analysed to reveal visitors' perception (sense) of the place, as a concept of attitude. Some of them reflected aesthetical or value judgements, others were provocative, as shown below.

- *It is a special place of interest* – expected agreement from respondent resulting in a high score
- *State ownership of the WHS safeguards its protection* – expected agreement from respondent resulting in a high score
- *Selling speleothems is a sustainable from of generating revenues* – expected disagreement from respondent resulting in a high score
- *There are too many restrictions in the area* – expected disagreement from respondent resulting in a high score
- *Visitor interested in other assets* – expected agreement from respondent resulting in a high score
- *Considering the cave awe-inspiring* – expected agreement from respondent resulting in a high score

The statistical summary on this set of answers (5-degree Likert-scale) informs us that 74 % of visitors have a high level sense of the place, i.e. within the 3.6 – 4.5 score range. Further nineteen percent of respondents, in fact, have very high level of sense of the place (4.6 – 5). No respondents can be found in the "very low" and "low" categories, i.e. below 2.6 points.

The mean average of these selected variables was 4.15 (high), with the minimum of 2.32 (low) for the question if visitors felt that there were too many restrictions at the site, and the maximum of 4.76 (very high) for the question whether the cave was beautiful.

Applying the non-parametric Chi-square statistical test, it could be concluded that cave visits actually had a significant influence on the sense of the place perception (X^2= 14.455; df=4; p<0.01).

The relationship between knowledge and the sense of the place

The research investigated to what extent knowledge influenced the sense of the place perception. Indeed, the analysis showed that knowledge significantly affects how visitors perceive the cave(s) and the broader environment (X^2= 182.161; df=129; p<0.01). So visitors with an increased knowledge (either preliminary or newly gained) tend to have an attitude that is closer to the management's expectation, i.e. more pro-conservationist.

This simple, illustrative example suggests that shaping visitors' knowledge and understanding of a show cave does influence their attitude, so managers can rely on this process and orient the public to an expected form of behaviour.

CONCLUSION

The importance and potentials of interpretation is often underrated in heritage tourism. It draws on several principles from visitor studies, psychology and learning theories, but its primary function is communication between site managers and visitors. But show cave managers consciously using interpretation actually gain an effective management tool by which they can greatly enhance the success of their corporate objectives for the mutual benefit of the site and its visitors.

References

Association for Heritage Interpretation (n.d.) *What is interpretation?* [online].

Beaumont, N. 2001, 'Ecotourism and the Conservation Ethic: Recruiting the Uninitiated or Preaching to the Converted?', *Journal of Sustainable Tourism,* 9, 4, 317-341.

Beck, L. and Cable, T. 1998, *Interpretation for the 21st Century – Fifteen Guiding Principles for Interpreting Nature and Culture*, Sagamore Publishing, Champaign IL.

Black, G. 2005, *The Engaging Museum*. Routledge, Oxon.

Briseño-Garzón, A., Anderson, D. & Anderson, A. 2007, 'Entry and Emergent Agendas of Adults Visiting an Aquarium in Family Groups', *Visitor Studies*, 10. 1, 73-89.

Capital Regional District Parks 2003, *Visit, Experience, Learn*. Victoria, BC.

Carter, J. ed. 2001, *A Sense of Place*, 2nd ed., Scottish Interpretation Network.

Fishbein, M. & Ajzen, I. 1975, *Belief, Attitude, Intention, and Behavior: An Introduction to Theory and Research.* Reading, MA: Addison-Wesley.

Graefe, A. R., Thapa, B., Confer, J. J. & Absher, J. D. 2000, 'Relationships Between Trip Motivations and Selected Variables Among Allegheny National Forest Visitors', *USDA Forest Service Proceedings*, 15, 4, 107-112.

Ham, S. 1992, *Environmental Interpretation – A Practical Guide for People with Big Ideas and Small Budgets*, North American Press, Golden.

