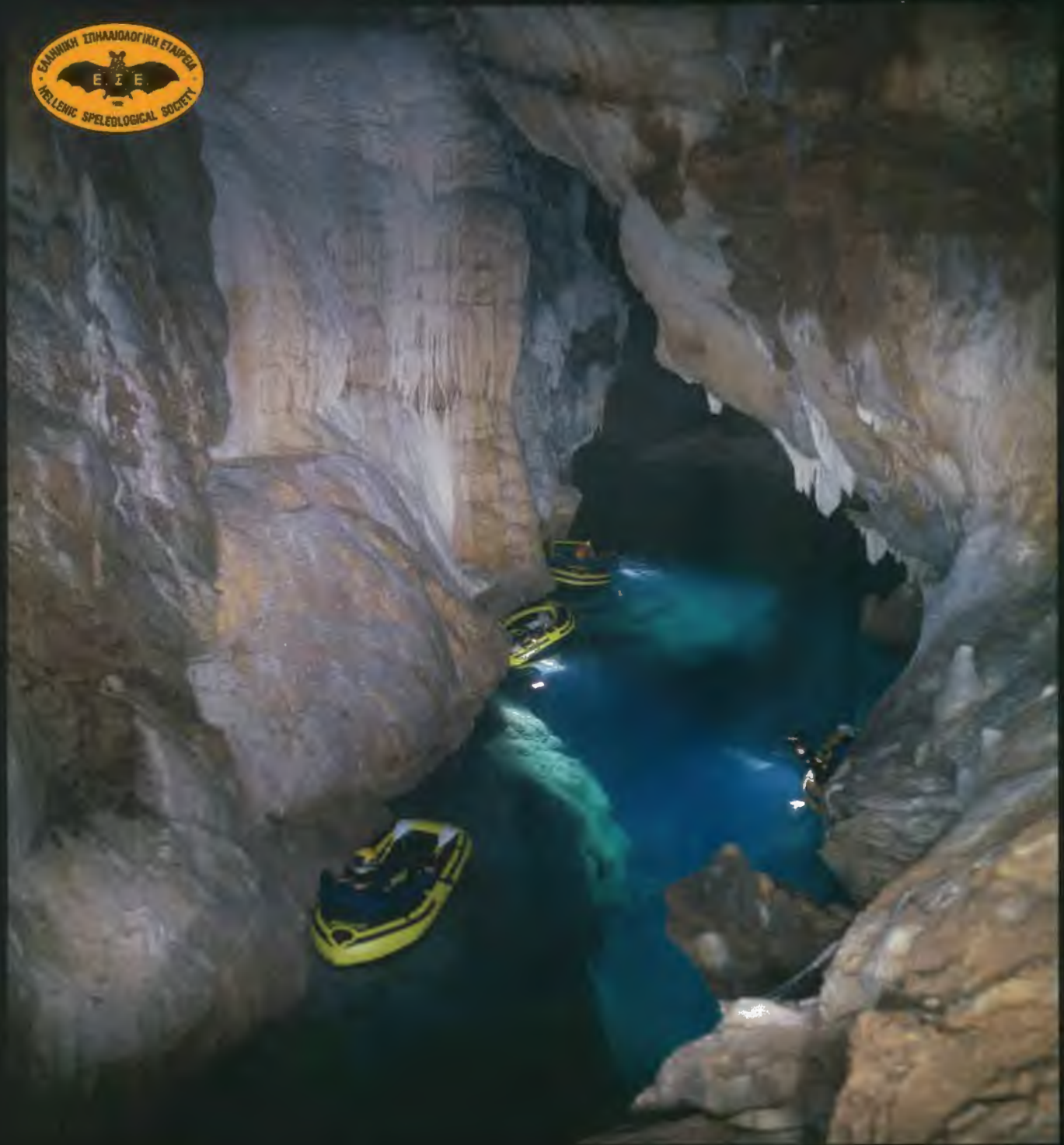


Proceedings of the

14th International Congress of Speleology

Proceedings of the 14th International Congress of Speleology • 21-28 August 2005, Kalamos, Hellas • Volume 2



Volume 2

21-28 August 2005, Athens, Kalamos, Hellas



INTERNATIONAL UNION
OF SPELEOLOGY (UIS)



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*Proceedings of the 14th International
Congress of Speleology.
21-28 August 2005, Kalamos, Hellas*

Volume 2

HELLENIC SPELEOLOGICAL SOCIETY

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Athens 2005

ΕΛΛΗΝΙΚΗ ΣΠΕΛΙΟΛΟΓΙΚΗ ΕΤΕΡΟΣΗΜΙΑ
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Published by: HELLENIC SPELEOLOGICAL SOCIETY

Volume 2: ISBN 978-960-98020-0-0

ISBN 978-960-98020-2-4

O-126

Classification of karst features in Mount Lebanon

F. Nader

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The Republic of Lebanon is located between latitudes 32°34'N and 34°41'N, along the central-eastern coast of the Mediterranean Sea. The Lebanese land surface totals about 10,450km², with some 7,000km² (or 67%) of the territory covered with Mesozoic and Cenozoic karstified carbonate rocks. Basically, three distinct physiographic units characterize the Lebanese territories. These are: Mount Lebanon (or the Lebanon - sensu stricto), the Anti-Lebanon and the Beqaa valley. The Lebanon and Anti-Lebanon are two parallel mountainous ranges, trending north-northeast-south-southwest; they are separated by a high-plain called the Bekaa. Mount-Lebanon has average altitudes exceeding 2200m above sea level for a length of 170km, forming an efficient obstacle for the westerly Mediterranean winds. About 80% of precipitation falls from November through February, while almost no rain occur from May to October (the dry/recession period). There are 11 perennial streams flowing from the high ranges of Mount Lebanon - mainly from typical karstic springs. The karstic features that are present in Mount Lebanon are characterized by a broad diversity, due to the complex combination of various factors (e.g.

climatic, tectonic, geomorphologic, topographic, hydrological) and the relatively small dimensions of carbonate structures (e.g. high altitude plateaus). Deep karstification in fractured carbonate strata at high altitudes allows rapid infiltration contributing to a considerable reserve of groundwater, which emerges eventually from karst springs as well as coastal and submarine confined springs. Cave networks are inherently associated with their location. Accordingly, coastal sea-caves and phreatic caves (the latter forming lateral collectors of reserved groundwater) are discussed separately from the relatively high altitude caves, which mainly fall in two groups according to the corresponding rock formation and lithology - deep, vertical caves in the monotonous Jurassic limestone sequences; and labyrinth, lateral caves in the marl/volcanics and limestone interlayered Cretaceous sequences. In addition, those caves that are present in the eastern side of Mount Lebanon (facing the Bekaa) also show distinct speleological and hydrogeological characteristics. The present contribution attempts to classify - for the first time - the various karstic features present in Mount Lebanon. Keywords: Karst types, Speleogenesis, Lithology, Precipitation rates, Labyrinth caves, Sinkholes, Lebanon

O-127

Cave Ulica and the denudation of the karst surface - case study from Kras, SW Slovenia

A. Mihevc

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In the Kras plateau, that is slowly rising, the hydrological zones in karst are moving downwards.

Caves were transformed and reshaped from phreatic to vadose. The general karst denudation brought caves closer to surface. In many cases denudation already thinned and removed the cover rock above the caves creating unroofed caves that becomes a part of the surface topography. The 120 m long horizontal cave Ulica Peθina has 10 m thick ceiling left. It continues to 250 m long unroofed cave Ulica. By comparison of the morphology of the cave and the surface above the cave and along the unroofed part of the Ulica, we can infer on the type and intensity of the processes

in the caves and on the surface. Rough karren relief, with clints several meters high and small dolines show intensive corrosion and dissection of the surface. The smooth cave ceiling and walls preserved in the cave show no signs of corrosion or disintegration by percolating water. This can be possible if the cave walls are case hardened by the percolating water that deposits calcite into the karstified rock which surrounds the cave. This has also effects on the very small inflow of the water into cave indicating that the cave is to a great extent isolated from the epikarst vadose water circulation. Key words: karst denudation, epikarst, unroofed cave, case hardening, Slovenia

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O-128

The underground legend of Carbon Dioxide heaviness

Giovanni Badino

*Dip. Fisica Generale, Università di Torino • Associazione La Venta***Abstract**

The interpretation of carbon dioxide traps as due to the "heaviness" of this gas is discussed, with the fact that in spite of water vapour "lightness" in comparison with air, no water vapour trap exists on the cave ceilings... In fact the underground atmospheres with special composition are not due to gravity but to the absence of any air movement around gas sources.

A very common idea between cavers (and not only) is that "heavier" gases tends to accumulate in depression and, especially, in the bottom of caves. It is so widely known that the CO₂ accumulates at the bottom of shafts, that so far nobody has discussed this idea. That is trivially false, an underground legend.

Introduction

It is well known that the measure of how much common is an idea, does not contain information about its truthfulness. We are going here to discuss a case.

Gas densities

A first indication that those who use this idea are simply repeating it, without any reflection, is that they generally say that "the heavier gas accumulates"... Obviously 10 kg of Nitrogen are heavier than 2 kg of carbon dioxide, or even 1 kg of Radon... The carbon dioxide is not heavier than

O₂ or water vapour, it is denser than those gases.

Do denser fluids sink in the other?

In case of liquids the answer is complex, it is necessary to take into account many effects connected with the molecules interactions. The gases behaviour is much simpler than the liquid sedimentation, because the gas molecule do not interact each other, and they behave in some ideal way, as also many solutions do. Each air molecule is free to diffuse in every direction and it is easy to calculate the atmosphere structure at the equilibrium. If the sedimentation, in the meaning of the people that declares that "heavier" gases accumulate in depressions, does really exist, then we would live in a carbon dioxide atmosphere in the few metres above the seas, in oxygen up to the top of main mountains, in nitrogen above, to find finally all the water vapour (and rains!) in the stratosphere. Is it true? No, it is not. Neither the legend of carbon dioxide "heaviness".

The gravitational sedimentation

Let us then discuss the gas sedimentation stratified in the gravitational field ($g=9.8 \text{ ms}^{-2}$) on a flat surface. The hydrostatic equilibrium impose a pressure (P) variation with altitude z (positive upward) as

$$\frac{dP}{P} = -\frac{M_{mol}g}{RT_0} dz$$

Gas	M_{mol} [$10^{-3} \text{ kg mol}^{-1}$]	L_z [m]	$P(1000)/P_0$	$P(10000)/P_0$
Nitrogen	28	8700	0,89	0,32
Oxygen	32	7600	0,88	0,27
Air	28.9	8500	0,89	0,31
Hydrogen	2	120000	0,99	0,92
Methane	10	24000	0,96	0,66
Water vapour	18	13600	0,93	0,48
Carbon dioxide	38	6400	0,86	0,21
Radon	222	1100	0,40	0,000113

Atmospheres of pure gases in diffusive equilibrium stratify exponentially, which means that each altitude increase of L_z causes a relative reduction to a factor $e^{-1}=0.36...$ of pressure. For instance, in pure oxygen we have to increase 7.6 km to reduce the pressure of 63%, in pure hydrogen the rise have to be 120 km, in radon 1.1 km and so on.

The real atmosphere is a gas mixture, but the gases behave in independent manner, they collaborate to create the final total pressure, but the partial pressure of each one behaves as the others do not exist. So, the atmosphere can be considered not only a different gases mixture, but roughly also a different atmospheres mixture, each one composed by pure gases. So, they have a tendency to separate each other on a tenths kilometres scale-altitude, but the strong vertical mixing processes in the lower layers (called "homosphere", up to 80 km) prevents such diffusive separation and create a quite uniform chemical composition. Nevertheless it is really true that in its upper layers ("heterosphere") the Earth atmosphere is arranged into four shells, the lower dominated by molecular nitrogen, the second by atomic oxygen, the third by helium and finally by hydrogen atoms [LUTGENS, 1998].

The gases scale lengths are around ten kilometres what means that, also in perfectly calm atmospheres, it is possible to appreciate chemical composition differences only working with large altitude differences. The table says us that 1 km above the seas the different gases have essentially the same pressure, we would not be able to detect the different "weight" measuring the partial pressures, also in absence of vertical mixing.

Then some sedimentation does exist, but it works on kilometres... On

Where M_{mol} is the gas molar mass and R is the gas constant. It is easy to integrate between the surface ($z=0, P=P_0$) and ($z, P(z)$) to obtain

$$P = P_0 \exp\left(-\frac{M_{mol}g}{RT_0} z\right)$$

It gives an exponential pressure decrease with altitude. This equation can be used to describes the upper parts of Earth atmosphere, from 10 to 80 km, where the temperature is quite constant.

It is not correct to use it in the lowest part of atmosphere because also the temperature changes with altitude, but the equation describes very well the chemical gas sedimentation in caves where the temperature is quite constant.

The term in parenthesis must be dimensionless and then we can intro-

$$L_z = \frac{RT_0}{M_{mol}g}$$

duce the scale length of a gas sedimentation in the gravitational field

We can now calculate the scale length at $T_0=288 \text{ K}$.

few metres it is impossible to detect any partial pressure variation between gases due to their different densities, neither radon.

So, the water vapour and methane do not concentrate on the ceiling, carbon dioxide and radon do not concentrate on the floor, unless we consider cave altitudes of many kilometres.

The sedimentation idea, repeated thousands times from a caving book to the other, is trivially false.

The carbon dioxide traps

But there is a problem, because we know that it is true. We have worked in Tropics, we met caves filled with carbon dioxide, we have developed techniques to work in these conditions, we have studied shaft equipments to descend in holes where was possible to meet deadly atmospheres [ANTONINI, 1997]. Did we work for something that does not exist?

No, the problem does exist, but its classical interpretation is false, the shafts are not filled by carbon dioxide because it is an "heavy" gas, but because the carbon dioxide is produced at the bottom of the shaft in an absolutely calm atmosphere.

Note that the false idea depends on the fact that the gas is potentially deathful. If in the shaft there is a lake the air at the bottom is filled with water vapour. We do not interpret this obvious fact as due to the "heaviness" of water vapour (that, in any case, is less dense than air), but as merely due to water presence. This is absolutely correct, the water vapour is concentrated just near the water surfaces.

In exactly the same way, the carbon dioxide is concentrated just near the "carbon dioxide sources". And in the same way the gases of upper atmosphere are concentrated near the source, in ionosphere the X and UV solar radiations produce atomic oxygen and hydrogen, and they accumulate there.

The carbon dioxide comes essentially from putrefaction of organic substances, that are much denser than the air, and tend to accumulate in the lowest parts, as water does (but often water can flow away and often the dead organic substances cannot). So, the carbon dioxide and water vapour tends to accumulate in the depressions that often are more humid, and sometimes deadly enriched with carbon dioxide.

There is something worst, but often neglected because not only the carbon dioxide is dangerous at high concentration, also oxygen-poor atmospheres are deadly, independently by the presence of other gases.

Each carbon dioxide molecule comes exactly from the reaction of a carbon atom with an oxygen molecule; then, in general, near the carbon dioxide source we can meet a deadly presence of carbon dioxide and a deadly absence of oxygen. So, the problem is double, if we have the organic compounds on left, we have to calculate the oxygen flux to the left and the carbon dioxide flux to the right.

We have to make also a note about another smaller underground legend, the idea that is possible to monitor the lethality of an atmosphere looking if the acetylene light works well. We have two independent way to produce a lethal atmosphere, high concentration of carbon dioxide, low concentration of oxygen. The light burn if there is sufficiently oxygen, that is all. So, in an atmosphere composed with 28% of oxygen and 25% of carbon dioxide we die quickly with a wonderful light on head.

The gas diffusion in gases

Let us at first discuss why and how a gas diffuses in some direction.

It happens because the gas molecule are quite free to move and then they move. If we consider a surface in the space, the molecules flow through it in the two possible directions. If the number n_1 of molecule per volume unit near one surface side is the same as n_2 near the other, the net flux is almost the same, and no net gas transfer rate through the surface is observable. But if n_1 is higher than n_2 , then from the 1-side more molecule will flow than from 2-side, and we then say that the gas diffuses through the surface.

It is easy to see that the equation that describes the diffusion processes are exactly the thermal transfer equation (Fourier and Laplace) because also those describe a diffusion, the "heat" diffusion.

The total flux (molecules per second per square metre) through a distance Δz that separates two gas volumes with c_2 and c_1 gas concentration (kilograms per cubic metre) is given by

$$F = D_g \frac{c_2 - c_1}{\Delta z}$$

The D_g is the gas coefficient of diffusion, that depends on the gas viscosity η_g and density ρ_g as

$$D_g = f \frac{\eta_g}{\rho_g}$$

Where f is a factor of order unity. From this we easily obtain the D_g dependence on the state variable

$$D_g \propto \frac{1}{P}$$

$$D_g \propto T^{3/2}$$

The detail of diffusion processes are quite complex and generally only the self-diffusion (the molecule diffusivity in a gas of identical molecules) is described. The real case, in which different gases diffuses one inside the other, have to take into account different molecule sizes, asymmetries, masses, details of repulsion forces between molecules. A review of these details can be found in the beautiful [JOST, 1952] but are not important to us here.

We obtain that the diffusion coefficient changes reasonably, but the variability is not so large. The table [JOST, 1952] gives this parameter at TPNC.

Gas in gas	D_g [$\text{m}^2 \text{s}^{-1}$]
O_2 in O_2	1.89×10^{-5}
N_2 in N_2	1.98×10^{-5}
CO_2 in CO_2	1.04×10^{-5}
O_2 in air	1.78×10^{-5}
CO_2 in air	1.38×10^{-5}
H_2O in air	2.36×10^{-5}

The diffusion equation are not simple to be solved in practical cases, especially in transient condition, that is in the period in which the system tends to stationarity. Nevertheless it is easy to show that in practical cases very small carbon dioxide production in a not-mixing atmosphere can create deathful concentrations near the source. The key role here is played by the thermal uniformity of caves, that hampers air movements, and worst, can create "traps" of cold air, because the "heavy gas sedimentation does not exist, but the thermal sedimentation does. Complex, too...

It is possible to make estimation in this way. We can introduce the maximum gas flux that can evacuated by diffusion along Δz

$$F_{\max} = \rho_g \frac{D_g}{\Delta z}$$

That for carbon dioxide becomes

$$F_{\max} = 1.61 \frac{D_g}{\Delta z} = \frac{2.2 \times 10^{-5}}{\Delta z}$$

If the produced flux is greater than F_{\max} the gas concentration around the source will tend to saturation. So, we can obtain a perfectly toxic atmosphere of almost pure carbon dioxide thanks to a very small flux and very calm conditions, at the bottom or at the top of a cave.

What about the "weight" of carbon dioxide? Nothing, it does not matter; exactly the same things can be said for an oxygen or nitrogen (or methane, in coal mines) source to obtain pure gas atmospheres near it.

We can say this also for a water vapour source, but this gas is so far to

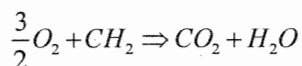
be perfect at TPNC that saturation, condensation, enthalpy releases, eddies and so on appear (the problem of its diffusion in stable atmospheres is very complex).

The double diffusion

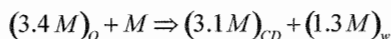
We are now ready to confront the problem of double diffusion. In general we have not a carbon dioxide source, but some organic storage (vegetables) in contact with oxygen.

The oxidation and dismount of long organic molecules causes an Entropy increase, so it must happen: each carbon atom, each Hydrogen atom of this deep storage will surely be bounded with oxygen, to flow away to return to be wood, skin, milk... The flowing away is generally very quick, helped by a numberless type of creatures that lives of the going away of this died order and distribute it to the surrounding life: they are fungi, bacteria, birds, jackal, humans and so on. But when the organic compounds stay in a very stable situation, far from these workers, as in a cave, only the Second Principle can work. And work, slowly. By diffusion, by slow air draughts, by small temperature differences.