Moscardo, G. & Woods, B. & Saltzer, R. 2004, 'The Role of Interpretation in Wildlife Tourism', in K. Higginbottom (ed.), *Wildlife Tourism: Impacts, Management and Planning*, Common Ground Publishing Pty Ltd, 253-251.

Moscardo, G. 1996, 'Mindful Visitor: Heritage and Tourism', *Annals of Tourism Research*, 23, 2, 376-397.

National Association of Interpretation (n.d.) *What is interpretation?* [online].

Orams, M. B. 1995, 'Using Interpretation to Manage Nature-based Tourism.' *Journal of Sustainable Tourism*, 4, 2, 81-94.
Packer, J. & Ballantyne, R. 2002, 'Motivational Factors and the Visitor Experience: A Comparison of Three Sites', *Curator*, 45, 3.
Puczkó, L. & Rácz, T. 2000, *Az attrakciótól az élményig – A látogatómenedzsment módszerei (From the attraction to the experience – Methodology of visitor management)*, Geomédia, Budapest.
Scottish Interpretation Network (n.d.) *What it interpretation?* [online].
Stewart, E. J. & Kirby, V. 1998, 'Interpretive education: Towards a place approach', *International Journal of Heritage Studies*, 4, 1, 30-40.
Tilden, F. 1967, *Interpreting Our Heritage*, 2nd ed., The University of North Carolina Press.
Tolnay Zs. 2010, An Evaluation of Environmental Interpretation as a Visitor Management Tool at the Caves of the Aggtelek Karst World Heritage Site (MSc thesis).
Tubb, K. 2003, 'An Evaluation of the Effectiveness of Interpretation within Dartmoor National Park in Reaching the goals of Sustainable Tourism', *Journal of Sustainable Tourism*, 11, 6, 476-498.

Appendix 1

THE PROBLEM OF LAMPENFLORA IN SHOW CAVES

Arrigo A. Cigna

Former Chairman of the ISCA Scientific and Technical Committee
Fraz. Tuffo, Str. Bottino 2, I-14023 Cocconato (AT), Italy

Abstract: Lampenflora is a typical problem of show caves, because the light that is necessary for the visitors supplies enough energy to some plants, mainly algae and mosses, which may grow to the point of defacing and damaging seriously the cave itself.
After a description of the main characteristics of lampenflora and a detailed list of the environmental conditions contributing to its development, the best methodology to control such a development with particular attention to an easy and successful implementation is here described.

Key words: lampenflora, lighting, control of lampenflora.

INTRODUCTION

In a wild cave the flora, i.e. any kind of plants, exists only in a part close to a natural entrance where the outside light reaches the cave environment. According to the species, the plants may grow inside a cave until the light intensity ranges between one to three orders of magnitude less than outside.

Most of the show caves are fitted with a lighting system and in an area more or less around a lamp plants can develop. In general these plants are algae or mosses but sometimes also ferns till superior plants may develop and grow. This phenomenon was firstly studied mainly by Austrian scientists (Kyrle, 1923; Morton & Gams, 1925) and, later, in France (De Virville, 1928). A rather exhaustive book on the cave flora, with many references dating back to the XVIII century, is that due to Morton & Gams (1925).

Only in 1963 the word "lampenflora" (a German word which means "plants of the lamp") was firstly introduced by Dobàt (1963) and is presently adopted everywhere in the world to identify any kind of plants growing in the vicinity of lamps.

WHAT IS LAMPENFLORA AND HOW IT DEVELOPS

The plants classified as lampenflora range, in general, from cyanobacteria (also known as blue-green algae), algae, lichens, mosses to ferns. Cyanobacteria, green algae and mosses are the most common components of the lampenflora in show caves, their abundance varies from cave to cave (Padisàk *et al.*, 1984; Grobbelaar, 2000; Aley, 2004). Algae and cyanobacteria exist in wild caves (Claus 1962, 1964; Hajdu, 1966; Kol, 1967) also in the dark sections. This means that a release of spores brought in by the visitors is not strictly necessary for a successive growth of these algae. When a cave is developed as a show cave the algae proliferate in the vicinity of the light sources thanks to the energy released by the lamps.

In general the lampenflora is firstly composed by algae at the beginning of its development, to be followed by mosses, ferns and sometimes by vascular plants (Mulec & Kosi, 2009). The negative effects of lampenflora is due to the fact that plants may produce weak organic acids, which in time can corrode both limestone and formations (Aley, 2004). When a prehistoric cave is concerned the paintings may be seriously damaged as happened in Lascaux cave in France (Ruspoli, 1986). In addition, without any intervention the lampenflora spread rather quickly (e.g. in Baradla cave, Hungary (Hazslinszky, 2002), lampenflora doubled in 7 years) and may become an important source to colonise wide areas. A typical example is observed in Cango Caves, South Africa, where large surfaces of coral-like formations far away from the lighted section of the cave are covered by green algae.

Lampenflora's growth and distribution depend on light intensity, temperature, moisture and substratus.

The lux (symbol: lx) is the unit of illuminance and it is used to measure the intensity of the light, as perceived by the human eye that hits a surface. As a rough indication of the light intensity resulting in the development of 85 % of the lampenflora, a value around 40 lux was measured when the light was switched on for most or all the time that the caves were open. A continuous lighting yields more lampenflora growth than short periods of lighting for the same length of time because the adaptation of plants to light and dark phases requires both time and plant energy (Aley, 2004). The established lampenflora populations can survive long periods of very low levels of illumination or total darkness (Johnson, 1979).

Chlorophyll (types a and b) has two absorption peaks, in the ranges 430 – 490 nm and 640 – 690 nm. Therefore if a lamp has an emission spectrum in the range 500 to 630 nm the contribution to the photosynthesis process of green algae is reduced without important aesthetic problems. In Mammoth Cave, USA, lighting with LED at an intensity of 49.5 lx and a yellow light (595 nm) prevented regrowth for 1.5 years after complete lampenflora removal (Olson, 2002).

Sometimes a UV irradiation was used to suppress the lampenflora on account of its germicidal effect (Mulec & Kosi, 2009). Recently in Grotta Gigante, Trieste, Italy, a new set of germicidal lamps, provided with an electronic starter, which obtained the *2008 Green certificate*, in order to inhibit the development of lampenflora and to ensure an environmentally-friendly use of the cave were installed. These lamps, whose use aims at keeping under control the development of lampenflora, turn on when all the other lights in the cave are turned off (Fabbricatore, 2009).

Incandescent lamps produce an increase of the temperature and a decrease of the humidity. Within some tens of centimetres from the lamp the increase of temperature may be of the order of 10°C and the decrease of the relative humidity to 70 – 80 %, this condition results in an algal growth unless the decrease of humidity is excessive and the algae cannot proliferate (Mulec & Kosi, 2009). In fact lampenflora develops on moist or damp surfaces and therefore soft surfaces as cave sediments and moonmilch provide higher moisture storage than hard surfaces with the chance of luxuriant growths (Aley, 2004).

HOW TO CONTROL LAMPENFLORA

The most obvious action is the reduction of energy supply by both a reduction of the light emitted and the adoption of a light spectrum with a low emission in the wavelength absorbed for growth the lampenflora (Smith & Olson, 2007). Unfortunately such an action

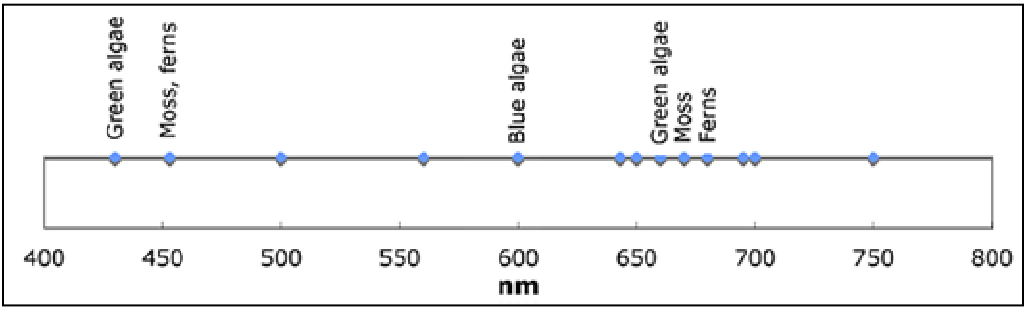


Fig. 1 – The most important absorption peaks of lampenflora (from Caumartin 1994, modified).