We have an organic deposit S, with some mass M per square metre. To mass is organic and its chemical composition is very roughly some $C_n H_{2n}$ plus details. The putrefaction (oxidation) of these molecules is



That in term of masses gives



In volume this means that the putrefaction of one kilogram of vegetable mass needs 12 cubic metres of air and emits 2 cubic metres of carbon dioxide. But above all it needs the oxygen arrival on it.

It is reasonable to assume that the oxidation rate of compound is proportional to the local oxygen concentration in S. The proportionality depends on exposed surface, compound type, reactivity, temperature, presence or bacteria, total mass of S and so on. We do not want to calculate the K_o , that is almost impossible, we only say that a K_o does exist.

So, the flux of CO_2 from S becomes

$$F = K_o c_{O,0}$$

Where $c_{O,0}$ is the oxygen concentration on the compounds. We can also assume that the free atmosphere that feeds oxygen to S, is also the same that evacuate carbon dioxide (it is not a trivial assumption, but in general it is true), so our free atmosphere is at Δz from S.

At the equilibrium the system parameters do not depends on time (note that this assumption is extremely important) and then we must have that the evacuated CO_2 molecules rate exactly equals the incoming oxygen molecules and exactly equals the carbon dioxide production. Here we are

going to call $c_{CD,0}$ and $c_{O,0}$ the gases concentrations in S and $c_{CD,1}$ and $c_{O,1}$ those in the free atmosphere. It is easy, but quite long, to show that the gas concentrations are reduced due to this two-ways diffusion flux. Let us call F_0 the oxidation rate of S in free atmosphere, then the general formulas are

$$c_{O,0} = c_{O,1} \frac{F}{F_0} = c_{O,1} \frac{1}{(1 + 1.8 \times 10^5 F_0 \Delta z)}$$

$$c_{CD,0} = \frac{F \Delta z}{D_{CD}} = \frac{1}{\left(\frac{1.38 \times 10^{-5}}{F_0 \Delta z} + 2.5 \right)}$$

The oxidation flux is reduced as compared with free atmosphere, and correspondingly are reduced the concentration of oxygen as compared with free air and also that of carbon dioxide as compared with that calculated before. It is interesting to see the behaviour of our results in extreme conditions.

We have assumed a very stable atmosphere around S, but does it makes sense? An oxidation always involves enthalpy releases (the reaction of organic substances with oxygen releases 3×10^7 J/kg) and then temperature increases and, finally, convective processes that transfer air much more efficiently than diffusion does.

Is this enthalpy it able to mix the surrounding air on the Δz that separate S from the "free" atmosphere? It is not possible to answer without the knowledge of system geometry.

If we consider typical temperature differences between the organic deposit and the cave around 0.1-0.5 K, we can estimate in few centimetres per second the typical air flow velocities, in general much more efficient than diffusion to evacuate so small carbon dioxide fluxes. The situation that appear to be the most favourable to use this energy for convective movements is when we have S on a vertical wall: the heated air forms eddies in front of S and at the same time the water flows away from it reducing its cooling role.

The worst situation is surely if S is on the roof (or, more reasonably, in a closed ascending cave branch): the energy released create a thermal sedimentation that traps air in the bubble, only diffusion can evacuate gases from there, also if the entrance is quite large.

We may say that it is in general a very small energy release, but its effects depends on system shape details: organic deposit orientation, reactivity and depth, water presence in the deposit.

In any case, it appears that extremely low air fluxes are sufficient to prevent the formation of carbon dioxide rich or oxygen poor atmosphere inside caves, and really these conditions are quite difficult to meet.

Transient conditions

We cannot discuss here other detail like "thermal diffusion" or "Soret effect", but we have to spend some words about the volcanic carbon dioxide "rivers" that sometimes have been able to kill many people, and on the general fact that if we have a cup filled with carbon dioxide we can pour it in another cup, gravitationally. How can it be possible?

It is simple, are typical transient situations. A gas filled cup it is very similar to a hot stone, which is going to cool, slowly, with similar diffusion law.

This means that if we produce, in some way, the filled cup with an external effort, its gas will hold there for some times, like the cold air in supermarket freezer, but the situation is not stable. The freezer situation

is stabilized by a continuous air cooling, the carbon dioxide trap can be stabilized by a gas source (and we return to "stationary" physics), but if these "sources" are absent the system evolves to a maximum entropy state, one to uniform temperature and the other to complete mixing. In this case the gas will then diffuse away to fill the Earth atmosphere, very slowly, but meanwhile can be poured like a liquid or flow along a gallery floor.

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Calibrated Holocene Paleotemperature Record for North America from Stable Isotopic Analyses of Speleothems and their Fluid Inclusions

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Abstract

The secular variation of the oxygen isotope composition of speleothem calcite provides a powerful but qualitative index of climate change. In principle, it is possible to calculate the true temperature of calcite deposition from the partitioning of oxygen isotopes between the speleothem calcite and the formation water. The obstacle to completing this calculation is the need for samples of the original drip water from which the calcite precipitated. We are now able to extract this drip water from fluid inclusions trapped in the calcite matrix using new techniques partly developed by the McMaster working group. The oxygen of the fluid inclusion water may have exchanged with the enclosing calcite after entrapment and therefore should not be used as a direct measure of the temperature of formation. The deuterium/hydrogen ratio (dD) of the entrapped water will be unchanged, however, allowing us to use the dD of the fluid inclusion combined with the Craig-Dansgaard meteoric water line (assumed to be valid over the Holocene) to reconstruct the initial d18O ratio of the drip water. Using this with the d18O of the speleothem calcite we may then determine the actual temperature of calcite deposition, a value which is of great interest as it will be approximately equal the mean annual temperature above the cave in most instances. Validation of this method is being provided by analysis of modern speleothem calcite combined with an an-

nual cycle of monthly bulk drip water samples, and instrumental records of drip rate, temperature and total dissolved solids from 18 monitoring stations placed in six caves in 2004. The speleothem climate change records including the calibrated temperature record will allow us to assess important changes in regional climate through the Holocene along a west-east transect that is broadly across the middle of the North American continent and close to the modern mean position of the Polar Front. Towards this end, two eastern and two western field areas have been selected for intensive study. We will assess the gradient in d18O of the precipitation across the western cordillera of North America (from Vancouver Island on the Pacific coast to Bow Valley, Alberta) and thereby provide insight to the evolution and shifting of storm tracks as they move east from the Pacific into the rain shadow of the Canadian Rockies. Contemporaneous records from the mid-west (Indiana) and north-east (New York) will be used as continent-wide points of comparison. The Pacific Coast site includes three caves located over a range of altitude from sea level to 750m asl. Here we hope to observe shifts in the boundary between the northern and southern Pacific gyres which would affect the isotopic evolution of precipitation generating recharge to the caves. Results from the cave water monitoring and isotopic analysis of speleothems will be presented from this ambitious continental scale project begun in 2004.

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Origin of the Climatic Cycles from Orbital to Sub-Annual: Speleothem data

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Abstract

We developed a new real-space periodogram analysis algorithm to calculate, compare and calibrate the real intensity of the cycles in speleothem luminescence time series. We studied variations of the length of these cycles with time by evolutive power spectral analysis. We studied long cycles in luminescent speleothem records from Jewel Cave, South Dakota, US and from Duhlata cave, Bulgaria 10000 km apart, covering 89300- 138600 yrs B.P. and the last 250000 yrs respectively. These solar insolation proxy records contain orbital cycles of 41, 23 and 19 kyrs and solar luminosity cycles with duration from several centuries to 11500 years. The most powerful non-orbital cycle is 11500 years cycle (as powerful as the 23000 a. orbital cycle in our record). It was found previously to be the most intensive cycle in the delta C-14 calibration record and was interpreted to be of geomagnetic origin. Our recent studies suggest, that this is a solar cycle modulating the geomagnetic field. We determined

the Solar origin of the cycles with durations of 11500, 4400, 3950, 2770, 2500, 2090, 1960, 1670, 1460, 1280, 1195, 1145, 1034, 935, 835, 750 and 610 years. It was done by their detection both in proxy records of speleothem luminescence, D14C and the intensity of the geomagnetic dipole. It is well known that the main variations in the last two records are produced by the solar wind. These millennial solar luminosity cycles can produce climatic variations with intensity comparable to that of the orbital variations. We used the same digital analysis to calculate the intensity of the cycles of the speleothem luminescence (representing cycles of solar radiation or air temperature) in speleothems from Cold Water Cave, Iowa and Rats Nest Cave, Alberta. Obtained power spectra demonstrate that many speleothems recorded cycles of the soil temperature in the region with duration of about 11 and 22 years. These are the well-known solar cycles, which drive temperature changes in some climatic regions. Although this solar cycles produce variations of the solar constant with amplitude

of less than 0.4% cosmic rays influence on the atmospheric transparency provides a mechanism of strong multiplication of solar variations on the solar radiation at the Earth's surface. Cosmic rays have strong modulation by the solar wind, which roles their concentration at the Earth. It is proven that luminescence of speleothems from Rats Nest Cave, Alberta reproduce air temperature, but such records from this cave exhibit a strong cycle of 425 years, which is well known from D14C to be an important solar cycle. So it should modulate air temperature as well as cosmic rays flux recorded by D14C variations. The same records contain also the well-known cen-

tury and bi-century solar cycles. In addition to the annual cycle produced by the Earth's rotation we found sub-annual cycles with duration of 27, 23 and 14 days in an extremely high-resolution luminescent record from Cold Water Cave, Iowa. Such cycles can be produced by the period of rotation of the Sun, which produces similar variations in the solar wind modulating cosmic rays flux. This period produces periodical appearance of the active zones on the Sun, which are major emitters of solar wind so produce strong variations of its density.

O-131

Periodicity in environmental change revealed from New Zealand speleothems

P.W. Williams, D.N.T. King, J.X. Zhao, K.D. Collerson

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Abstract

Spectral analyses of stable isotope values from New Zealand stalagmites show distinct periodicities. A period of about 90 years is particularly

prominent. Speleothems analysed cover an interval of about 25,000 years from the Last Glacial Maximum until the present. Chronological control is provided by more than 40 TIMS dates.

O-132

A census of Italian sea caves

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Summary

In 2001 CLEM, an independent research center in marine sciences, performed a census of Italian sea caves. The aim was to gather a general view of scientific knowledge about sea caves in Italy. Thanks to the sponsorship of the Italian Ministry of the Environment, the census was published in 2003. A large multi-authored book collects 50 papers on the various aspects of sea caves scientific relevance. A bibliographic reference of nearly 1000 entries completes the book. An attached CD-rom contains the book papers in html format and the actual census. 1048 caves are registered, but many more are to be discovered.

CLEM produced two scientific books on red coral (with the sponsorship of the Italian Ministry of Agriculture and Fishery), a media campaign against the edible use of the date-shell (*Litophaga litophaga*) and the feasibility study of the "Punta Campanella" protected marine area (Naples, Italy).

Introduction

The scientific and environmental importance of sea caves is well known. The European Commission enclosed sea caves in the list of endangered habitats, that are worth a special protection status (LIFE Directive, 92/43/EC, Annex I).

However, scientific and environmental knowledge about sea caves in Italy was dispersed among several sources: caving associations, divers, cave-divers, sea biology researchers, geologists, archaeologists, sea-bound environmentalist associations and so on.

In 1997, Fabio Cicogna proposed a data collection of all scientific aspects of sea caves. Sponsorship and funding from the Italian Ministry of the Environment was granted to the project. The result is a large book with an attached CD-Rom, published in 2003.

Fabio Cicogna and CLEM

Fabio Cicogna (1925-2004) was a philanthropic supporter of marine science research. In 1978 he established CLEM (Centro Lubrense di Esplorazioni Marine - Lubrensic Center on Sea Exploration) in Massalubrense (Naples, Italy). CLEM was a non-profit organization; it sponsored and supported a large number of research works and dissertations, mainly on biology and ecology of marine habitats. From the beginning, the interest in sea caves was relevant. Such interest stemmed mainly from the parallel interest in red coral (*Corallium Rubrum*).

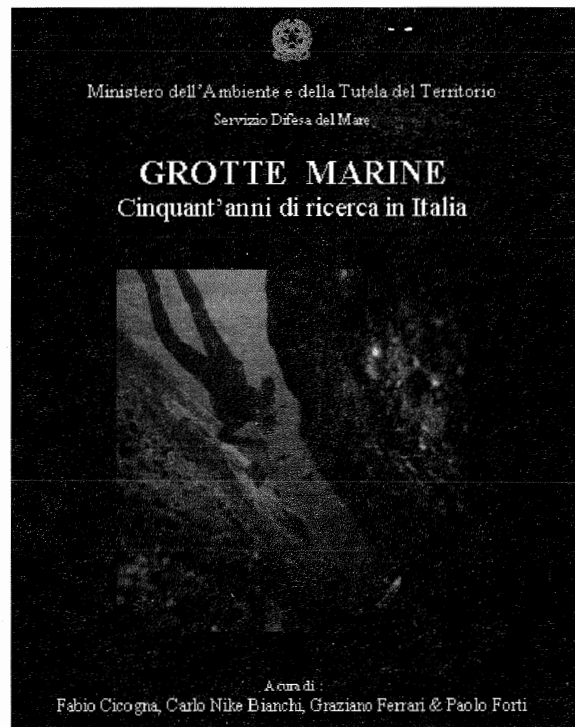


Figure 1 - The book cover (photo by R. Pronzato, about 1970)

History of the census on sea caves

In 1997, the general interest in sea caves evolved into a more defined project. Fabio Cicogna proposed to Prof. Paolo Forti (University of Bologna) and to the Italian Speleological Society to cooperate in a nation-wide, multidisciplinary collection of information about Italian sea caves. At the time, the author was the coordinator of the Cave Register Board of the Italian Speleological Society. The National Cave Register Board, structured in regional branches, summed up data sheets about nearly 30.000 caves, but sea caves owed no special evidence.

Furthermore, exploration of sea caves is carried out by several groups (cavers, university researchers, divers, etc.), and some of them do not report to caving associations. A data collection was needed, with the cooperation of all the involved groups. Fabio Cicogna and the author cooperated in the definition of a detailed project.

The author left the Cave Register Board, but continued to arouse interest in the project from the Cave Register and several regional and local caving associations. In the meantime, Cicogna aroused interest from geology and biology researchers and from Legambiente, a large environmental organization with a strong involvement in marine protection.

In 1999 the project was submitted to the Italian Ministry of the Environment, Sea Protection Directorate. It was approved and funded at the end of 2000.

Development of the sea caves' census

The project started effectively on 17th February 2001 and it was planned to last for 18 months. Fabio Cicogna acted as project manager, with help from the author. Prof. Paolo Forti supervised the geological section and Prof. Carlo Nike Bianchi (presently at the University of Genova) coordinated the biology / ecology section. The author was also in charge of the actual data collection. These four people composed a project management board, and they acted as the book editors.

The project result was designed as a multi-authored book collecting a large number of scientific contributions about several aspects of sea cave sciences. A specific section about technical issues was added (tools, techniques, training, rescue). An attached CD-Rom was designed to contain the papers printed in the book and the actual cave census data sheets, as plain web pages. Furthermore, a small collection of representative images and movies was added.

The editing work proceeded for about a year, with few problems.

On the register side, however, the Italian Speleological Society refused to sign an agreement about cave register data. Sea caves' data collection proceeded anyway. It was based on a comprehensive bibliographical research, performed in large part at the "Franco Anelli" Speleological Documentation Center, at the University of Bologna (thanks to Prof. Paolo Forti and to Michele Sivelli). Further data were collected thanks to researchers, divers, cave divers, diving centers.

Finally, the Italian Speleological Society agreed to share its data, mainly thanks to the present coordinator of the Cave Register Board, Prof. Paolo Mietto (University of Padova). This subsequent agreement, together with Fabio Cicogna's health problems, accounted for an overall delay of 6 months in the project completion. 1048 single caves were identified. A survey was available for 548 of them (429 directly from the survey authors or from publications, 119 from the Cave Register). Publication of each survey was explicitly permitted by the author, by the original publication ownership or by the Cave Register.

The book is not for sale. 1000 copies were printed; about 500 were sent free of charge to: regional environmental management agencies, marine protected areas, central and local directions of the Harbor Master's Office ("Capitanerie di Porto"), institutions and researchers involved in sea cave studies, scientific libraries, central and local cave register offices, national heads of the Cave Rescue Corp, members of the Cave Diving

Commission of the Cave Rescue Corp, single paper authors and single data contributors.

The book structure

The book is designed as a collective work, with 54 authors contributing a total of 50 single papers. All the contributions are in Italian, with a collective summary in English. It was gathered and edited by C. N. Bianchi and C. Morri. The following notes are abridged from the book summary.

The book starts with a Presentation by Dr. Aldo Cosentino, Director General of the Sea Protection Directorate of the Ministry of the Environment. The Introduction by Fabio Cicogna and the list of authors follow.

The book is structured in seven largely independent parts. The first part shortly retraces the history of exploration and scientific research on sea caves.

Geology

The second part, coordinated by Prof. P. Forti, with considerable help from Dr. F. Antonioli, is devoted to the geology, geomorphology and palaeontology of sea caves.

Dealing with cavities of continental origin and their marine evolution, the authors maintain that the short period variations (induced by tides and atmospheric pressure) may be disregarded because they have practically no effects on speleogenesis. But other factors like ice melting due to climatic variations, tectonic movements, elastic movements induced by glaciostasy and isostasy, and also subsiding movement of the coastal plains must be taken into consideration because they may heavily control the evolution of caves along the seashore. Therefore it is important to know the variation of the sea level zone by zone in detail because the effect of isostasy, the tectonic behaviour and many other factors, may change dramatically even within a few kilometers. The evolution of the sea caves is normally proportional to the period the sea water remained in contact with the hosting rock and therefore the largest of such cavities have been normally observed where the average sea level has been relatively constant in time.

On the basis of the definition given at the beginning, sea caves may develop in any kind of lithology, but their genesis may be extremely different. Therefore it is useful to split sea caves into two different categories:

- Marine ingressions caves
- Sea caves (*sensu strictu*)

All the continental caves belong to the first group, their genesis being independent from the presence of the sea: they may be tectonic, eolian, volcanic or karst cavities flooded by the sea when its level rose. The marine ingressions caused nothing else than the stop in the speleogenetic evolution of such cavities.

A whole chapter is devoted to the caves of the second group, which are said to be far more interesting from the genetic point of view: in fact, their evolution has been directly controlled by the sea water, in a passive manner (primary caves in a reef barrier), in a mechanical manner (littoral caves made by marine erosion), or in a physico-chemical manner (mixing water caves). The genetic mechanisms for all these caves are shortly discussed.

A further chapter deals with chemical and physical deposits. Cave environment is extremely conservative; moreover nearly all the cavities, and mainly the marine ones, may be partially or totally filled by physical and/or chemical materials. The mechanisms which are responsible for sedimentations inside marine caves are briefly reported together with the description of the most peculiar of such sediments. These physical and chemical sediments have a fundamental importance for studying the paleo-climatic and paleo-environmental evolution, in particular for the recent Quaternary.

Finally, the most significant case studies, from the genetic and/or scientific point of view, are reported: minerogenetic environments, underground estuaries, both in Italy and abroad, ipogenic sea caves, important paleo-climatic and paleontological findings.

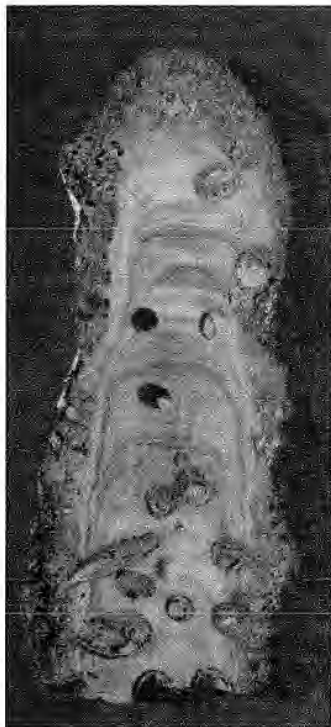


Figure 2 Stalagmite section, Grotta Scaletta, Palimuro Sampling depth: -48 m (photo by F. Antonioli)

Biology

The third and largest part of the book serves as an introduction to the biology and ecology of marine caves. The section was supervised by Prof. C. N. Bianchi. It begins with a purposely done Italian translation of "The role of sea cave investigation in marine sciences", a classical paper by R. Riedl originally published in 1978 by the old and prestigious Pubblicazioni della Stazione Zoologica di Napoli.