is not enough effective to solve the problem. Nevertheless it is convenient to use lamps with an emission spectrum poor of the wavelength mostly absorbed by lampenflora. In Fig. 1 its is reported a graph where the maximum of the absorption peaks are reported. The frequencies with the maxima from 460 to 453 nm around 600 nm and from 653 to 700 (particularly the latter) are the most dangerous for the proliferation (Caumartin, 1994). Preliminary experiments with cold cathode lamps reached a reduction of the growth of a green alga (*Dunaliella salina*) down to 57 % of the control (Antrox, 2009).

The technique of switching out the light for a prolonged time interval (e.g. one month) counteracts the proliferation of photosynthetic organisms in caves but may favour the diffusion of especially resilient organisms as *Phormidium autumnale* (and generically cyanobacteria) by reducing competition (Montechiaro & Giordano, 2006).

It must be stressed that, notwithstanding the reduction of light plays a positive role in reducing the proliferation of lampenflora, sometimes a moss intertwined with cyanobacteria may cover relatively wide areas which were only occasionally illuminated (Giordano *et al*., 2001).

When lampenflora proliferates, it is necessary to destroy it with chemical compounds. The herbicides have the disadvantage of being sometimes highly toxic for cave fauna and also the personnel must pay a special care. For this reason these biocides as DCMU, Atrazine, Simazine, Karmex, etc., are absolutely inappropriate in caves (Mulec & Kosi, 2009).

A comparison among an herbicide, sodium hypochlorite and sodium chlorate at the following concentrations:

Karmex™ Du Pont	3 g/L water
Sodium hypochlorite	2.75 % Cl
Sodium chlorate	30 g/m^2

gave similar results, but sodium hypochlorite had a faster effect while the results obtained with sodium chlorate were less homogeneous. The runoff of the solution should preferably be collected and disposed outside the cave. In any case after the treatment the surface should be rinsed with water.

A test to evaluate the corrosive action of sodium hypochlorite was carried out on some broken formations. After 10 minutes of treatment about 41 mg/m^2 were dissolved without any further increase over 17 hours (Bertolani et al., 1991). For this reason the treatment with sodium hypochlorite is currently adopted in the Frasassi Caves, Italy, since many decades with no disadvantages for the formations, which are as shining as when, they were discovered. But according some authors (Faimon et al., 2003; Mulec & Kosi, 2009) it represents a burden for the cave environment.

Therefore hydrogen peroxide, which is an environmentally friendly agent was proposed (Grobbelaar, 2000). The threshold concentration for the destruction of lampenflora was found to be 15 % vol. but the solution attacked the carbonates with a dissolution rate around $2*10^{-2}$ mol m^{-2} h^{-1}. In order to avoid such an effect a preliminary peroxide saturation was obtained by adding of few limestone fragments into the peroxide solution at least 10 hours prior to its application (Faimon et al., 2003).