The Riedl seminal paper is followed by a large number of chapters organised in six sections, the first of which updates knowledge on the biota of marine caves and opens with a chapter that provides a general outline of the flora and fauna.

Single papers report about present knowledge on sponges, hydroids, scleractinians, molluscs, serpuloidan polychaetes, decapod crustaceans, bryozoans, brachiopods, fish, insects, birds, bats and, finally, the monk seal.

The second section of the biological and ecological part explores evolutionary patterns of marine cave biota, and is composed of three chapters on evolution and speciation, adaptations in marine invertebrates and the anchialine habitats.

The third section consists of four chapters that engage in the main bio-coenoses living in submarine caves. They are related to spatial zonation, the infaunal communities, the meiofauna and the plankton.

The fourth section takes into account environmental factors. It comprises papers about the relationship between light and marine vegetation, the hydrological confinement and the trophic depletion,

The fifth section approaches ecosystem studies, which take into account community structure and ecosystem functioning. These papers in-

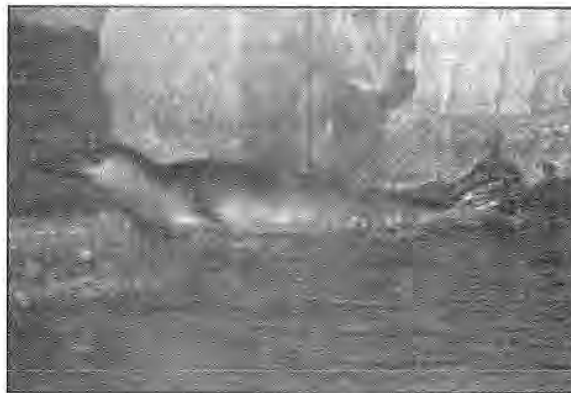


Figure 3 - Monk seal (*Monachus monachus*) Grotta del Bue Marino (Sardinia) (photo by E. Altara, 1967)

clude community structure, trophic organisation, the origin and fluxes of matter and energy in submarine caves and bacterial metabolism.

Last but not least, the sixth section of the biological and ecological part takes care of methodological aspects. The currently adopted sampling and measurement techniques and experimental ecology methods are considered.

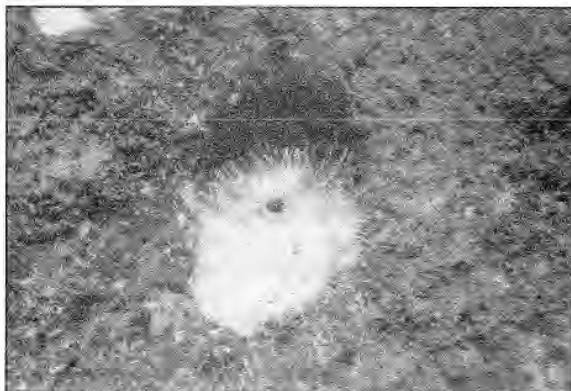


Figure 4 - *Petrosia* sp. genetically adapted to cave habitat (photo by G. Bavestrello)

Archaeology

The fourth part of the book is devoted to archaeology. A chapter describes techniques and provides examples of researches performed by scuba diving in Italian submarine caves.

Social sciences

The fifth part of the book considers the socio-economic importance of submarine caves and the need of environmental protection. The diving department of the environmentalist association "Legambiente" takes care of these issues, providing a chapter that underlines the positive and negative impacts of recreational scuba diving in sea caves. Possible sources on pollution are stressed, both from inland and sea (oil spill). The several forms of legal area protection are discussed.

Technical issues

Exploring and registering submarine caves is a central topic to all research and management issues about this peculiar environment. It is tackled in the sixth part of the book, comprising four chapters. The first underpins the need for proper underwater techniques and safety rules. Cave diving requires knowledge not included in traditional training. Independently of skills, special equipment is needed and definite rules have

to be followed, because safety must be the primary point. Diving materials, dangers and techniques are briefly analyzed. In consequence of the growing diving tourism and in order to avoid accidents and environment damages, it's up to Port Authorities, Diving Centers and Scientific Communities to establish precautionary measures.

What to do to prevent accidents in sea caves and how to operate for



Figure 5 - Cave Rescue Corp training (photo by G. Spaziani)

rescue is the concern of the second chapter. An accident in a confined underwater environment, as sea caves are, is usually very serious and results often in fatalities. Prevention relies on a high level psycho-physical training and on suitable specific tools. In case of an accident in a sea cave, several organizations can operate in the rescue. The Corpo Nazionale Soccorso Alpino e Speleologico (CNSAS - National Mountain and Cave Rescue Corp), through its Cave diving Commission, is able to provide a medicalized rescue.

The third chapter reports about the present status and future projects of the Italian cave register, managed by the Italian Speleological Society (SSI).

The fourth chapter describes technical aspects and the training structure of the Cave Diving School (SNSS) of the Italian Speleological Society (SSI).

The seventh and last part of the book presents the sea cave census. In five comprehensive chapters, G. Ferrari in turn introduces entry data forms, describes maps, analyses data quality, assesses criteria for quoting sources and data property, and provides an example of form.

In conclusion, Fabio Cicogna reports about the problems concerning a complete and correct multidisciplinary study of a marine cave: professional diving instruction, a homogeneous data collection to permit a comparison among different marine caves and that means the necessity of a particular research protocol.

The book ends with an impressive list of nearly one thousand bibliographic references on all aspects of marine cave science.

The CD-Rom

The attached CD-Rom contains five sections:



Figure 6 - The CD-Rom front (photo by H. Jantschke)

- Brief presentation of the sponsoring institution (the Italian Ministry of the Environment), of the project coordination associations (CLEM) and of the two main cooperating associations (Legambiente and the Italian Speleological Society).
- The papers printed in the book, converted in plain html format. The reader can easily surf them in sequence or hierarchically.
- The cave census (more on this later).
- The bibliographic references, ordered alphabetically.
- A selection of photos and videos.

The CD-Rom is designed to provide an easy distribution of information. It is independent of the book, so it can reach a wider audience than the limited edition of the book.

All authorship rights about papers, photos, video and surveys are properly acknowledged. In this way, future researchers can properly reference other people's contribution to sea caving science.

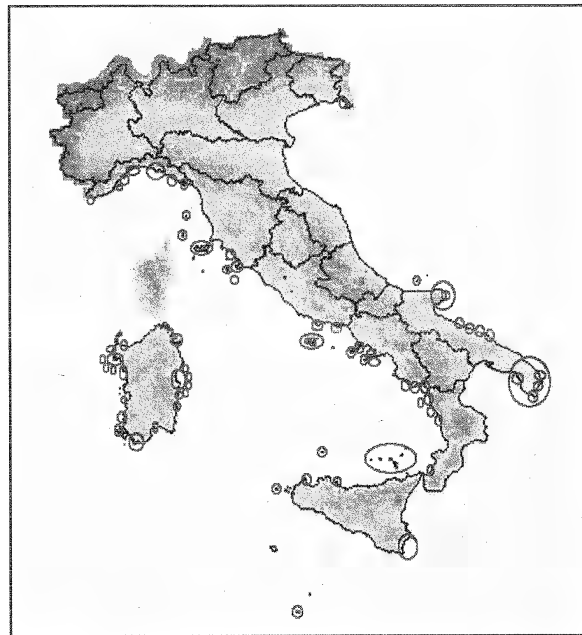


Figure 7 - Map of sea cave areas

The census

According to the census rules, a sea cave is a cave containing a water body directly or indirectly connected with the sea. The indirect connection accounts for the so called anchialine caves, which contain salt water bodies with no apparent connection with the sea.

Marine related caves which are presently at a higher elevation than the sea level are not comprised in the present version of the census. Both coastal (semi-submerged) and (fully) submerged caves are present.

Of course, data collection is far from complete. Most coastal caves are well known. In some areas, a detailed positioning and surveying work is yet missing or incomplete. On the other hand, few areas can claim that submerged caves have been thoroughly explored and reported. In some areas, the only information is a number of citations from local divers.

As far as size is concerned, the official UIS rules were applied, where possible:

- Development longer or equal than 5 meters.
- Entrance width and height lesser than development.

Of course, most sea caves open in limestone cliffs. However, some caves in sandstone, schist, andesite and tuff are registered. A submerged lava tube is reported in Sardinia.

Each cave is represented by a fact sheet with four main sections:

- Geographic, metric and position data.
- A brief description, usually taken from a publication.
- Surveys and photos, with references to authors and publications.
- Bibliography.

Each fact sheet is designed as a web page, to be displayed on PC with a web browser (Netscape Navigator, Microsoft Explorer, etc.). The overall register has a geographic structure, divided in Regions and in main sea caving areas. The geographic structure allows an easy display of related caves and most searches and selections.

Other available searches are: by Municipality, by name (or part of), by

development, by entrance elevation (or depth), by longitude, by latitude.

The collected data were also integrated within the SIDiMar, the geographic information system of the Ministry of the Environment Sea Protection Directorate.

The following table summarizes facts about Italian sea caves, divided by Regions. Separate entries are provided for caves already included in the National Cave Register and for caves not yet included in the Cave Register (due to failure to transfer data to the Cave Register, or to missing / incomplete positioning or missing survey). Each specific data column is further divided into caves with and without survey.

Region	Caves	Already registered			Not yet registered		
		Surveyed	Unsurveyed	Surveyed	Unsurveyed		
Basilicata	17	17	9	8	0	0	0
Calabria	25	18	15	3	7	0	7
Campania	238	113	85	28	125	43	82
Friuli-Venezia Giulia	4	4	4	0	0	0	0
Lazio	103	38	12	26	65	0	65
Liguria	53	30	18	12	23	7	16
Puglia	201	185	132	53	16	9	7
Sardegna	247	156	155	1	91	7	84
Sicilia	108	23	12	11	85	12	73
Toscana	52	27	21	6	25	7	18
Italy	1048	611	463	148	437	85	352

Future developments

Since the present census is far from complete, the main objective is to further push data collection, with more publications in the geological and biological areas. The diving magazines often report references to unpublished submerged caves. This means more field information from professional divers is needed.

The increasing interest in sea caves caused the definition of a law proposal at the national Parliament. The proposal aims at the protection and the exploitation of sea caves. Care must be taken not to exploit sea caves before the proper scientific studies are performed. The risk is to over-use or abuse little known resources.

A better approach would be the definition of a nation-wide plan of local area research campaigns, aimed to collect a complete and detailed knowledge of sea caves, area by area.

In this sense, a powerful help would come from the use of the multi-beam side-scan sonar. This was the last Fabio Cicogna's idea about sea

caves. Entrances as small as 0.5 meters wide can be identified at depths down to 50 meters. The following pictures show the results of a test performed in Salento (Lecce, Puglia).

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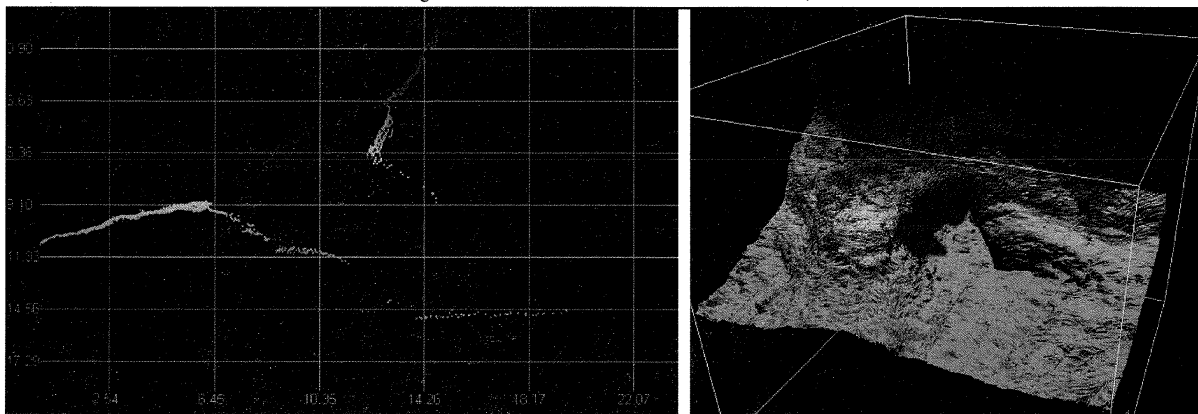


Figure 8 - Sonar profile and 3D digital terrain model of the Grotta delle Corvine entrance (Lecce, Puglia)

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A school for cave rescue managers

Corrado Camerini, Graziano Ferrari

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Summary

In 1999 the Italian Cave Rescue adopted a formal technical training model, structured in seven steps, up to National Instructor. A national technical school was established.

In addition to the technical training, the need for a formal training of cave rescue managers appeared of the utmost importance. In 2004 an experimental manager school was established and a three-years comprehensive training model was outlined. Courses subjects range from high-level management of rescue operations to bureaucracy, funding, relations with mountain rescue organizations and so on.

The paper details the rationale of the training model and reports about the first year experience.

Introduction

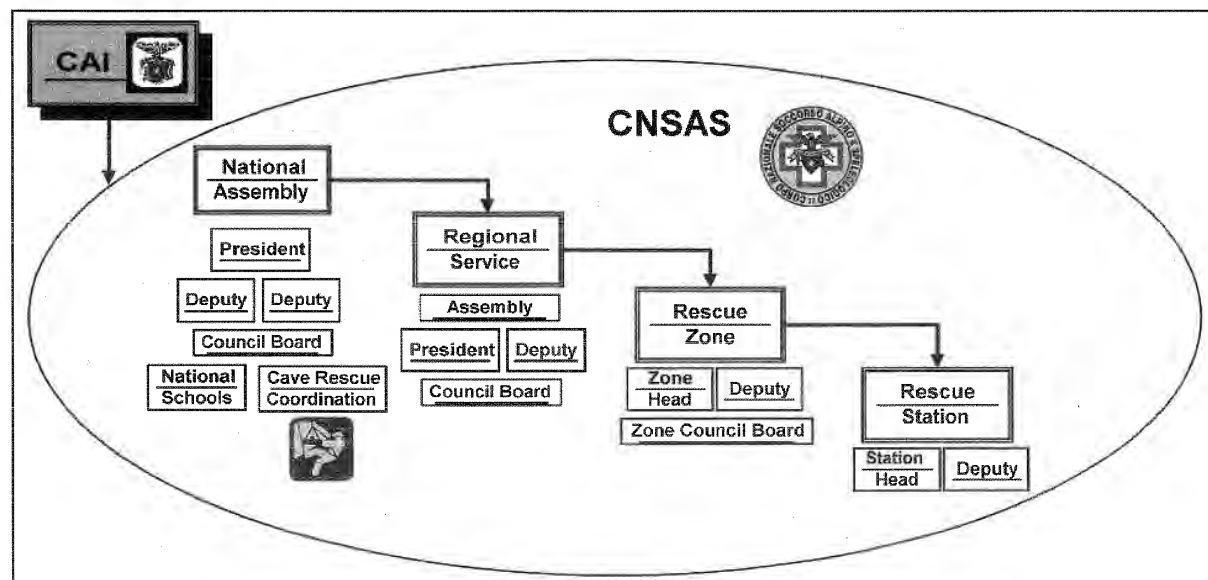
Cave rescue in Italy is performed by a specialized structure established in 1966. It collects volunteers selected from the caving community. The Cave Rescue belongs to the Corpo Nazionale Soccorso Alpino e Speleologico (CNSAS - National Mountain and Cave Rescue Corp), which in turn is part of the Club Alpino Italiano (CAI - Italian Mountain Club). CAI is a large non-profit association established in 1863, with about 300,000 members. The Mountain Rescue in turn was established in 1954; the table at left summarizes some facts about CNSAS in 2004 (CNSAS, Annuario 2004).

The CNSAS is a national structure, with an Assembly of Representatives, a Council Board, a President and two Deputy Presidents. On the mountain rescue training side, a National Technical School was established. In 2004 it relied on 29 National Technical Instructors. Specialized

Schools for physicians, avalanche search dogs and surface search dogs are also present. On the local side, the CNSAS is structured in Regional Services, Zones and Stations. The Rescue Station is the operative branch. It manages most rescues, under the direction and the responsibility of a Station Head and a Deputy. The Zone is the management structure: it collects several Stations under a Zone Head and a Deputy. A Regional Service collects several Zones. It manages the general Regional activity, on both the operative and training side. Furthermore, it manages political contacts with the Regional Public Administration. In several Regions, the CNSAS has an agreement in order to provide an highly specialized mountain and cave rescue service, in the framework of the Public Emergency Service (usually identified with the toll-free emergency phone number "118"). Several National and Regional Laws recognize the CNSAS structure; CNSAS is a component of the Civil Defense at national level.

21 Regional Mountain and Cave Rescue Services
32 Mountain Rescue Zones
255 Mountain Rescue Stations
15 Cave Rescue Zones
32 Cave Rescue Stations
7,151 Rescuers (243 Physicians)
5,188 Rescue Operations
5,595 Rescued People
29,983 Involved Members (Member/operation)
3,485 Helicopters

385



The Cave Rescue in Italy

The Cave Rescue is a specialized structure inside the CNSAS, with some autonomy. It collects about 700 members and it is managed by a National Head and a Deputy, together with a Council Board and a Zone Head Board. Each Cave Rescue Zone is usually related to a single Region. At national level, several specialized commissions were established:

medical, technical, cave diving, blasting techniques, news agents. In Cave Rescue, Station Heads are usually the operational team leader inside the cave, while the overall operation management and responsibility falls on the Zone Head and its Deputy.

In addition to cave accidents, the Cave Rescue is involved also in canyoning accidents. This means that a canyoning commission was es-

established, too. In many areas, Mountain Rescue Stations can provide an important support in canyoning rescues. Many minor canyoning accidents are quickly resolved by the Mountain Rescue alone.

Luckily, cave accidents are infrequent (in 2004: 13 accidents with 24 victims). However, a cave rescue is often considered a big emergency, due to its duration, large number of involved rescuers and impact over the media both at local and national level.

On the technical training side, a training plan was adopted. The plan defines five steps:

1. Admission tests and introductory training;
2. Cave Rescue Operator (in-cave basic rescue techniques);
3. Cave Rescue Technician (further technical and medical training, helicopters, eventual snow and avalanche training);
4. Specialized Technician (advanced rescue techniques);
5. Team Leader (in-cave operations management, human resources management, cooperation with the operation head).

Steps 2 to 5 are usually defined by three events: an initial prerequisite test, a specific training (with final evaluation) and a periodic maintenance test. Each new entry must reach level 3 within four years.

A Cave Rescue Technical School was established in 2001 with the task to provide technical training to all members of the Cave Rescue. The Technical School is structured in a National School (28 National Instructors) and in Regional Schools, with Regional Instructors. Steps 1 to 3 are provided by the Regional School, while the national structure provides training to levels 4 and 5 and to Regional and National Instructors. In cooperation with the technical commission, an Operation Manual ("Tecniche di Soccorso in Grotta", at left) was published in 2002. In few years, the Technical School was able to establish an organic training program and to raise the general technical level of the Cave Rescue. The technical training model is now reaching maturity. Its definition relied on past

work by the commissions (mainly the technical one) and by the Zone Head Board; a first edition Cave Rescue Handbook was published as several booklets from 1992 to 1996.

A National School for Cave Rescue Physicians was also established, in order to update and to share experiences and techniques.

The managing heads

In Cave Rescue, the Zone Head is usually the general manager of a rescue operation, with help from the Deputy Head. However, the overall management is a very complex and demanding task, with several components to take care of:

- Coordination of the operation teams;
- Management of external radio and internal phone communications;
- Management of contacts with Local Authorities;
- Management of human and material resources, logistics and warehouse;
- Contacts with the Media;
- Contacts with the Air Force (helicopters);
- Contacts with other Zones;
- Contacts with the Regional Service;
- Contacts with the Cave Rescue National Head and the Commission Heads.

Technical, operational, logistic, media and political competences are needed, in the framework of a medical and technical emergency. The Zone Head becomes a "disaster manager" of a very special kind. Of course a single person is not able to sustain such a workload. Usually contacts with Media are deputed to a news agent, logistics and warehouse to a specific responsible. Nevertheless, the operations management needs a small direction team as the Head of Operations Staff.

The normal management of a Cave Rescue Zone is also very demanding. The main tasks of a Zone Head are listed here:

- General Zone management: accounting, logistics, warehouse, communications, staff, updating
- Organization of cave rescue practices
- Organization of training events
- Organization of promotional events
- Participation to regional and national events
- Funding
- Contacts with the Public Authorities: Administrative Authorities, Police, Civil Defense, Medical Emergency Service (118), Media and so on.

Also in this case the Zone Head needs a small staff of people who take care of the different responsibilities. Some of these tasks come from the fact that a Zone Head should act also as an "image promoter" for his/her structure. Actually, in order to effectively manage all facets of the charge, a Zone Head should be endowed with competences and experience comparable to those of a high level company manager. Furthermore, the legal responsibilities of the Zone management are relevant. However, Cave Rescue members and heads are volunteers; the time devoted to the Zone management is usually stolen from the actual work or from the social and family life.

Managing charges are elective. This means very few people have the needed experience, training and free time to be considered optimal candidates. However, the organization needs to improve as far as possible the training of its managing heads; it needs also to convey the experience of its long-time heads to the newly appointed ones. Furthermore, a common



knowledge background is a strategic asset in establishing and improving the competence and the efficiency of the organization as a whole.

As a first step in the Operations Head training, a "Zone Head Handbook" was developed; it was included in the Cave



The role playing game at the 1999 Zone Head stage

Rescue Handbook as a separate booklet. In this way, each member of the Cave Rescue was able to understand and accept the logics of the rescue management directions. This means a further step toward the improvement of the overall structure effectiveness.

A simulated cave rescue operation was developed. It resulted in a "role playing game": a "game master" (a long time head of operations) proposes several typical situations, from the emergency phone call to the operation development and completion. Each participant reacts to the single situation and states its proposed actions for the future operation development.

The periodic Zone Head Board meeting often resulted in a brainstorming about actual accidents management. In 1998 a three-days specific Operations Head stage was designed to share experiences and to train on specific topics. It was the first step toward a formal training plan. The stage was open also to interested Cave Rescue members, with the aim to train in advance people who are willing to share the Zone management load with the actual Zone Head. In this way, Zone Heads-to-be were able to gain competence and confidence long before the elections. The Operations Head stage was organized annually until 2002.

In 2001 a large simulated operation was designed in order to test the Cave Rescue at a national level on a high depth and long duration emergency. From the Operation Heads point of view, it acted as a very detailed and comprehensive field training.

However, a more detailed and formalized training plan was needed.

The school for cave rescue managers

At the end of 2003, the Zone Head Board charged a small team of experts with the task to define the draft of a training plan. After several



The Operations Room at the national high-depth practice Matese 2001

meetings, a training plan was defined and approved. It is structured over three years, with three training courses and three updating courses.

Training courses:

- T1 Operations management
- T2 Basic Zone management (Laws, Insurances, External contacts, Training)
- T3 Advanced Zone management (Planning, Resource management, Macro-emergencies)

Updating courses:

- U1 Basic update: Communications
- U2 Basic update: Role playing game on operations management
- U3 Advanced update: Accounting, assessment, technical update, other CNSAS structures, Public Administrations

In each year, a T course and a U course are organized. This means the whole plan is as follows:

- Year 1:** T1 Operations management
U1 Communications
- Year 2:** T2 Basic Zone management
U2 Role playing game
- Year 3:** T3 Advanced Zone management
U3 Advanced update

Such plan has two main rationales:

1. In a three year period, all basic and advanced training is provided. The three year period is phased with the elective period of the CNSAS offices. This means a newly appointed Zone Head or Deputy can have its training within the office period. On the other side, an interested but not yet appointed member can have a complete training in an office period, so as to be a competent candidate in the next period.
2. The most important and urgent training, operations management, is the first one to be provided. It is stressed again in the second year, in the role playing game. The third year is reserved to advanced topics.

Furthermore, the School for cave rescue managers has no fixed Instructor staff. The expert team manages the course organization and defines a detailed program. Each relation is assigned to a specific topic expert. In this way, actual field experience is gathered together to build a whole training framework.

Each T course is planned to last three days, and each U course is planned to last two full days. The following tables show the six courses program in deeper detail.

T1 - Operations management

- Structure of CNSAS
- Operations 1 - The call, summoning of teams
- Operations 2 - Operations planning
- Operations 3 - Operations execution
- End of operations
- How to prepare for an emergency
- Case studies

T2 - Basic Zone management

- Duties and responsibilities of CNSAS offices
- The operative center, the warehouse, vehicles
- Practices planning

Laws and rules, Zone bureaucracy, purchase of goods, assembly summoning

Personnel assessment

Contacts with local and national CNSAS structures

Case studies

T3 - Advanced Zone management

Purchase rules, bids

Accounting assessments and inspections

Disciplinary actions

Persuasion techniques

Operational limits (in-scope and out-of-scope operations)

Planning of inter-Zone or national practices

Accident to a technician in operation

Macro-emergency: definition and operative strategies

Case studies

U1 - Communications

Internal communications: theory of communication models, disaster manager and communication

Public communications: the news-agent task, the media system, the press conference, the TV interview

Communications tools: cave phones, mobile phones, radios, radio-links, mobile phone links

Exercises: bulletins, interviews, press conferences.

U2 - Role playing game

Full simulation of an operation

Management of a Macro-emergency

External and internal search in an area with many caves

Search of missing people in cave (management of several search teams in parallel)

U3 - Advanced update

Quality control and assessment

ISO 9000 rules

CNSAS techniques

Mountain rescue techniques:

- Canyoning

- Avalanche search dogs

- Surface search dogs

Public Administrations and Corps:

- Fire Brigades: organization and operations

- Financial Police: organization and operations

- National Forester Corp: organization and operations

- Civil Defense: organization and operations

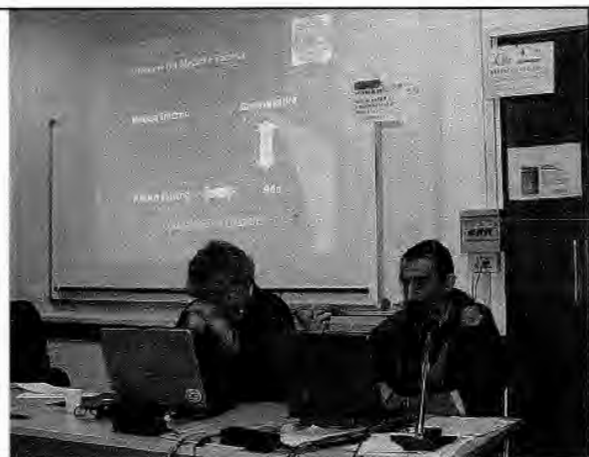
A note about the Public Corps: in Italy the Financial Police traditionally patrols the national boundaries. It performs mountain rescue with helicopters; also the Forester Corp, which patrols public forested areas, performs mountain rescue. On the other side, Fire Brigades raised a structure trained in technical rescue (river, mountain and cave).

In 2004 the first courses were organized: T1 - Operations management and U1 - Communications. Each of them gathered most Zone Heads and Deputies, and many other interested Cave Rescue members. About 40 people attended each course. Among the T1 invited speakers, there were six in-charge- or past-National Heads or Deputies and the two CNSAS Deputy Presidents. Relations detailed all aspects of a cave rescue operation and the various management tasks. It was a very comprehensive experience and it provided the participants with a brainstorming about the many peculiarities of a cave rescue operation. Furthermore, the experience of the older heads was collected and rationalized to the advantage of the younger ones.

The communication course was compressed in just one day and a half, due to external reasons. In this way, it resulted too intensive and it missed most exercises. Anyway it provided a complete framework of cave rescue communication, from internal communication between operational teams and the operation heads to media management. Also some Station Heads attended this course.

In 2005 a second national long-duration practice is planned to be organized in Sardinia in September. This is a large role playing game about a cave rescue operation by itself, so the planned U2 course will be converted to a set of actions in parallel with the main practice: internal search of missing people, simulation of a second accident and so on.

The Cave Rescue managers training plan arouse interest in the Mountain Rescue side of the CNSAS. Considering the National Heads, the Regional Services Heads, the Zone Heads and Deputies and the Station Heads and Deputies, the CNSAS has more than 600 managers to be trained. Most mountain rescue operations are performed by small teams, in cooperation with the Medical Emergency Service (118). However, several operations (canyoning, avalanche, surface search, big emergencies,



The course U2 - Communications (Bologna 2004): the attendance (left), communication between the in-cave physician(s) and the Operations Management (right).

...) deploy in a way similar to a typical cave rescue operation (long duration, many technician involved, several teams in parallel, several helicopters, interaction with Public Corps, high media profile, ...). In this sense and in the general management of a rescue organization, the experience raised by the School for Cave Rescue Managers may be very useful to the CNSAS as a whole.

Acknowledgements

The authors wish to thank:

- Luca Calzolari and Paolo Verico, the other two members of the organizing 'expert team': common passion and enthusiasm in the project produced hours and hours of intensive brainstorming all together;
- The participants to the 2004 courses, both on the speaker side and on the attendant side: all people were eager to share experience and

competence.

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Chemical and stable isotopes profiles along two cores from the snow deposit in the Lo Lc 1607 ice cave (Grigna Settentrionale, Italian Alps)

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Abstract

Two snow cores from the Lo Lc 1607 "Crepaccio superiore in media Val Laghetto" ice cave were analyzed for their chemical and stable isotopes composition. The cave, located at an altitude of 1948 m a.s.l., contains a snow deposit fed by windblown snow showing a yearly thickness variability of some metres in connection with winter snow availability.

We compare data from the two snow cores data and discuss the characteristics and significance of the observed enriched levels. A distinctive pattern characteristic of the ablating top snow surface is described, with particular attention to the behaviour of those ions typical of the carbonatic environment (Ca^{2+} , Mg^{2+}) when compared to the other ions. These results can be useful in developing a method for detection of buried ablation surfaces in cave snow cores. A first simple attempt to derive such a method is proposed.

Introduction

The entrance to the Lo Lc 1607 "Crepaccio superiore in media Val Laghetto" ice and snow cave is located at an altitude of 1948 m. a.s.l. on the northern slope of Grigna Settentrionale (Central Italian Alps), in the Moncodeno high altitude karst area (Fig. 1). Surface morphology of the area is dominated by dolines, bare rock surfaces and karren. Buried karst surface landforms testify of a time when the very poor present soil cover was more abundant. Field work started in 1999 and developed from a general survey of a selection of the many caves known to host ice deposits to the coring of two snow cores year 2000. Further work on cave ice in the area is summarized in Citterio et al. (in press); since autumn 2004 at a nearby ice cave a large microclimatic system is collecting data both from the epigeal and the hypogean environments down to a depth of 100 m.

The Lo Lc 1607 is a small cave in the infiltration zone of a karstic system decapitated by glacial exaration (Bini & Pellegrini, 1998). The cave has been surveyed in the past decades and the presence of perennial

ice and snow deposits is reported since the first surveys (published many years later by Bini & Pellegrini, 1998), which also show a now obstructed down-going passage in the ice. The present setting of the cave is shown in Fig. 2: the snow deposit at the bottom of the entrance doline has an unknown depth and is directly and abundantly fed by snowfalls. Following to the entrance of the cave and the steep debris slope is another snow deposit where accumulation is due to windblown snow. In summer 1999 the deposit featured a stratigraphy composed of more than one hundred layers over a total thickness of about 2.5 metres. These layers were bounded by irregular undulated surfaces produced by refreezing of a usually millimetric wet snow level. The proximity to the cave entrance allows for the relatively wide temperature oscillation needed for the development of such features. The thickness of this deposit showed a rapid variability: the few metres observed during summer 1999 were found to have reduced to less than one metre when the cores have been drilled in summer 2000. Nevertheless, the two short cores allowed precise sampling and high quality samples for chemical and isotopical analyses. At the time of drilling the snow deposit was undergoing a strong ablation phase also promoted by sparse dripping from the cave roof.

The interest for ice and snow deposits in caves is mostly connected with the attempt to use them as sources of past environmental data, both for the last years or tens of years (in the case of deposits near to the cave entrance) and for the last centuries or even thousands of years (at deeper and more stable ice deposits). Dating by various techniques at some ice caves have already confirmed the existence of cave ice deposits reaching these ages (Serban et al., 1967; Achleitner, 1995; Citterio et al., 2005). Nevertheless, for a snow or ice cave deposit to be a viable source of information about the past, it has not only to represent a long time interval with good resolution, but its stratigraphy also has to be clearly defined. Most importantly, melting episodes resulting in stratigraphic gaps have to be readily recognizable somehow. Direct observation of vertical exposures on the sides of the deposits are not always available or even reliable, and the advantages of working on ice and snow cores back in a cold room calls

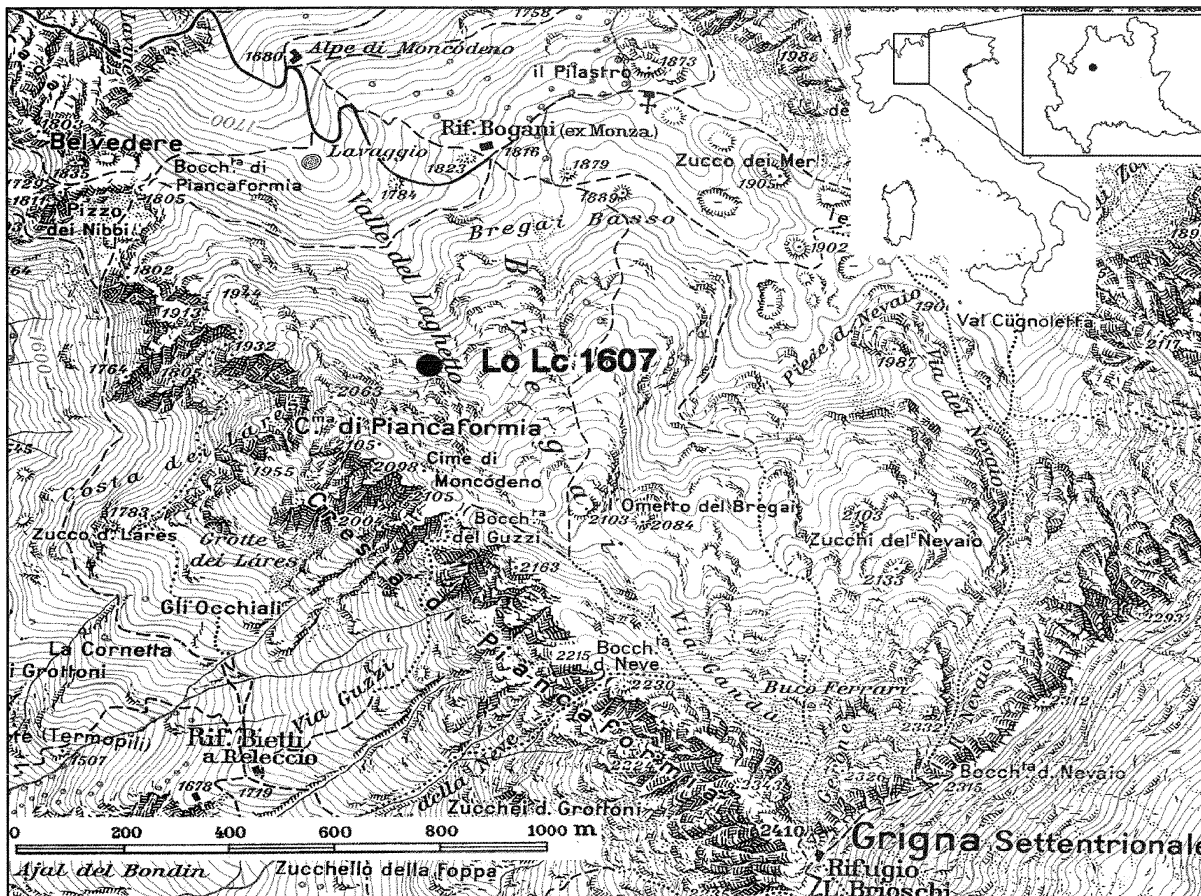


Figure 1 - Map of the Moncodeno area; the black dot marks the location of the Lo Lc 1607 cave.

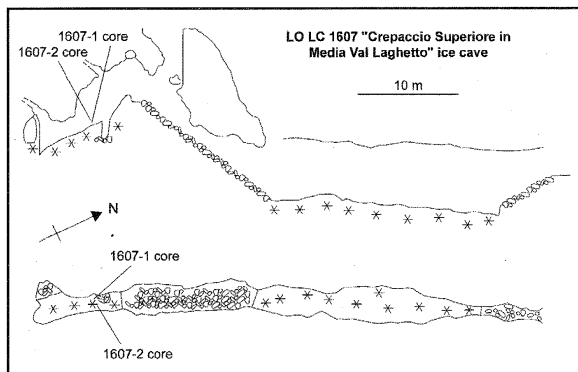


Figure 2 - Plan and vertical cross maps of the Lo Lc 1607 cave (simplified and updated from Bini & Pellegrini, 1998).

for the development of practical methods for detecting ablation surfaces buried by successive accumulation events. What makes this an even more challenging issue is the present lack of a crystallographic and textural evolution model of snow in cave environments. Due to the different thermal regimes of ice caves with respect to epigeal snow covers, the well known sequence of recrystallization stages involved in metamorphism of snow into firn can be expected not to be immediately portable to hypogean snow evolution (Perşoiu, pers. comm.). Similarly, snow composition profiles available from the nivological and glaciological literature may not be directly compared with findings from cave environment.

Materials and methods

Many technical details are involved both in field and laboratory operations on ice cores. The Environmental Sciences Department (DISAT) at the University of Milano Bicocca is active in leading ice drilling projects in Antarctica and the Alps; building on this expertise, research assets and resources we cored a total of four cores in the Moncodeno area (Italy), and a fifth one in the Padiş area (Romania) in cooperation with the Cluj section of the Speleology Institute "E. Racoviţă" of the Romanian Academy of Sciences. For the Lo Lc 1607 snow core, the same conventional lightweight corer used in all of the other caves was selected. The drill head is an aluminium ring bearing three hard metal alloy knives of selectable shape and geometry. The stainless steel corer barrel has an internal diameter of 10 cm, it is 1 m long and it can accept up to 60 or 70 cm of ice in every single run. Its external helicoidal trail drives the ice chips to the upper part where two windows let them enter and collect in a chamber. Rotation is provided by a 220 V, 1.5 kW low rpm electric engine and the operator both supplies the thrust force and contrasts the torque manually; a heavy duty power line was used to connect to a 2.5 kW power unit located near the entrance of the cave. The core was drilled from the top surface of the snow deposit down to the coarse rock debris found at the bottom of the snow deposit. The cold transport from the coring place was a two steps process: first, the cores were immediately closed in plastic bags, hauled to the surface inside sections of rigid PVC pipe to protect them from handling shocks, and placed in insulated boxes cooled by solid CO₂; at the end of the coring operations the boxes were taken downvalley with the help of two mules and finally to cold storage by car. Once in the cold room of the University of Milano Bicocca the cores were cut with

a band saw and 5 cm thick continuous samples were cut for chemistry, stable oxygen isotopes, pollen content and insoluble particles analyses. This sampling procedure of the core, which produces a virtually continuous record of equal, regular, prismatic subsamples under controlled conditions, is impossible to be reliably carried out in the field.

The chemical analyses have been carried out by ionic chromatography on melted and 0.45 μm filtered samples at the Analytical Chemistry Dept., University of Firenze; the oxygen isotopes analyses have been performed at the Geological, Environmental and Marine Sciences Dept., University of Trieste.