CONCLUSION

There are different actions to control the development of lampenflora in show caves. First of all, there is the reduction of energy introduced into the cave by the lighting:

- Lights switched on when necessary only
- Minimum distance of indicatively 1 m between lamp and cave wall or formations
- Emission spectrum with minima in the ranges 430 – 490 nm and 640 – 690 nm
- UV lamps switched on when visitors are absent

These actions can be implemented together or each one according to the local situation and possibilities. Obviously the lamps switched on only when the visitors are present in their vicinity reduce the energy release as well as the cost of electric energy. Since the amount of radiation emitted from a lamp decreases as the inverse of the square of the distance, it is always convenient to avoid the placement of lamps too close to walls or formations also because the temperature increase can interfere with the growth of formations. A spectrum poor of the wave length mostly absorbed by lampenflora can be easily obtained with discharge lamps (cold cathode lamps) or LED. The effect of UV irradiation was found to have only a transitory suppressing effect (Dobat, 1998). In addition the effective range is between 50 and 70 cm for a 30 W lamp and therefore in order to have a wider area treated to a distance, e.g. of 3 m, a 400 W lamp would be required or a multiple low power lamps (Kermode, 1975). Some experiments are being carried on presently, as in Grotta Gigante (Trieste, Italy) where the whole electrical system has been replaced recently (Fabbricatore, 2009). The result of the UV irradiation will be appraised in the very next future. In particular its effects should be considered with reference to the expenses of installation and maintenance.

Once the lampenflora is present, it is necessary to avoid its further development and destroy it by chemical methods:

No herbicides! Too toxic for the cave environment
Sodium hypochlorite 5 %
Hydrogen peroxide 15 % vol

Herbicides, used frequently in agriculture, must be avoided because their degradation in the cave environment is rather slow and their toxicity may affects seriously the cave fauna. Sodium hypochlorite treatment releases gaseous chlorine, which may have bad side effects on the cave fauna. Some air circulation may avoid such bad effects. Hydrogen peroxide, once it is saturated with calcium carbonate, is surely the most "friendly" chemical compound, but its use required some precautions by the personnel, while the personnel can apply the sodium hypochlorite without special attention.

ACKNOWLEDGEMENTS

The author is very grateful to A. Fabbricatore, M. Giordano, D. Summers and D. Traferro for the useful discussions and contribution to bibliography.

References.

Aley T., 2004. Tourist Caves: Algae and Lampenflora. In: Gunn J. (Ed.) – *Encyclopedia of Caves and Karst Science*, Taylor and Francis-Routledge, New York: 733–734.

Antrox, 2009. Personal communication by Daniele Traferro, President, Antrox srl., Via Fioretti 10, 60131 Ancona – Italy

Bertolani M., Cigna A. A., Macciò S., Morbidelli L. & Sighinolfi G.P., 1991. The karst system "Grotta grande del vento-Grotta del Fiume" and the conservation of its environment. *Proc. Int. Environmental Changes in Karst Areas* – I.G.U.-U.I.S., Italy, 15 – 27 Sept. 1991, Quaderno Dip. Geografia N. 13, Univ. of Padova: 289–298. Also as: ENEA Report RT/AMB/92/19.

Caumartin V., 1994. *Reflexion sur la conservation des grottes amenagées pour la visite touristique.*. ANECAT, Paris.

Claus, G. 1962. Data on the ecology of the algae of Peace Cave in Hungary. *Nova Hedwigia,* 4(1): 55–79

Claus, G. 1964. Algae and their mode of life in the Baradla Cave at Aggtelek II. *International Journal of Speleology,* 1:13–2

De Virville D., 1928. *Influence de la lumière électrique discontinue sur la flore d'une grotte.* Imp. Libr. Goupil., Laval.

Dobàt K., 1963. "Höhlenalgen" bedrohen die Eiszeitmalereien von Lascaux. *Die Höhle,* Wien, 14(2): 41–45.

Dobàt K., 1998. Flore de la lumière artificiélle (lampenflora-maladie verte). In: Juberthie C. & Decu V. (Eds.). *Encyclopaedia Biospeleologica* . Tome 2, Société de Biospéologie, Moulis-Bucarest: 1325–1335.

Fabbricatore A. (Ed.), 2009. *Grotta Gigante, tursimo, ambiente, cultura*. Società Alpina delle Giulie, Trieste: 1–24.

Faimon J., Stelcl J., Kubesova S. & Zimak J., 2003. Environmentally acceptable effect pf hydrogen peroxide on cave “lamp-flora”, calcite speleothems and limestones. *Environmental Pollution*, 122: 417–422.