Results

Chemical profiles (Fig. 3) show a pattern consistently present in both the cores and for any of the measured ionic species: the topmost 5 cm high sample is always more enriched than the sample immediately below it, usually by three to five times. The strong enrichment of the topmost sample can be clearly observed in every plot. A strong peak in the Ca^{2+} content and a lower one for Mg^{2+} , typical ions of the carbonatic environment, can be observed both in the 1650-1 and in the 1650-2 cores at a depth of 35 cm and 20 cm respectively. No significant enrichment in any other ion has been found at these same depths. Cave samples show lower values than samples from an old snow patch sampled in the cave area in June, 2001 (Tab. 1) with the exception of Ca^{2+} and Mg^{2+} , which are more abundant in the cave samples.

	Na^+	NH_4^+	K^+	Mg^{2+}	Ca^{2+}	Cl^-	NO_3^-	SO_4^{2-}
	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb
1607-1 core, average	48	17	35	65	844	72	27	71
1607-2 core, average	24	12	12	32	550	57	20	43
snow patch, val Laghetto, June 2001	85	259	30	24	445	258	970	505
Colle del Lys Glacier, summer average	49	206	31	21	243	111	437	505
Colle del Lys Glacier, winter average	27	35	19	9	86	68	149	245
Colle del Lys Glacier, year average	36	108	24	14	152	86	272	855

Table 1 - Major ions average content in the two snow cores (5 cm high continuous samples), in samples from a nearby epigeal old snow patch and in the Colle del Lys core (this last data set is from Radice, 2000).

When considering as a rough reference the averaged data from an Alpine glacier high altitude coring (Colle del Lys Glacier core, representing the 1971 to 1997 snow accumulation), where seasonality has been found to be particularly strong in NH_4^+ , NO_3^- and SO_4^{2-} contents (Radice, 2000), it can be seen that these same ionic species show the largest differences between cave and epigeal old snow patch data. The chemical profiles fol-

low similar trends in the two cores (Fig. 3) but, despite having been cored in two very near locations (less than one metre apart from each other) the 1607-1 core has a higher ionic content. The correlation coefficient matrixes for both cores are similar and Tab. 2 shows the correlation coefficient matrix for the 1607-1 core.

	Na^+	NH_4^+	K^+	Mg^{2+}	Ca^{2+}	Cl^-	NO_3^-	SO_4^{2-}
Na^+	-	0,99	0,99	0,84	0,15	1,00	0,81	0,99
NH_4^+	0,99	-	0,99	0,84	0,15	0,99	0,82	0,99
K^+	0,99	0,99	-	0,86	0,19	0,99	0,80	0,99
Mg^{2+}	0,84	0,84	0,86	-	0,64	0,86	0,77	0,88
Ca^{2+}	0,15	0,15	0,19	0,64	-	0,18	0,30	0,22
Cl^-	1,00	0,99	0,99	0,86	0,18	-	0,81	1,00
NO_3^-	0,81	0,82	0,80	0,77	0,30	0,81	-	0,85
SO_4^{2-}	0,99	0,99	0,99	0,88	0,22	1,00	0,85	-

Table 2 - Correlation coefficients matrix for the 1607-1 core data.

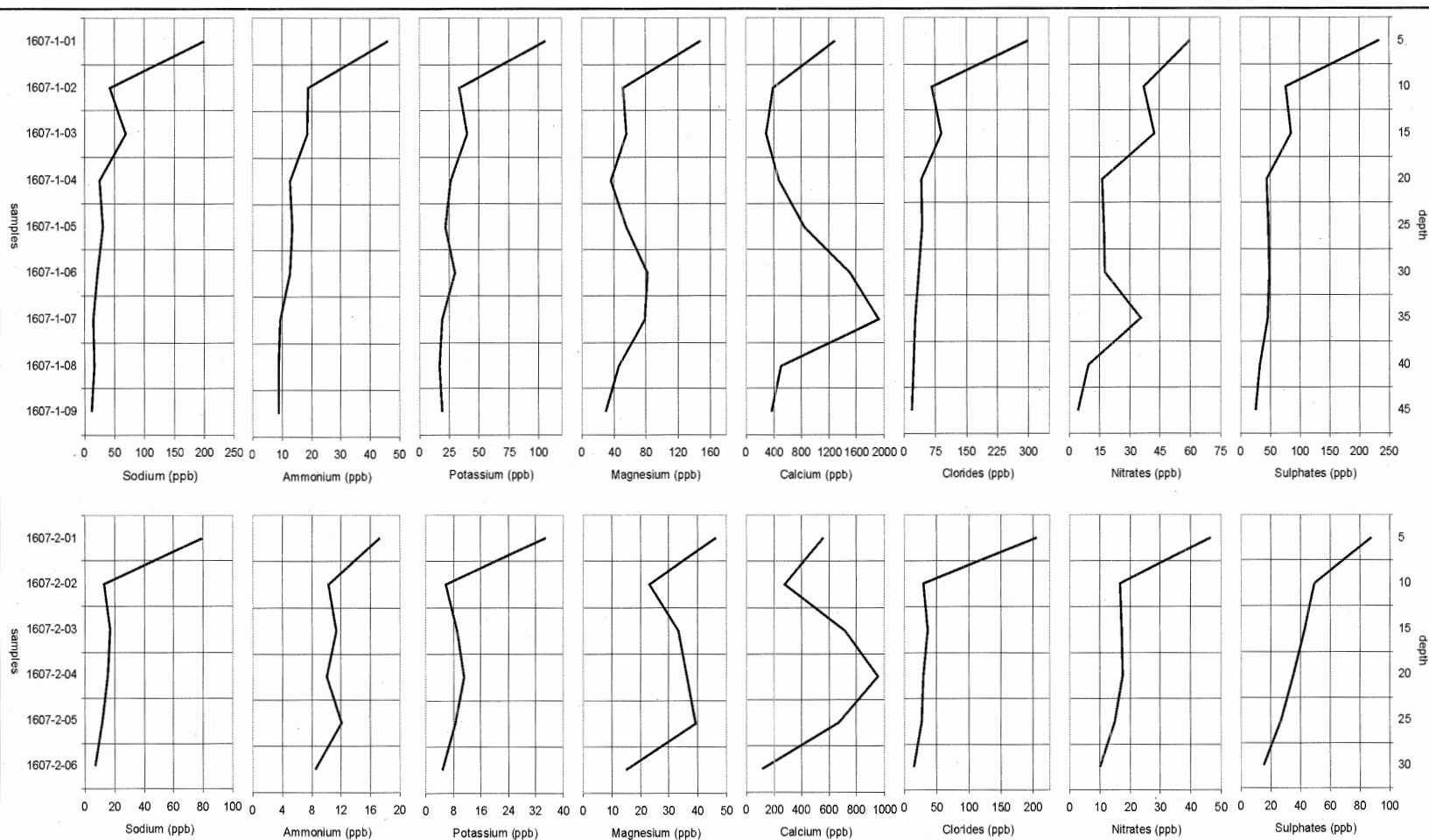


Figure 3 – Major ions content profiles along the two snow cores (5 cm high continuous samples). The strong enrichment of the topmost sample can be clearly observed in every plot. Very strong peaks in the contents of Ca^{2+} and Mg^{2+} , typical of the carbonatic environment, can be observed at a certain depth in both the cores, while the other ions consistently feature a fairly constant content, without showing any enrichment at that same depth (see the text for a discussion of this patterns). Concentrations in ppb, depths in cm.

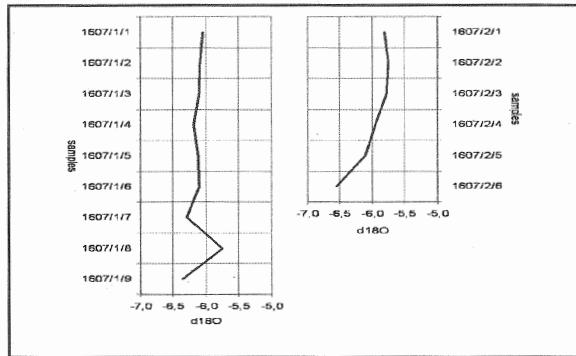


Figure 4 - $\delta^{18}\text{O}$ profiles expressed in ‰ units for the 1650-1 (to the right) and the 1650-2 (to the left) cores.

As can be seen from Tab. 2, while in general the correlation coefficients are quite high, the correlation coefficients of Ca^{2+} is very low with any other ionic species except Mg^{2+} .

$\delta^{18}\text{O}$ values are remarkably constant along the core length (fig. 4), with average values of -6.0 and -6.1 ‰ in the two cores. The chemical and oxygen stable isotopes plots with depth show no correlation, being the constant $\delta^{18}\text{O}$ values does not reflecting neither the generalized ionic enrichment at the top of the core, nor the deeper Ca^{2+} peak described above.

Discussion and conclusion

The main focus of our discussion will deal with the different nature of the two levels of comparatively higher ionic content which have been found in the two snow cores from the LO LC 1607 ice cave. Further discussion may deal with the lower content in most ionic species (notably in the industry-related species such as SO_4^{2-}) with respect to the Colle del Lys core, despite the fact that the latter is from a site located at much higher an altitude, but this falls beyond the main purpose of this paper, which is to investigate the feasibility of detecting stratigraphic discontinuities in the snow deposit. The fundamental difference between the two enriched levels, which are found one at the very top of the core and the other at the depths of 35 and 20 cm in the 1607-1 and 1607-2 cores respectively, is the enrichment in all ionic species opposed to the enrichment in Ca^{2+} (and to a lesser extent, of Mg^{2+}) only. The common feature of both levels is the complete absence of any corresponding signal in the oxygen stable isotopes ratio data. In order to interpret the evidences found, it is necessary to take into account the setting of the investigated snow deposit, and its consequences on the accumulation, possible contamination and ablation of the deposit. The coring location is a few metres inside the cave and is not reachable neither by free falling snow nor by avalanching snow because of the peculiar internal topography of the selected cave. Accumulation is thus represented by windblown snow only, the strong winds being also responsible for the presence in the cave of leaves from the broadleaf forest a few hundred metres of altitude lower. This accumulation process can also be expected to mix to some extent the snow before it enters the cave, thus smoothing the chemical and isotopical differences of the various snowfalls. Dusts are also likely to be blown into the cave by the strong winds. The deep Ca^{2+} and Mg^{2+} enriched levels are clearly related to contributions from the carbonatic environment, either under the form of aerosols due to water dripping and enriched in these ionic species typical of the carbonatic environment or to the presence of light wind-blown layers of carbonatic dust of local origin or finally to other means of contamination of the snow deposit by rock derived content. It is also likely that this process is acting slowly in nature, so that the Ca^{2+} peak will only develop during a temporary accumulation stop. The different depths at which this level is found in the two cores is an effect of the different

thickness of the snow deposit in the two coring sites and it is interesting to observe that, when measured with reference to the bottom of the core, they it is found at 10-15 cm in both of the cores. This last note actually supports the described genetic model of the deep enriched layer, since it is more likely that a roughly regular surface was produced by windblown snow accumulation instead than by ablation. In fact, the ablation surface at the time of coring was quite undulated and irregular.

As for the enriched surface level, we must exclude any process leading both to isotopic fractionation or allowing for the preferential accumulation of certain ions at the top of the deposit. Warm season ablation in the cave can be considered as dominated by melting, being the humid, cold and solar radiation shielded cave environment not favourable to significant evaporation and sublimation processes. During the ablation season, as was the case at the time of coring, the snow deposit is melting and the surface of the snow gets enriched in ionic content without undergoing any significant isotopic fractionation; this may be accompanied by some amount of percolation through the first millimetres and centimetres of snow by the slightly enriched meltwaters. During the frequent cloudy weather some small and isotopically undetectable amount of condensation on the snow surface may also take place from the humid air entering the cave, but the dominant phenomenon seems to be acting concentrating in the top surface the ionic content already present in the melting snow, since the ratio between different ions remains roughly constant.

Unfortunately the short length of the two cores prevented from fully investigating the occurrence and characteristics of a series of many high concentration layers, but it is obvious that a new accumulation event would have buried the surface level here described and a new surface level would have started getting enriched during the following ablation phase.

These observations makes for the main conclusions of this work: it seems possible to detect from chemical and isotopical profiles the occurrence of missing gaps (marked by peaks in the content of every ion and constant $\delta^{18}\text{O}$ values) or even of stopped accumulation (marked by Ca^{2+} and Mg^{2+} peaks only and constant $\delta^{18}\text{O}$ values). Further work on this and other similar cave deposits is needed in order to confirm the reliability and convenience of this method and to refine the suggested models for the development of the enriched levels.

Acknowledgments

We wish to thank Marco Filipazzi for the assistance with operations in the field and in the cold lab.

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The speleologist's psychology and fears

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Abstract

Key words: Fear of the unknown, confronting panic, cave phobia, inner self.

I have a fear of falling! What about you?

I was always afraid of falling! I understood then that the fall will not kill you! The fall is a journey downwards... What kills you is... the sudden stop at the END! The evolution of the human species depends on the type of information that they receive from the environment. All creatures need to feel secure and this applies mainly to the human creatures. Without a sense of security, our nerves would be shredded. On the other hand, when our lives become easy and without problems, we tend to become inactive and relaxed. Maybe we would even commit suicide, if we cross the border to the unreasonable. Many people want to do something but do not know how. So, they start searching the mysteries. The feelings produced by mysteries are fear, anxiety and surprise. However, it is surprising how little we know about fear itself. Basically, it is primitive animal feeling that exists in order to protect the integrity or security of the person. It is a defense mechanism or a mechanism for maintaining the safety limits.

However, the message we try to send out is which way can we convert the unknown and unfriendly environment into familiar through direct contact with it. First of all, it should be noted that very often nowadays the term "phobia" is used in a wrong way. Opposed to "fear", a "phobia" has no direct and real object. Therefore, the "threats" we receive are imaginary and originate in our minds. The fear of heights as well as claustrophobia can be overcome.

Having these phobias, before each descend the descender must convince himself on the reason of his descend inside the cave, since very often he is not sure of what he is about to do. The answer could be easy: simple curiosity! The secret of success in life is to dare take risks. We need to defy fear and go on in life, even if we are terrified. In this way, we will eventually conquer our fear. We must confront fear and win a very powerful and merciless enemy: our negative feelings.

We confront our other self, our inner self. The need for a personal dialogue with ourselves is created. The other self that we obstinately kept in dark, breaks free and comes searching for us. And maybe because most of the times that other self is the true self while we are the false, the victory belongs to him and in a way to us as well, since we are the other half.

Panic does not allow the mind to think, to combine, to devise and to invent. It is a matter of faith. Panic brings up on the surface all our hidden fears, makes us feel that suddenly we are the center of the world and that even worse things will come in a few moments. The modern cave

explorer may never meet the various mythology creatures, but he is sure to confront them all at once, inside his own self. If he manages to master this other self, then he will have achieved the much desired self-knowledge.

The fear of death is the biggest and most important fear of people. Due to the fact that we do not know exactly what death is, what awaits us after death, in essence the fear of death is nothing more than the fear of the unknown.

And what is exactly that renowned self-knowledge? The person turns to himself, time stops and you realize that the world is different worlds inside other worlds! When you detect the evil standing in front of you, in essence you detect the evil inside you. When you detect the good in anything, it's because you are good inside.

George Katsiavos

Curriculum Vitae

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1987-1989 Mechanical engineer studies, working as maintenance supervisor.

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1996 member of SPELEO club.

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The formation "scientific team-member" of the French Federation of Speleology

S. Jaillot, D. Cailhol, M. Meyssonier

*Commission scientifique Lyon - France*Abstract :**The formation "scientific team-member" of the French Federation of Speleology**

The French Federation of Speleology set up, since 1998, a new formula of scientific training course. The training course lasts 5 days and constitutes a module of the formation of the monitors of speleology. The formation is open to all autonomous speleologists and the trainees carry them out even observations in hydrology, geomorphology, biospeology or archaeology. At the end of the formation, a report and articles are published.

Key-words : Scientific formation, French Federation of Speleology

Résumé :

La Fédération Française de Spéléologie a mis en place, depuis 1998, une nouvelle formule de stage scientifique. Le stage dure 5 jours et constitue un module de la formation des moniteurs de spéléologie. Il reste cependant ouvert à tous spéléologues autonomes. Durant le stage, les stagiaires réalisent eux même des observations dans le domaine de l'hydrologie, de la géomorphologie, de la biospéologie ou de l'archéologie. A l'issue du stage, un rapport et des articles sont publiés.

Mots clés : Stage scientifique, formation, Fédération Française de Spéléologie

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L'enseignement scientifique à la Fédération Française de Spéléologie

Il a toujours été présent. Depuis la construction des premiers stages de spéléologie et en particulier de formation de cadres, ceci, avant même l'existence de la Fédération Française de Spéléologie, le souci d'un contenu scientifique accompagnant la technique a été présent. Parmi les artisans de cette époque citons Pierre Chevalier ou Philippe Renault. Plus tard dans les années 70, Font d'Urle (Sud Vercors) sera le théâtre d'une série de stages techniques et scientifiques marquants. Vers la fin des années 80, autour de Philippe Valet et Pierre Mouriaux, une série de stages scientifiques se met en place avec une implication forte des commissions enseignement et scientifique de la Fédération Française de Spéléologie. Ces formations ciblées pour les cadres de l'Ecole Française de Spéléologie sont d'une très bonne qualité mais ne font pas toujours le plein de stagiaires.

Dans les années 90, Jacques Bauer organise autour de la Pierre Saint Martin une série de stages orientés sur la connaissance de ce magnifique massif. Le succès est grand.

Enfin à partir de 1998, avec l'aide de Remy Limagne puis celle de Joël Possich, nous mettons dans le cadre de la réforme des stages de formation de l'Ecole Française de Spéléologie, une nouvelle grille pour les stages scientifiques (fig. 1).

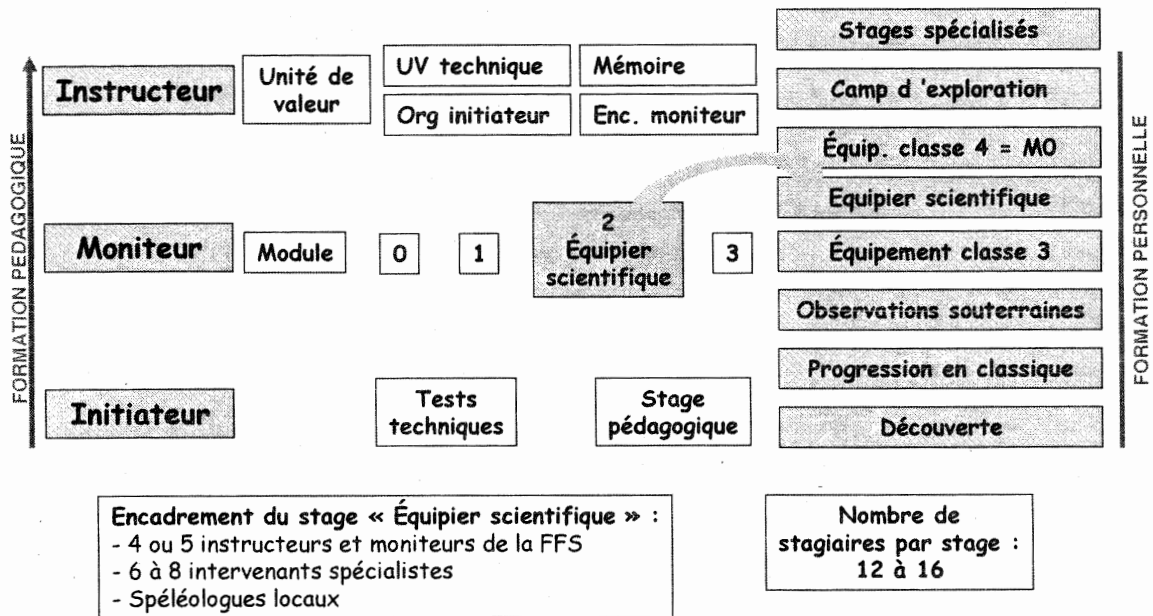


Figure 1 : Organigramme des stages de l'Ecole Française de Spéléologie et place des formations scientifiques.