Grobbelaar J. U., 2000. Lithophytic algae: A major threat to the karst formation of show caves. J. Applied Phycology, 12: 309–315.

Giordano M., Mobili F., Pezzoni V., Hein M. K. & Davis J. S., 2001 – Photosynthesis in the caves of Frasassi (Italy). *Phycologia*, 39(5): 384–389.

Hajdu, L. 1966. Algological studies in the cave at Maytas Mount, Budapest, Hungary. *International Journal of Speleology,* 2: 137–149.

Hazslinszky T., 2002. Übersicht der Lampenflorabekämpfung in Ungarn. In Hazslinszky T. (Ed.) *Proc. Int. Conf. on Cave Lighting* , Budapest, Hungary, Hungarian Speleological Society: 41–50.

Johnson K., 1979. Control of Lampenflora at Waitomo Caves, New Zealand. In: Robinson A. A. (Ed.) *Cave Management in Australia III*. Proc.Third Aust, Conf. Cave Tourism and Management, Mt. Gambier, South Australian National Parks and Australian Speleological Federation, Adelaide.

Kermode L., 1975. Glow-worm Cave, Waitomo. Conservation Study. *New Zealand Speleological Bulletin,* 5(91): 329–344.

Kyrle, G. 1923. *Grundgriss der theoretischen Speläologie*. Wien: Österreichischen Staatsdruckerei

Kol, E. 1967. Algal growth experiments in the Baradla Cave at Aggtelek. *International Journal of Speleology,* 2: 457–74.

Montechiaro F. & Giordano M., 2006. Effect of prolonged dark incubation on pigments and photosynthesis of the cave-dwelling cyanobacterium *Phormidium autumnale* (Oscillatoriales, Cyanobacteria). Phycologia, 45 (6): 704–710.

Morton F. & Gams H., 1925. Höhlenpflanzen. *Verlag Eduard Hölzel,* Wien: 1–227 + 10 Tables.

Mulec J. & Kosi G., 2009. Lampenflora algae and methods of growth control. *J. of Cave and Karst Studies*, 71 (2): 109–115.

Olson R:, 2002. Control of lamp flora in Mammoth Cave National Park. In: Hazslinszky T. , Ed., *Proc. Int. Conf. on Cave Lighting* . Budapest, Hungarian Speleological Society: 131–136.

Padisak J., Rajczy M., Paricsy-Komaromy Z. & Hazslinszky T., 1984. Experiments on algae and mosses developing around different lamps in the cave “Pal-Völgyi-Barlang”. *Proc. Int. Colloquium on lamp flora, Budapest, 10 – 13 October 1984*: 83–102.

Ruspoli M., 1986. *The Cave of Lascaux: the Final Photographs*. New York, Abrams and London, Thames and Hudson.

Smith T. & Olson R., 2007. A Taxonomic Survey of Lamp Flora (Algae and Cyanobacteria) in Electrically Lit Passages Within Mammoth Cave National Park, Kentucky. *Int. J. Speleology,* 36(2): 105–114.

Appendix 2

INTERNATIONAL COMMISSION ON PREHISTORY IN SHOW CAVES

Address of Joëlle Darricau – Chairman

At the time of the preparation for the **I.S.C.A. conference in Toulouse in 2008**, I presented my idea to President David Summers for creating a special commission in the Association dealing with prehistory.

I had been feeling a growing concern at our meetings because the prehistoric caves lacked a dimension for prehistory, these highly symbolic and significant places, bearing witness to our Humanity.

I would like to thank the Board for bringing the specialized subject on prehistory into existence in August 2008

I hope very much that during this congress we will be able **to identify the full member caves that contain evidence of prehistory** in their caves and get to know the people who represent each of them.