Le stage « Équipier scientifique »

D'une durée de cinq jours, le stage national « équipier scientifique » de la commission scientifique est aussi le module 2 du cursus moniteur. Quand en 1998, l'idée a germé de refondre la formation des moniteurs de spéléologie, il devenait aussi nécessaire de relancer l'activité enseignement au sein de la commission scientifique. De 1998 à 2004, sept stages ont eu lieu autour de cette formule : la grotte du Château de la Roche (Doubs), la grotte de Foissac (Aveyron), le système de Foussoubie (Ardèche), la Caborne de Menouille (Jura), le réseau de Pont de Ratz (Hérault), la Pierre Saint Martin (Pyrénées-Atlantiques) et la Cocalière (Ardèche).

En 1998 a lieu à la grotte du Château de la Roche, dans le Doubs, le premier stage « équipier scientifique ». Ce fut un stage très sympathique où tout le monde a pu travailler sur cette cavité passionnante (réalisation d'un traçage et d'observations géomorphologiques). Cependant l'hétérogénéité du niveau des stagiaires ne facilita pas le déroulement du stage (un stagiaire quasi débutant en spéléo, un autre déjà instructeur...). Il devenait nécessaire de définir un référentiel précis et de fixer un niveau d'entrée au stage. La réforme de la formation moniteur allait le permettre.

Dès lors, le stage se structure autour d'une durée et d'un canevas. Il répond à un certain esprit, celui de former des spéléologues déjà autonomes à des techniques de relevés et d'observations

en grotte. Il devient nécessaire que les stagiaires arrivent avec un certain niveau minimum de pratique de spéléologie. Ceux qui sont déjà initiateur ont une pratique de spéléologie satisfaisante. Il est demandé aux autres stagiaires d'être totalement autonomes en progression souterraine avec un sac pour une durée de 6 à 8 heures. Ils doivent, en outre, connaître les techniques de topographie souterraine (levé et report avec la méthode graphique au moins). Avec un groupe de stagiaires plus homogène en niveau, mais qui reste heureusement divers en origine, il devient plus riche d'attaquer directement les techniques d'observations face à un public de toute façon à l'aise sous terre.

Car l'objectif n'est pas de faire en cinq jours des scientifiques du karst, mais bien de former des spéléologues aux techniques scientifiques du karst. On entre en science non pas par des cours et des exposés, mais directement en manipulant sur (et sous) le terrain des instruments, des appareils qui sont ceux de la science. Ce n'est qu'après, pris par le goût de l'acquisition des données (et de la restitution) que les stagiaires se plongeront dans les bouquins, rejoindront les colloques et autres rencontres et finalement animeront la vie scientifique de leur région. L'esprit du stage, ce n'est donc pas : « venez m'écouter, je vais vous parler de mon karst » (même si ce type d'approche est dans le stage quand même), c'est plutôt de dire : « faites le vous même, ce n'est pas si difficile, vous y prendrez goût ».

L'organisation du stage « Equipier scientifique »

La cavité étudiée, ou portion de cavité, est choisie en fonction d'un objectif avant tout pédagogique : richesse et diversité des problématiques, potentiels attractifs du site, difficultés techniques limitées et surtout temps d'accès au site d'observation réduit au minimum. L'équipe d'animation est pensée autour de deux pôles, celui des encadrants et celui des intervenants.

Les encadrants sont des instructeurs (nécessaires pour valider le module 2 du cursus moniteur), des moniteurs en cycle instructeur ou non et enfin un ou deux spéléos « du coin » qui connaissent parfaitement le massif, assurent le relais avec les spéléologues locaux. Les intervenants sont des spécialistes régionaux en géologie, géomorphologie ou hydrologie et des spécialistes de leur discipline. Ils ne participent pas à l'organisation du stage mais interviennent ponctuellement avec leur spécialité. La durée de leur intervention varie d'un court exposé en salle à plusieurs jours de présence sur le terrain. Ils font véritablement la richesse du stage. Tantôt universitaires, tantôt personnels des administrations de l'état (service archéologie de la Direction Régionale des Affaires Culturelles par exemple), tantôt spécialistes reconnus, ils sont géologues, géomorphologues, hydrogéologues, archéologues, biospéléologues, historiens etc...



Figure 2 : Jacques Bauer explique la géologie de la Pierre Saint Martin. Stage juillet 2003.

Quel que soit le lieu, quelle que soit la cavité, le déroulement du stage est calqué sur un canevas qui sans être rigide structure les cinq journées du stage en deux périodes respectivement de deux et trois jours (fig. 3).

Période	Jour	Activités
1	Lundi	Accueil - Contexte géographique et géologique régional Contexte du réseau souterrain - Définition des problématiques Travail en autonomie sur atelier souterrain (Lever et mise au propre)
	Mardi	
	Mercredi	
2	Jeudi	Travail en autonomie sur atelier souterrain (Lever et mise au propre) Dernière mise au propre et soutenance des travaux Rangement
	Vendredi	
	Samedi matin	

Figure 3 : Organisation du stage sur un canevas de cinq jours.

Le lundi commence par une prise de contact avec l'ensemble du groupe. La journée est ensuite consacrée à la visite de la région. Sur la journée, il doit être possible de « faire le tour du massif », c'est à dire d'en percevoir sa dimension générale, de comprendre et voir les zones d'alimentation, le ou les exutoires. Un phénomène géologique particulier peut être reconnu, une grotte touristique visitée, une petite cavité aux remplissages intéressants est parcourue.

Le jour suivant (mardi) est consacré à la cavité proprement dite, que l'on parcourt si possible sur une large portion en prenant le temps de se poser et de discuter fréquemment. C'est à ce moment là que l'équipe (stagiaires et encadrement) se retrouve face aux sites qui seront les enjeux des études de la suite du stage. On se pose des questions, on réalise quelques premières observations et on oriente les thèmes des études à faire. Le soir, le groupe est divisé en équipe généralement de trois stagiaires. Chaque équipe prend en charge un thème. L'une va par exemple relever les concrétions érodées dans cette portion de galeries et en faire un report cartographique pour déterminer une surface de pointe de crue. Une autre va réaliser une petite opération de traçage pour apprécier la variabilité des vitesses de déplacement d'un nuage coloré en fonction de la morphologie des conduits. Une troisième va relever des anciennes traces d'exploitation de minerai pour positionner correctement un balisage de protection. Une dernière va conduire un préinventaire des espèces souterraines pour apprécier leur évolution dans l'espace de la cavité.



Figure 4 : Lever topographique dans la salle Chevalier. Stage juillet 2003.

Ces différents travaux, les stagiaires vont les mener en autonomie quasi-complète au cours des journées du mercredi et du jeudi. C'est à dire que sur le terrain, accompagnés d'une ou deux personnes ressources, ils vont conduire eux mêmes leurs expériences de terrain, noter seuls le fruit de leurs observations, gérer intégralement leur équipe, le matériel nécessaire etc... De retour en salle, ils vont mettre au propre ces données, compléter éventuellement les observations (analyse du traçage au spectrocromimètre, identification des espèces récoltées...). Jusqu'au vendredi midi, ils devront produire un texte et des figures. Ces dernières doivent refléter au mieux le fruit de leurs observations (topos, coupes, graphes, schéma...). Le texte doit comporter au minimum : le nom des participants, la problématique, les outils employés, les observations réalisées et éventuellement une interprétation de ces observations. A l'issue du stage, les équipes produisent généralement 3 à 6 figures et un texte de 2 à 8 pages. L'aspect « interprétations des résultats » n'est pas particulièrement poussé dans le stage, non que cela ne soit pas intéressant ou que les stagiaires n'en soient pas capables, mais pour bien montrer le caractère fondamental des observations brutes correctement mises au propre et bien présentées.

Le vendredi après midi enfin est le moment des échanges. Chaque équipe présente (avec des transparents ou grâce à un vidéoprojecteur) les observations qu'elle a menées et mises au propre au cours de ces deux jours et demi de fin de stage. C'est à ce moment que l'on prend la véritable mesure de la moisson de données que peut apporter une équipe même réduite sur un espace bien limité dans un temps très court.



Figure 5 : Identification à la loupe binoculaire des espèces récoltées dans le système de la Cocalière. Stage avril 2004.

Les résultats de cette formation

Ils sont à la fois nombreux et pourront apparaître disparates et peu aboutis. A chaque stage, un rapport est réalisé. Il comprend outre les informations générales sur le déroulement du stage, la totalité des observations menées par les différentes équipes sur chacun des thèmes. C'est le corps du rapport. Il est suivi de compléments bibliographiques, et d'un ensemble de photos illustrant la semaine passée ensemble. Au delà de cette production papier, tirée à une centaine d'exemplaire et diffusée le plus largement possible, des articles ont été réalisés dans les actes de la rencontre d'octobre (de 1998 à 2004 sans interruption). Cette valorisation du travail du stage était au départ réalisée par l'équipe d'encadrement. Mais de plus en plus, on voit les stagiaires prendre en charge eux-mêmes cette partie et présenter les résultats de leurs travaux. En outre, d'anciens stagiaires réalisent des observations dans leur région, d'autres participent à l'encadrement du stage « équipier scientifique », d'autres structurent la vie scientifique de leur Comité Spéléologique Régionaux ou de leur Comité Départementaux de Spéléologie. Tout ceci constitue un premier pas qui devrait à terme relancer les observations menées en grotte et motiver la publication spéléologique régionale ou nationale.

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Qattine Azar Cave in Lebanon: From Speleology to Socio Economic Development.

Le gouffre de Qattine Azar - Liban : De la spéléologie vers un développement socio-économique

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Discovered in summer 1996 and explored by members of Association Libanaise d'Etudes Spéléologiques (ALES), Qattine Azar is the second deepest sinkhole in Lebanon (-515m). Its total known development reaches 4365m and exploration is still on going.

At its bottom and through the "Galerie de la jonction" the sinkhole links to an underground river of 1800m length with a flow of 8000 cubic meters per day. The importance of such a river in a mountainous area where potable water is an urgent need, has pushed the Government of Lebanon to undertake a complete study of the network in order to tap the water, raise it to the surface and distribute it to 22 villages in the nearby area. A professional topographical survey effected by the French topographic speleologist Mr. Paul Coubon with the support of Lebanese speleologists allowed locating on the surface the Qattine Azar's terminal lake. A further electromagnetic positioning confirmed the accuracy location of the terminal lake position.

By late 2003 the first borehole of 285 meters depth pierce the ceiling of the terminal lake. ALES speleologists will report his exact point of emergence compared to the room dimensions, thus allowing further three boreholes to be drilled successfully by end of year 2004. Furthermore, in an attempt to find the origin of water, ALES *spéléonautes* dived the upper sump searching for the origin of the water. Due to narrow passages they were unable to cross it. Actually exploration is focused on a lateral gallery by use of artificial climbing.

Liban, pays petit par sa superficie (10450 km) mais le plus riche au Moyen-Orient avec la Turquie par la diversité de son monde souterrain, que les spéléologues libanais ont inventorié depuis plus de soixante ans. Plus de cinq cent cavités à ce jour ont été recensées dont 293 ont un développement où un dénivelé supérieur à 20 mètres.

Le Liban occupe la limite ouest de l'Orient arabe. Il est constitué par une côte bordée par la mer Méditerranée et par deux chaînes montagneuses dont le point culminant est à 3083m. Ces deux chaînes sont séparées par la riche plaine agricole de la Beqaa. Le relief karstique représente 65% de sa superficie. Avec une pluviométrie annuelle moyenne de 900mm et un enneigement hivernal de ses haut plateaux, de nombreuses sources jaillissent du flanc de ses montagnes et à travers d'impétueux torrents printaniers encaissés dans des gorges profondes, elles vont se jeter dans la Méditerranée.

En 1996 les spéléologues de l'ALES découvrent à 1415 mètres d'altitude un nouveau gouffre « Qattine Azar » où ils atteignent à -437 mètres une belle rivière souterraine qui se termine à -515m dans un vaste siphon en forme de lac de 34m x 18m (voir plan et coupe).

Une coloration à la fluorescéine permet de connaître la résurgence de l'eau qui émerge après 14 jours non loin de la mer, à +60m, dans la très belle grotte d'Antelias soit un parcours de 15 km à vol d'oiseau et un dénivelé d'environ 900 mètres à partir du siphon terminal.

La découverte d'une richesse hydraulique aussi importante pousse le Gouvernement Libanais à entreprendre une étude exhaustive du réseau souterrain en vue d'une exploitation de ces eaux pour permettre l'alimentation en eau de 22 villages de la région du Metn Nord. En effet ces régions intensivement habitées en période estivale souffrent précisément d'un rationnement d'eau important durant les mois d'été. L'eau à venir facilitera ainsi un développement socio-économique puisque ce projet de captage sera suivi par la construction d'un lac collinaire qui collectera les eaux de pluies pour des besoins d'irrigation. Ainsi, le cumul des eaux de ces deux projets sera suffisant pour avoir un bilan hydraulique positif couvrant les besoins jusqu'à l'an 2035. Ceci favorisera le développement tant de l'activité estivale touristique que celle de l'agriculture.

Pour les spéléologues, la tâche requise est ardue. En premier lieu, il s'agit de délimiter exactement en surface l'emplacement du lac terminal pour y effectuer des forages permettant ainsi de pomper l'eau sur une hauteur de 280 mètres pour la distribuer à travers canalisations et réservoirs à toute la région avoisinante.

Pour y parvenir, les spéléologues vont collaborer activement avec le B.T.D., (Bureau Technique pour le Développement), bureau d'ingénieur conseil spécialisé en hydraulique, dans le but d'établir un relevé topographique précis du réseau depuis l'entrée du gouffre jusqu'au lac terminal et cela à travers une succession de puits dont l'un d'entre eux est le plus profond au Moyen-Orient (180 mètres), pour atteindre la base du gouffre. A partir de ce point, il faut parcourir 450 mètres de galeries sinueuses pour rejoindre le cours de la rivière, puis suivre l'eau sur 1800 mètres en vue d'arriver au lac terminal. Deux campagnes topographiques seront lancées durant les étés de 1997 et 1998 sous la direction du topographe français Paul Courbon. Un camp de base est installé à la base des puits à -412 m car la topographie de la section aval jusqu'au lac terminal prendra trois jours de suite. Après la projection en surface de la rivière souterraine, l'emplacement du lac souterrain se trouve délimité sur une des gorges du Nahr Beyrouth. Pour y parvenir, il faut percer une route de 1200 mètres de long à partir du village de Aintoura.

Des mesures de débit de la rivière souterraine montrent un débit d'étiage de 8000 m³/jour dont 6000 m³/j sont exploitables et qui peuvent être augmenté jusqu'à 9000 m³/jour durant la période hivernale et printanière.

De plus un positionnement de l'emplacement du lac terminal par la méthode électromagnétique sous la direction de Joan Erra est effectué en 1999. Elle viendra confirmer les résultats de la topographie et

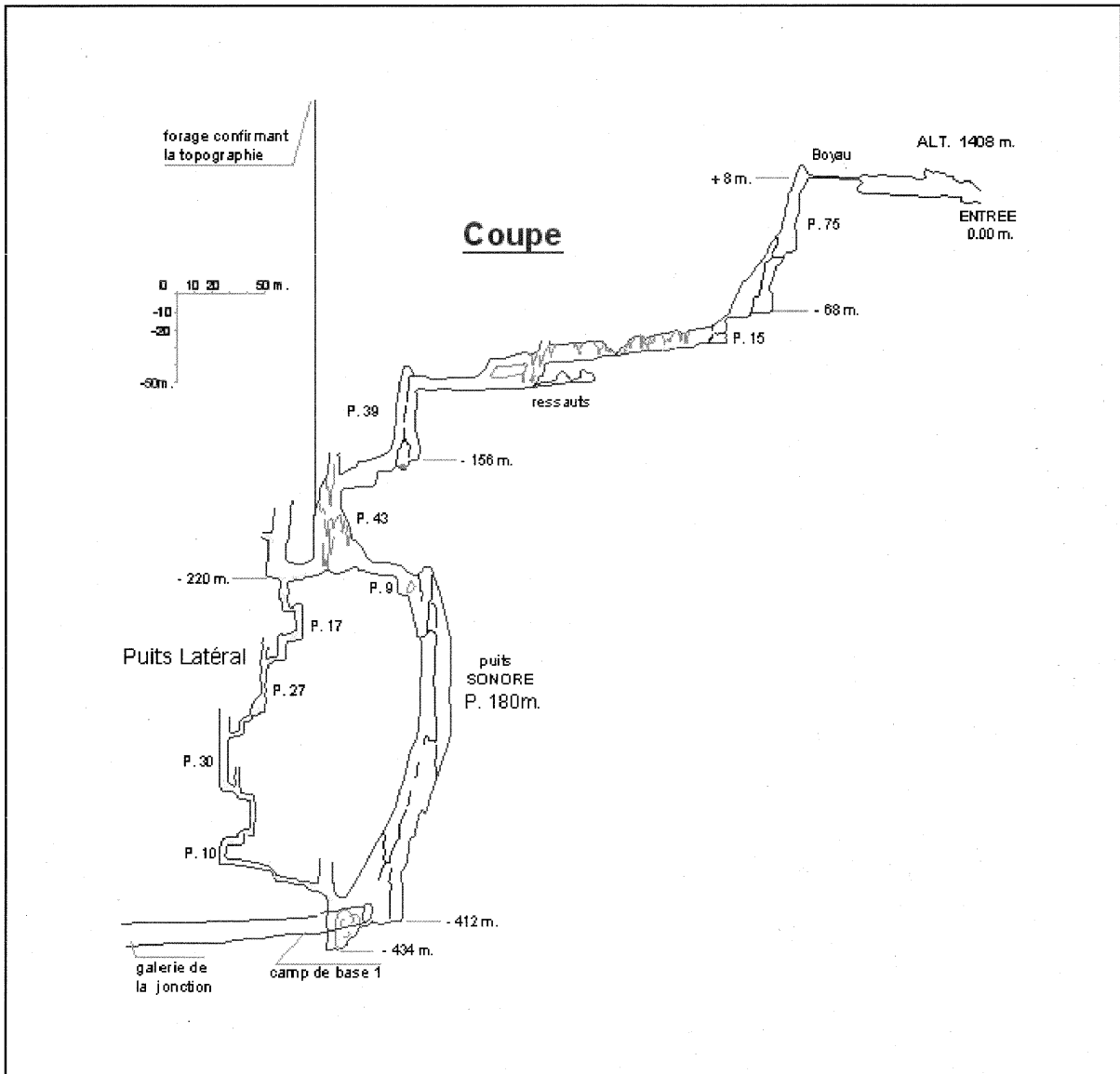
ainsi la marge d'erreur n'est plus que de l'ordre de 2 mètres ce qui est pleinement satisfaisant car une erreur d'emplacement du lac terminal entraînant des coûts de forages élevés aurait pu entraîner l'arrêt des travaux et l'annulation de la suite du projet (voir article de Mr. Paul Courbon : Modes de positionnement topographique et électromagnétique d'un siphon. Kastologia no. 40 P19-26 du 2/2002).

La mission des spéléologues de l'ALES va reprendre à partir de l'automne 2003 au moment où le premier forage débute. Il s'agit en effet de situer exactement l'emplacement de l'émergence du forage dans le lac terminal par rapport aux parois en vue de délimiter l'endroit du forage suivant. Les spéléologues de l'ALES sont au rendez-vous et les informations retransmises par câble téléphonique à la surface permettent de fixer le point exact du second forage. Il est prévu d'implanter trois forages sur une distance n'excédant pas 15 mètres de long et 7 mètres de large pour qu'ils atteignent la partie profonde du lac. Plus de 20 missions vont se succéder durant l'année 2004 entraînant de longs séjours souterrains excédant à chaque fois les 30 heures avec des arrêts au le camp de base. En

définitif 3 forages d'exploitation de 44 cm de diamètre ont atteint le lac terminal. Ils ont été tubés et sont prêts à recevoir 3 pompes submersibles qui refouleront l'eau vers la surface 285 mètres plus haut.