This is the greatest difficulty that I have had since the beginning in activating this network. **I need one manager/contact person per each cave containing prehistory, with their E-mail addresses.**

The subjects covered in this commission, are diverse and varied. They cover all of the archaeological sciences. New, and rather surprising research techniques, are now being used at certain prehistoric sites, to better understand the data that exists within them.

I will only mention one of these sciences: **the application of criminal laboratory techniques**.

Other practices are **environmental studies**: climatology, bacteriology.

For archaeological digs: sedimentology, the study of raw materials, the working of bone and stone.

Social anthropology... understanding the social links of a prehistoric economy.

The Introduction of the cognitive sciences: the neurosciences.

Anthroposophy: spiritual science, which leads the spirit that lives in humans towards the spirit that lives in the universe.

Spiritual science, path of knowledge and way of life.

Biomechanics, human behaviour, physical and psychic approaches, the conceptualization of gestures.

Spatialization –**Taking a new look at** the works: malleability, and **taking into account** the sound and resonance dimension. Cultural links that join all the various ages together.

These are all new forms of research used **to understand** their way of life, **to discover** their know-how, **to imagine** behaviours and then **supposing** their way of thinking.

Perhaps you will think that this list of research techniques – some of them revolutionary – and these new ways of looking at this heritage **do not concern you**, or not very much!

But managers of caves containing example of prehistory must be aware, and be sensitive to these new research techniques.

These new approaches bring us – as the managers of these sites – many things to think about and open up to us. **New outlooks** for the development of an **efficient, innovative, qualitative** offering, made available to **increasingly demanding visitors,** who are hungry for accurate information, who want to discover and understand.

These sites that are open to the public then become **real links** between scientists and the general public, through an appropriate mediation that brings together **these two worlds** that rarely meet.

When I have recently taken part in various International **Symposia:** Lascaux, Ifrao, **network committees**: "Pyrénées Préhistoriques", "Chemins de l'Art Aurignacien," and "Caminos de Arte Rupestre", I am often the only owner-manager of a prehistoric cave site present.

These are the places where **I find new ideas**, where **I nourish my thinking** to be able to explain and think about the site of the caves, **Prehistory to the Present,** in a more original and up-to-date offering... this is also where **I think about our future**... that **I can decide to apply breakthroughs** to move away from obsolete practices, **to be innovating** in terms of presentation, **to gather around me** people with very specific competencies. Also knowing how to talk about others, **about you,** and in the end passing on through this network, **of ours**, everything that we are able to gather from our travels and our reading.

Knowing how to present the specificities of our prehistorical sites with, in the background, **a broader notion of the history of prehistory**.

At the present time we are all fragmented and each of us addresses only a part of our subject.

The committee exists. It will be a place for reflection thanks to the **web site, internet and intra-net** space.

A formidable tool for working and sharing. **It's up to us to make the most of it**.

To achieve this, we must adopt a new way of acting...

Let us create a collective intelligence with the new communication technologies.

Changing our habits, thinking about other people.

Let's be curious about others.

Let's share, exchange, and above all make the time to do it, to create the mechanism of **click and copy, click and send**.

Human beings have survived thanks to exchanges, sharing, in a lived intuition of interdependency of the world of living things and of nature.

Cultural diversity is an enrichment of humanity in motion, we are constantly evolving. **We are the actors.**

Now more than ever, we must **develop a capacity for adaptation**, nourished with substantial and **patient thinking** in making our choices.

I don't have time to go into it now, but I would like us to consider the issue of **tourism for our caves with prehistory**. How far can we go? Again, the management of paradoxes.

What training is needed for our personnel in charge of mediation? The dangers, the notion of fashions, profitability, competency.

Speaking of prehistory...

Like them, let us be **Hunters** of information...

Gatherers of new ideas...

Nomads for a broader vision and sharing that witch will enrich all of us.

Prehistory! Our family history which is far from being finished!!!

Thinking that **the more we think we know, the more we realize that we don't know very much.**

These are the approaches that I would like to explore with you in our future exchanges.

This commission will be **what we are able to build together.**

Thank you – Merci – Gracias – Milesker