De par sa conception, c'est un projet unique au Moyen-Orient et peu répandu mondialement car il est très rare qu'une étude spéléologique détaillée entraîne un captage réussi à une aussi grande profondeur. Le Gouvernement libanais décerne aux spéléologues de l'ALES la médaille en Argent du Mérite Libanais avec Palmes le 25 Novembre 2004 en reconnaissance des services rendus dans la réussite de ce projet tant dans sa partie de découverte que dans l'exécution des travaux demandés.

Les explorations du réseau ne sont pas encore terminées. Les spéléonautes de l'ALES ont effectués des plongées dans le siphon amont d'où émerge la rivière souterraine sans réussir à le franchir et des galeries parallèles sont actuellement sous exploration. Le développement total du réseau atteint 4365 m faisant de Qattine Azar le gouffre le plus développé du Liban.



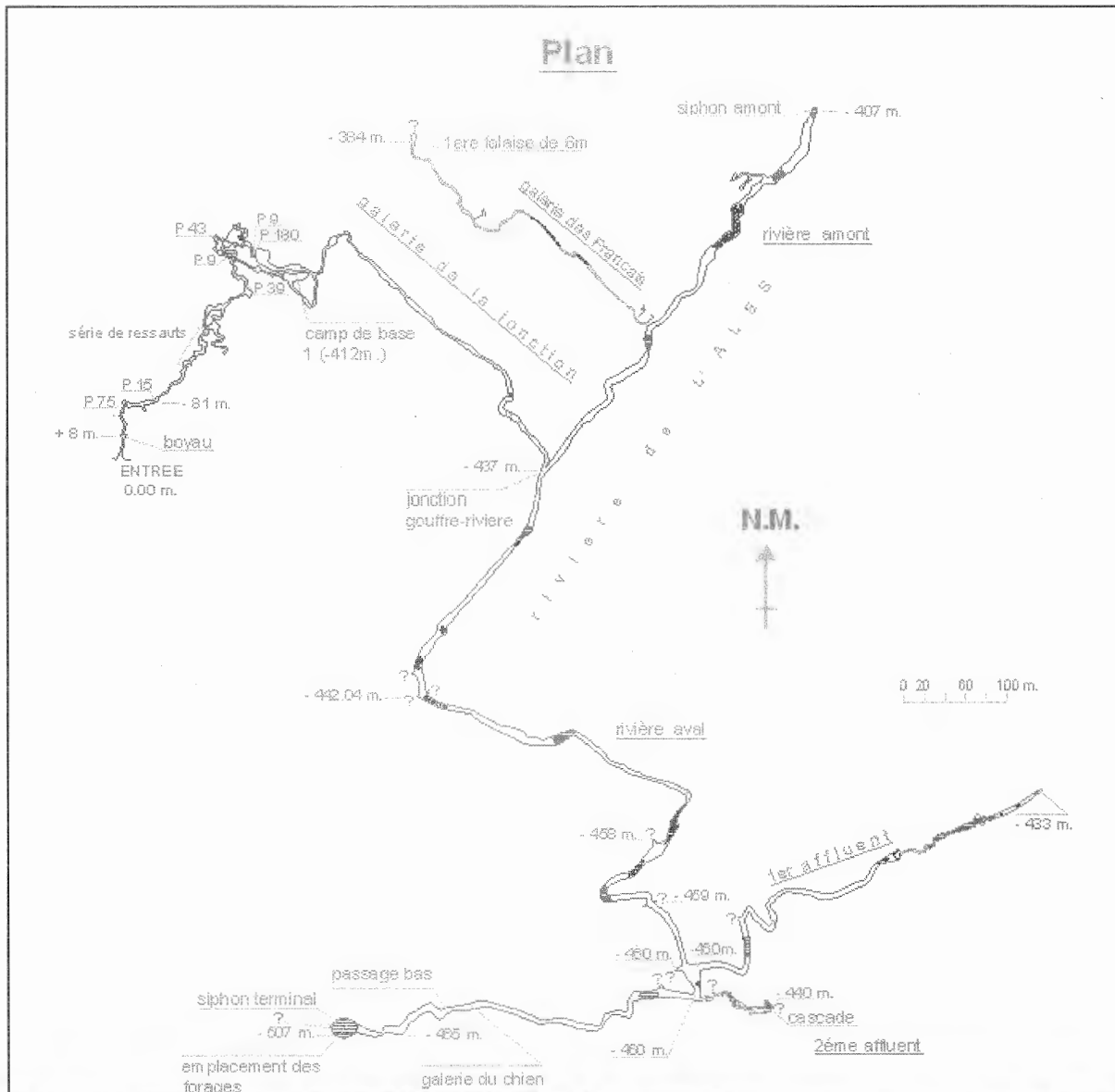


Photo 1: La rivière souterraine se déversant dans le lac terminal.



Photo 2: Premier forage réussi. Le trépan de la foreuse perce le plafond près de la paroi droite du lac terminal.

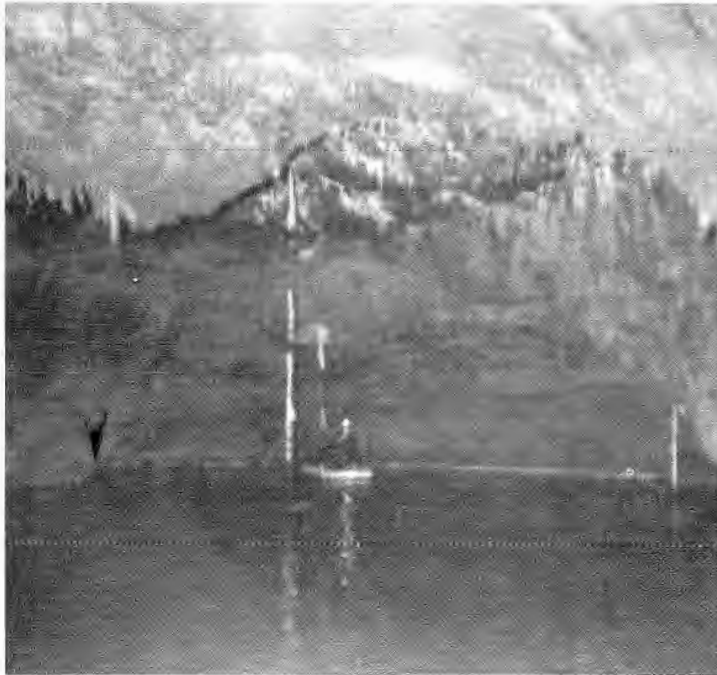


Photo 3: Dans la partie profonde du lac, trois câbles d'acier descendus de la surface et marqués par des turbans rouges indiquent l'emplacement des forages.



Photo 4: Puits de 43m la remontée de deux spéléologues sur les cordes.

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The role of chemical weathering in the erosional speleogenesis of some caves in igneous rocks

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Abstract

Long mislabeled as "talus" caves, several of the most notable caves in crystalline rocks in the western United States have little or no association with talus. The thirteen caves of the Lost Creek System in Colorado, Hurricane Cave on Pikes Peak, Colorado, and the Greenhorn and Millerton Lake Caves in California have formed through a three- to four-step process in which talus building processes play only a minor, or no, role. The Colorado caves formed in the potassium feldspar and biotite-rich Proterozoic Pikes Peak granite. The California caves formed in a Cretaceous quartz monzonite (tonalite). All these sites lie within major mountain ranges that have been subject to intense tectonism, which caused rectilinear fracturing. These joints provided pathways for groundwater flow through the otherwise mostly impermeable rocks. The groundwater concentrated in situ chemical weathering (i.e., hydration and hydrolysis) along the joints, converting biotite to hydrobiotite and vermiculite and feldspars to clays. The phyllosilicate product crystals take up notably larger volume than their parent minerals and, hence, further fractured the crystalline rock along the pathways. Rocks lining the tectonic fractures were converted to grus. Stream cutting formed narrow, steep-walled canyons or subterranean suffusion formed bedrock-enclosed conduits and mechanically removed the grus as the third common step in the process of

developing these caves. Although short segments of some of these caves were completely formed at this point, most of the passages experienced a fourth, roof-forming step. The roof of the Millerton Lake Caves mostly formed by the catastrophic collapse of immediately overlying rock that had been undermined by the enlargement of sub-horizontal joints in step three. The dominant roof-forming (step four) process in the Lost Creek System involved the settling and wedging of very well-rounded, overlying or nearby corestones that had formed in steps two and three. The expansion of talus accumulations helped roof over some cave passages, particularly above Hurricane Cave. However, the Lost Creek and Millerton Lake Cave Systems have no nearby cliff or true talus landforms that could have contributed roof material in their development. Erosional caves in other poorly soluble rocks probably formed through similar three- to four-step processes. Vadose, dendritic, conduit passages in an unusual ~750 m long cave in Jalisco, Mexico, are almost completely enclosed in a Quaternary ash fall breccia bedrock. Instead of chemical weathering focusing along a tectonic fracture, a paleosol between flow units provided a thin, impermeable layer focusing intermittent water flow along its surface. Chemical weathering alters the mafic minerals to clays, which are readily removed by suffusion. In this example, only steps two and three appear critical to the process.

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Decoupled and depth stratified circulation in a coastal carbonate aquifer: Yucatan Peninsula, Mexico

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The conventional model for saline groundwater circulation in coastal carbonate aquifers is that a shallow zone of saline outflow is entrained coastward by the discharge of the overlying fresh water lens, with a compensatory inflow of sea water at depth. However, this model is supported by only a limited number of field observations as in situ monitoring of groundwater circulation remains logistically challenging. Here we present an alternative model based on instrumental records (velocity, salinity, temperature) and dye tracing of groundwater circulation in extensive flooded cave systems on the Caribbean coast of the Yucatan Peninsula, Mexico. The conduits are the focus of this study as they account for >99% of the aquifer flux. The saline flow to ~5 m below the fresh-saline mixing zone is modulated by the semi-diurnal tides, while lower frequency alternating cycles of net inflow and outflow correspond to the annual periods of high and low Caribbean sea levels. The shallow saline groundwater temperatures are comparable to that of the Caribbean seawater at the coast but decline by 1.8°C at 9 km inland indicating that the saline inflow penetrates far into the aquifer. The semidiurnal tides impound the fresh water on top of the mixing zone during high tides, however all data indicate a persistent net discharge of fresh water regardless of mean sea level. The coastward freshwater discharge is decoupled from the revers-

ing shallow saline groundwater circulation. As a result, the mixing zone within the conduits is characterised by very steep density gradients and strongly sheared flows. In contrast to the reversing shallow saline circulation, velocity measurements of deeper saline water in three conduits to depths of 45 m below the mixing zone indicate continuous inland flow irrespective of mean Caribbean sea-level. Whilst this is consistent with the conventional circulation model, it may also indicate a unidirectional cross-platform circulation channelling water from the Caribbean Sea into the Gulf of Mexico, the drive for which may be a head difference across the platform. A limited number of deeper profiles reveal a second but smaller density interface a few metres below the mixing zone suggesting shear and decoupling between the shallow and deep saline flow regimes. The pathways for the cross-platform saline flows may in part be via a deeper tier of karstification formed during previous low sea levels. These results challenge the conventional circulation model specifically by providing direct observation of decoupling of fresh and saline groundwater flows across the mixing zone, although we recognise that further research is required to confirm the proposed deeper cross platform saline circulation. Our findings present new insight into speleogenetic processes in density stratified carbonate aquifers, as well as indicate the difficulty of predicting the fate of effluent pumped into the saline water

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Improving karst subsurface cartography using geophysics

Jeremy A. Tallent*, Josh Brewer, Patricia Kambesis, Leigh Ann Croft, Nicholas C. Crawford

*Center for Cave and Karst Studies, Applied Research and Technology Program of Distinction, Western Kentucky University, Bowling Green, Kentucky, USA***Abstract**

All cave survey data inherently have errors due to factors including, but not limited to: inaccurate cave survey data due to conditions inside the cave, inaccuracies associated with compass and tape measurement techniques, survey instrument calibration errors, and errors related to magnetic fields. In locales where urban planning and construction are conducted upon karst landscapes, it becomes important to know the exact location of caves, cave roof collapses, regolith voids, bedrock crevices and other potential sites for sinkhole collapses. Therefore, subsurface survey errors must be detected and corrected before the subsurface data can be correlated with the surface cartography. This paper will demonstrate how geophysical data including microgravity and electrical resistivity data, cave radio-location technology, geo-referenced geologic and topographic quads, and cave survey data can be correlated using GIS software to produce a highly accurate subsurface-to-surface cartographic representation of an area.

Introduction

A few decades ago, the ethics behind caving began to change, the number of cavers increased, virgin passage became scarce, and more people began to think about cave preservation, cultural resources, and the consequences of building upon karst landscapes. In these times cave cartography became an encouraged activity among caver groups, thus producing tangible data about the caves they explored. Now in the most

recent years, cave cartography has experienced a paradigm shift just as it did decades ago, due to GIS and other technological advances. Multiple forms of data including geophysical data can now be combined using GIS (Geographical Information Systems) technologies to produce levels of accuracy in representations of subsurface cartography that are greater than ever before. This is done by collecting various forms of geophysical data that are directly related (geo-referenced) to a cave map or other subsurface cartographic representation. This geophysical data along with the cave cartography and geologic and topographic data are combined into a GIS for this high level of accuracy. To further demonstrate this, the paper will examine two case studies conducted by the authors and other staff at the Center for Cave and Karst Studies (CCKS), Western Kentucky University, where these techniques were used.

Geophysics, geophysical equipment, and software utilized

Before the research is examined, some background information needs to be discussed. The following sections review topics that are inclusive to this research. These topics are reviewed in the following headings:

I. Geophysical Equipment and Data:

A. Microgravity - This geophysical technique is conducted using a microgravity meter, specifically in this case, a Scintrex Autograv CG-3M Automated Microgravity Meter. This gravity meter detects changes in subsurface density, measured in micro-Gals. It allows non-evasive detection of voids due to the low-

gravity signature they exhibit, relative to the surrounding area. A properly located void or cave will have the look of an inverted bell curve on the X-axis of the data, if a perpendicular traverse is placed directly over the entire cave passage.

B. Electrical Resistivity - Electrical resistivity is another non-invasive geophysical technique that can indicate a void or cave presence. The particular electrical resistivity meter used in this study is an AGI Sting and Swift R1. This method also uses perpendicular traverses, just as microgravity does. Subsurface features like air-filled voids, etc, will typically show up as an area of high resistivity, surrounded by areas of low resistivity

C. Cave Radio - Unlike the previously discussed geophysical techniques, Cave radiolocation techniques require access to the cave to perform. The cave radio used by the CCKS was created by Brian Pease, and uses very low frequency 1-3 kHz electromagnetic waves to operate. The principle behind cave radiolocation is simple. A cave radiolocation transmitter located within a cave is leveled (for proper broadcasting) and its position noted relative to the nearest survey station within the cave (Figure 1). The transmitter is activated, causing an emission of very low frequency waves in an arching manner out from the transmitter. These waves are dispersed in 360 degrees, but as shown in Figure 2, the only location on the surface where a null zone occurs (location where the waves do not reach) is directly above the transmitter. The term ground zero is used to describe the exact surface location above the transmission site. By using a receive-

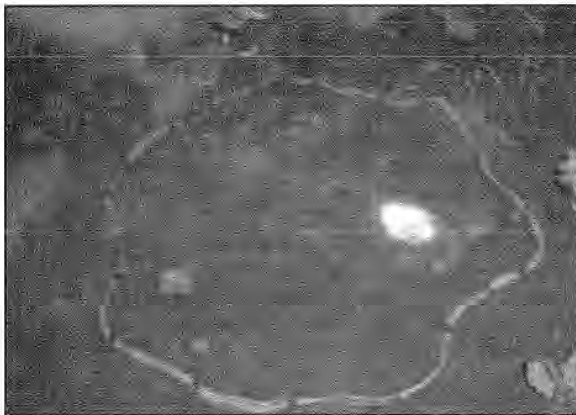


Figure 1: Cave Radio Transmitter.

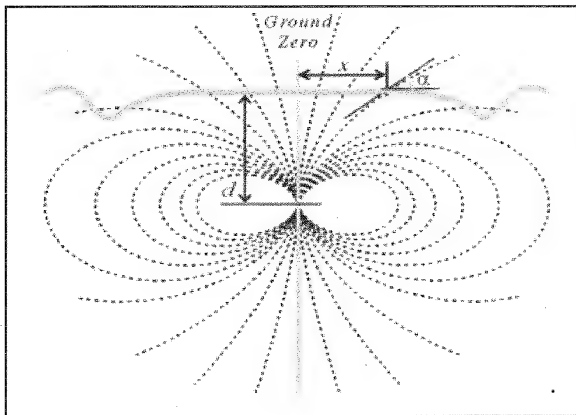


Figure 2: Electromagnetic waves emitted by the cave radio transmitter from within the cave. Gibson, (2002)

ing antenna, the null zone is determined through triangulation on the surface, thus creating a point on the surface that can be documented and have its GPS coordinates recorded. Given that the null zone on the surface is directly above the subsurface transmission point, this provides a surface to subsurface correlation point.

II. Software Used:

A. ESRI ArcGIS 9.0 - ArcGIS is computer software that allows the input of multiple forms of data into a geo-referenced database for analysis and comparison. There are other versions of GIS software available, but this version is most widely used. Data can be entered in as a point, line, or polygon. The data are entered into the system while maintaining its contextual data, and GPS coordinates.

B. Adobe Illustrator 10 and Cave Illustrator - Illustrator is a digital drawing/drafting program that is used to compose (electronically draw) cave maps. Cave Illustrator is a special plug-in for Adobe Illustrator created by Jim Olsen and is freely available for download online. Cave Illustrator works in tandem with Compass Cave plot and creates the ability to import a cave's lineplot and station data into Adobe Illustrator.

C. Compass Cave Plot, and CaveX - These programs are used to create a digital version of the lineplot created by the sketch artist. This digital lineplot is then used to compare with the data recorded in the cave and errors are looked for. The lineplot created can now be exported into multiple forms, including shapefiles. This new shapefile addition is available through CaveX (a lineplot viewer) also freely available via the internet.

Cave surveying and survey error

Cave cartography is the science of creating paper or digital representations of a subsurface void or cave. This is conducted via a set of processes. First, a lineplot of the cave is created. A lineplot is a two dimensional line that demonstrates the azimuthal change in a cave passage. This is called the plan view (bird's eye view). This lineplot is created by setting up a series of points that extend from within the cave, to its entrance. Each of these points are linked to the other points by recording the horizontal and vertical change of each point relative to the next and previous stations. These horizontal and vertical changes are measured using a compass, clinometer, and fiberglass tape measure (Figure 3). Each station has a direct



Figure 3. Cave surveying in Coldwater Cave (2005).

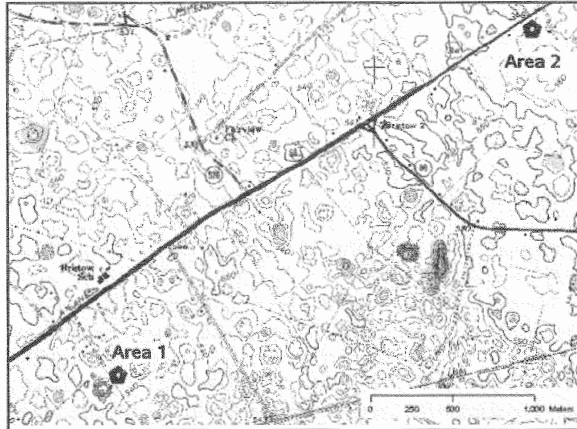


Figure 4: Map showing Case Study 1 and Case Study 2.

line of sight to the previous station. As has been discussed before, these plots, and measurements are never perfect due to human error and other factors. These errors can be detected and eliminated through the use of the techniques demonstrated in the following case studies.

Case Studies

Case study locale information: Both study locales are within close proximity of each other, and are related to the same industrial area, specifically the Kentucky Trimodal Transpark (Figure 4). Both case studies were also conducted by the CCKS. The following geologic and topographic information can be attributed to both case studies. Both caves are located in the Horse Cave Member of the Mississippian (Lower Carboniferous) St. Genevieve Limestone below an extremely fossiliferous silicified reef limestone bed called the Lost River Chert and directly above the Corydon Chert Member of the Mississippian St. Louis Limestone. The topography of the area can be described as a low-relief sinkhole plain, the Bristow Plain.

Case Study One

Selection of a monitoring well location for the Kentucky Trimodal Transpark.

A monitoring well is to be placed downstream of the Kentucky Trimodal Transpark to monitor water quality from this new industrial park. After reviewing the karst hydrology of the area, a cave (Grant-Palmore Cave) was found that is downstream of the Transpark. Given these facts, this cave was selected as one which could be used for a monitoring well location.

Description of Study area

A general description of Grant-Palmore Cave is as follows: The entrance to the cave is marked by a 200 meter wide collapse sinkhole, with the entrance to the cave at the bottom right (Figure 5). The passage continues to curve to the right around the perimeter of the sinkhole for about 150 meters. In this first portion, many layers of very large breakdown are present. The breakdown has a vertical extent of 15-20 meters at some points. At the bottom of the breakdown is a chert layer where a stream flows during most times. This stream is a tributary to the trunk cave stream that flows through the Graham Springs Groundwater Drainage Basin to discharge at Graham Springs. Continuing further in the cave, the passage moves beyond the boundaries of the massive sinkhole and



Figure 5: Lineplot of cave in Case Study One, note the perpendicular microgravity traverse (A-A').

the cave structure changes. In this structurally different portion of the cave, no breakdown is present and the floor has very large sinuous mud dunes. The fore-mentioned water flows out of discontinuous chert layers on the wall and flows downstream until it reaches either a deep pool at the termination of the cave or flows downward through small openings in the lower, continuous chert layer that serves as a basement rock for the cave. The water level of the deep hole fluctuates but it is typically never lower than 15 meters in water depth. Excellent examples of chert are numerous throughout the lower portions of the cave. Dye traces by the CCKS have revealed that the deep pool is connected to the large trunk cave stream that flows to Graham Springs. The cave has a current length of 320 meters.

Method used in determining subsurface cartographic accuracy

A monitoring well is to be drilled into the deep pool for systematic water sample collection and testing. Therefore, an accurate correlation of the location of the pool on the subsurface map with that of a surface topographic map was necessary. This required a highly accurate subsurface map so that it can be used to drill into the pool chamber. This goal was achieved using the following processes:

1. Survey teams drafted a map of the cave. This was conducted in the fashion described in the previous paragraph about cave survey (+ - 2 degrees accuracy using Suunto instruments).
2. The cave map was then digitized (drawn digitally using the program Adobe Illustrator) and its survey data was entered into Compass, cave plotting software. Compass created a lineplot that corresponded exactly with the survey measurements taken in the cave. This Compass generated lineplot was then used as reference when comparing other data such as survey data or geophysics.
3. Cave survey data, the Compass generated lineplot data, and digital topographic quads were next geo-referenced into ArcGIS. Compass cave editor and CaveX viewer have the ability to export objects and lineplots as shapefiles, loadable into ESRI's ArcGIS 9.0.
4. Geophysics was used to test the accuracy of the cave map, in this case, a microgravity analysis. A microgravity traverse was performed on the surface. This was done by locating the area on the surface directly above the large chamber which contains the mud dunes. This area was located by referring to the GIS map. The GIS allows the comparison of the cave map in respect to the topography of the area, and provided the exact GPS coordinates of the subsurface features, in this case the mud dune chamber. A perpendicular traverse was setup to intersect the center of this chamber (Figure 5).
5. Microgravity analysis was performed. The microgravity readings indicate that the perpendicular traverse may have been terminated

while still above this large chamber. This data indicates that the survey may be in error. An error of 3.5-5 meters was anticipated.

6. Cave radio was used next. With these conflicting reports, cave radio broadcasts were conducted near the edge of the pool chamber and in the dune chamber. These subsurface broadcast points were documented in survey notes and their positions relative to other survey stations were noted. As described before, these subsurface broadcast points can be interpolated on the surface using a triangulating antenna. The cave radio, not only provided the latitude and longitude for the broadcast site, but also the depth. Three different broadcasts were conducted on different days and their locations marked on the surface.
7. Highly accurate GPS technology was used to record the exact GPS coordinates of the different broadcast points.
8. This lat-long data taken from the GPS was then entered into the GIS. This was done through the usage of the input X/Y data command in ArcGIS.
9. The data was analyzed in the GIS.

Results of case study one

The original cave map was slightly in error causing a 3 meter discrepancy. The cave radio broadcasts and the microgravity data both indicate this discrepancy. Later, resurvey was conducted and found one of the stations readings to be in error, possibly causing this discrepancy. The cave radio locations were used to make minor adjustments to the cave map so that it accurately indicates its true position relative to the ground surface.

Case study two

Protection of prehistoric and historic cultural resources and archaeological sites near a proposed building location at the Kentucky Trimodal Transpark.

A cave was discovered during the excavation for a part of the storm water runoff treatment system near the proposed location for the Kentucky Technological College building presently being constructed at the Transpark. The cave was surveyed by the CCKS to determine its extent and proximity to the proposed building location. Until the recent discovery of this cave, its existence had not been known, and it is thought that its entrance collapsed or was filled in around 100 years ago.

Description of Study Area

The cave was accessible (now resealed to preserve the Native American burial sites, and petroglyphs inside) via an artificial entrance that was created during the construction of a storm sewer for the job site. This entrance consisted of a five meter drop from the surface into the cave. The cave continues in both directions, approximately north and south, and has multiple leads, all of which terminate in breakdown. The research indicates that these breakdown termination points sometimes correspond with sinkholes on the surface. The cave is shallow, and typically is 0.5-2 meters in height, though in some areas standing is possible. In some areas the ceiling reaches 4 meters in height. The cave never plunges below 10-12 meters in depth because all passages are above a continuous chert layer located around 10-12 meters below the surface. This is the Corydon Member of the St. Louis Limestone. The cave has a total length of around three-fourths of a kilometer. The cave seems to be very inactive hydrologically. Even during rain events, very little water enters the cave. It appears that during the hydrologically active period of this cave, water drained to the center portion, which is the deepest, where it then descended toward the water table (over 30-40 meters below) though a small opening in the

chert layer. Unfortunately, this opening through the confining chert layer is much too small for human entry.

During the course of surveying the cave by the CCKS, multiple cultural artifacts and archaeological resources were found. These included, but were not limited to, multiple petroglyphs (Figure 6), cane charcoal fragments, wood charcoal fragments, cultural artifacts from circa 1890, candle writings, and two intentional human burial sites. The Kentucky State Archaeologist, and the director of Anthropology and Archaeology at the University of Kentucky were contacted by the client, the Intermodal Transportation Authority (ITA) and hired to conduct an investigation of these archaeological findings.

Preliminary findings show that humans entered the cave at two distinct times in the past: most recently, around the late 1800's when the wood charcoal and candle writings were produced and around 2000-3000 BCE when the cane charcoal, geometric petroglyphs, and the human burials were placed in the cave. At the time of the writing of this research, carbon dating results were not yet completed, and these ages of the archaeological sites are estimated by the preliminary results of the archaeological investigation.

Method used in determining subsurface cartographic accuracy

The techniques used for this study area do not vary much from those used in the previous example (Case Study One) except for a couple of exceptions. Electrical resistivity data was analyzed and inserted into the GIS instead of microgravity, and more cave radio points were collected. This is due to a few factors:

1. The cave length is greater in Study Area Two.
2. Study Area Two has multiple objects of interest that must be accurately located in relation to the rest of the cave survey, namely the archaeological sites.
3. This cave is not as deep as the cave in Study Area One.

These differences resulted in a greater reliance on cave radio data in this study than that in Study Area One. Cave radio points (surface to subsurface correlation points) were placed in areas where they would provide the best accuracy for both, archaeological and cultural artifact location data, and provide accurate data for the entire cave. In other words, by placing the cave radio in areas near the extremities of the cave as opposed to the center of the cave, one can better gauge the accuracy of the entire cave map because a greater percentage of the cave is in close proximity to a cave radiolocation transmission site.

Results of case study two

The cave discussed in this study is approximately three-fourths of a kilometer long, much longer than Grant-Palmore Cave, the cave previously discussed in Case Study One. Therefore multiple cave radiolocations (and other surface to subsurface correlation points, [i.e. entry site GPS data]) were used in testing the accuracy of the cave survey. Also, the proximity of the archaeological resources and sites was taken into account. Logically, the closer in proximity to a radio-location broadcast point, the greater the accuracy of the sketch for that area. The broadcast points were selected to provide adequate coverage of the extremities of the cave, while also still being in close proximity to the petroglyphs and burial sites. Initially, before corrective measurements were made, the survey had an error of 3-4 meters. After GIS techniques were used, this error was reduced by more than two hundred percent. These results were then transferred into a computer file format that the site engineers could utilize and import into CAD for better planning. This allowed for better protection of the cave archaeological sites and cultural artifacts.

Conclusion

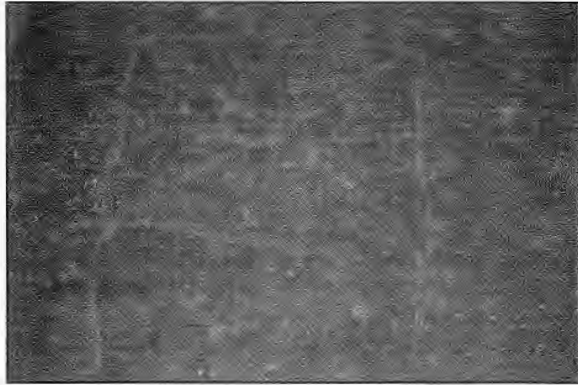


Figure 6: Petroglyphs from Case Study Two. Circa 2500 BCE

The techniques discussed in this paper increase the accuracy of subsurface cartography to levels that were not possible before. This level of accuracy is helping to improve and increase the usefulness of the GIS data as well. No longer are cave maps only the interest of the cave enthusiasts. Now, since GIS data is easily searchable, and transferable, multiple disciplines of scientific research are able to use cave cartography. Contextual data describing attributes of objects and features found in the caves can now be included in the GIS. These sciences include, but are certainly not limited to; paleontology, archaeology, geology, hydrology, and engineering, just to name a few. As technology continues to advance, it is hoped that more disciplines will continue to utilize GIS and subsurface cartography.

References

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Recent karst and cave studies of the Aladaglar Massif, Central Taurus, Turkey, and their significance to paleogeographic reconstructions

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Abstract

Aladaglar is an outstanding karst massif located in the Central Taurus Range within Adana-Kayseri-Niğde provinces of Turkey, between the regional Eceemis Fault on the west and the deeply incised valley of Zamanli River on the east. It is composed mainly by Triassic, Jurassic and Cretaceous limestones and has the local relief extending between 400m and 3750m elevations. During 2001-2004 extensive karst and cave studies have been carried out in Aladaglar under the joint Turkish-Ukrainian project, resulting in new data and insights into regional karst evolution, hydrogeology and geomorphology. The aquifer associated with Aladaglar covers about 1900 km². Most of discharge occurs at elevations ranging between 400 and 750m on the eastern flanks of the massif, where it totals in about 32 m³/sec. Hydrochemical and isotopic studies suggest the presence of "shallow" and "deep" circulation systems and rather small groundwater residence time in both. Sixty per cent of discharge comprises recharges of the last 3-4 years. Along with high concentration of the discharge, this points to the presence of well-developed and highly integrated conduit systems in depth of the massif. Geomorphologically, three types of karst are recognized in Aladaglar: (1) Covered (contact) karst along the margins of the retreating cover of the ophiolite mélangé and Miocene conglomerates at the altitudes between 1200-1900; (2) Polygonal karst of the utmost density of karstic landforms at the altitudes between 1700-2400m; (3) High mountain karst at the altitudes above 2600m. These types represent the evolutionary succession of the karst development in Aladaglar in the Plio-Quaternary. Besides, there are signs of paleokarst of presumably

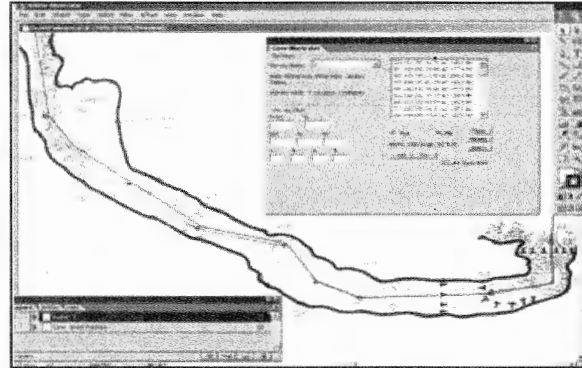


Figure 7: Adobe Illustrator showing the drafting of Grant-Palmore Cave.

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Late Miocene age and of paleokarst associated with hydrothermalism. During recent years over 150 caves have been explored, mainly vertical, of the total depth of 6640m. Of them 32 caves are deeper than 50m deep, and 12 caves are in excess of 100m. Fifty-seven caves are located above the 3000m altitude, the highest explored cave being at 3410m. The most remarkable is Kuzgun Cave, currently 1400m deep and 3187m long, with its outstanding variety of mineral formations and sediments. Cavities of at least five generations are preliminarily identified: (1) ancient (Late Miocene?) with massive speleothems, (2) hydrothermal, (3) pre-glacial and modern vadose invasion (commonly decapitated by the last glaciation in the high sector) and, (4) spring outlets. General potential of the Aladaglar Massif for deep caves is estimated to be up to 2500m, although the hydrologic system circulation depth can be up to 2700m. Major karst and cave development in Aladaglar started since Late Miocene, being guided by differential uplifts, uncovering of the carbonate rocks, hydrothermalism, formation (re-organization) and incision of the erosional network. The overall morphology and karst development were severely impacted by Quaternary glaciations, particularly by the last one that occurred between 9,500 and 7,500 years BP according to cosmogenic ³⁶Cl dating of morainic boulders. The Aladaglar Massif, with its intense neotectonic development, diversity of karst and cave types, various kinds of paleoenvironmental records and deep cave systems, appears to establish as an outstanding natural laboratory for studying complex karst evolution. The ongoing combined speleological, geomorphological and hydrogeological researches are aimed to reveal this evolution in more details.

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Results of the Field Work in Kapovaya Cave (Shulgantash) by a Team from the A. Karpinsky All-Russia Research Geological Institute of the Russian Geographic Society in 2001-2005.

Yu. Lyakhnitsky, A. Solodeinikov, A. Yushko

Theses:

1. *Ancient Drawings Need Protection*
2. *Digital Photography Revealed Details Invisible to the Naked Eye*
3. *Speleologists Found the Most Ancient Artist's Palette*

In 2001, the Ministry of Culture of Bashkortostan initiated a revival of comprehensive field work in Kapovaya Cave (Shulgantash). The cave is located in the South Urals near the river of Belaya in the Shulgantash National Preserve. This is a mildly branching three-level spelecosystem with a running length of 3 kilometers and vertical amplitude of 260 meters (including underwater syphon cavities) with large halls, galleries, underwater lakes, and a river.

In 1959, A. Ryumin, an employee of the preserve, found Paleolithic drawings in the cave. Later the cave was studied by archeologists O. Bader and V. Shchelinsky. Shchelinsky opened a cultural layer of the upper Paleolithic Age in the Signs Hall. Thus, the study of this monument proves the existence of a developed Paleolithic civilization in the Urals.

Our studies aim at preserving the cave with its unique Paleolithic drawings. We propose to organize a museum-preserve within the cave and to carry out scheduled improvement of the area surrounding the entrance to the cave. This is necessary for preserving the internal areas of the cave with their ancient drawings.

In order to track the changes in the condition of the cave and the cave drawings, as well as to develop measures for preserving the drawings, monitoring of dynamic parameters of the spelecosystem is taking place. The following factors are being studied: geological, geomorphological, hydraulic, hydrochemical, microclimatic, microbiological, and geoecological parameters. The set of monitored phenomena has been significantly extended through using new kinds and methods of research, such as radon contents and air ionization. A great deal of attention is being paid to monitoring the condition of Paleolithic drawings and its archiving.

As a result of the field work carried out by our team, a large number of new drawings have been discovered and a previously undetected structure of old drawings has recently been revealed. New, previously unknown extensions of the cave have been discovered. Field work of speleologists from Moscow has shown that phreatic zones of the deep circulation of the cave run 78 meters down from the surface—much deeper than the level of the Byelaya River. The unexplored underwater cavities run 3 kilometers under the valley and the Shulgan Canyon up to the Ozhiganovskaya Cave, a sinkhole of Shulgan stream, which feeds the karst system.

One of the main goals was detailed archiving of the drawings, some of which might be lost in the near future.

Topological surveying and photography of the drawings is taking place. In order to accurately copy or trace the interiors of the cavities and position of drawings, topological referencing of the halls with drawings is taking place. The drawings have been photographed by A. Solodeinikov and Yu. Lyakhnitsky using color and size standards and taking into account horizontal orientation of objects.

An original method of digital image processing has been devised. It allows for revealing drawings that are difficult to see or invisible to the

naked eye. This has led to the discovery of dozens of new drawings and around a hundred unclassified spots—remains of drawings damaged by the elements.

Studying the drawings has shown that in addition to realistic depictions of animals, numerous drawings depict geometric marks. The most abundant are variants of the trapezoid, which is characteristic of the Kapovaya Cave. Complexity, systematism, and variety of these marks allows us to suppose that they bear certain significance, i.e. are virtually hieroglyphs. We have observed several cases of, seemingly, ritual applying new drawings on top of old one, in order to distort or destroy the original drawings.

The accumulated materials allow us to publish a Catalog of Drawings and Marks Found in the Kapovaya Cave, which will include around 200 depictions of five types: red ochre, polychrome, black-charcoal, clay, and cave (partially modeled) bas-reliefs.

Limonite, found near the cave (getite, hydrogetite, and other minerals) was used for most drawings. It was kilned and mixed with various dyes, for example clay and carbonate ochre from eroded bark, and, probably, "animal glue" made from fat and blood. No certain results on organic compounds of the dyes have been obtained so far.

The group has not carried out archeological excavations; however, interesting chance discoveries have been made during research. An ancient "palette" has been found in the rocks. This was a flat rock with a layer of prepared red ochre. It was removed by archeologists and can now be observed in a museum in Ufa.

Several natural cavities have been discovered between large chunks of rock, some of which almost certainly were artificially extended or isolated. They are located along the perimeter of the Hall of Chaos and may have been used for rituals.

In conjunction with the State Hermitage (E. Melnikova), we have developed a method of coating the drawings with a protective layer of hydrophobic formula, which was tested on models but the final decision for its use has not yet been made. Measures for modeling hydraulic and micro-climatic conditions in the cave are also in development. This is necessary for preserving the Paleolithic drawings.

Thus, our speleologic team carries out detailed and comprehensive exploration of the spelecosystem, monitors its dynamic parameters, and archives ancient drawings. The results allow us to develop methods for improving the extremely unfavorable hydrological conditions of the cave necessary for preserving the unique Paleolithic drawings, and outline the prospects for organizing a contemporary historico-archeological and landscape-speleological preserve.

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Main 2001 to early 2005 results on the karst of khammouane, central laos : long caves, sloping caves, hollow stalagmites and others

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Abstract

The 2001-2005 explorations in the karst of Khammouane have led to the mapping of an additional 55 kilometres, bringing the total surveyed length to 130 kilometres (since 1991). The longest cave exceeds 24 km and the highest one reaches + 465 metres of relative elevation. Sloping caves have been discovered, one longer than 12 kilometres (Tham Phiseua). It has a phreatic origin and may have formed during the Late Miocene to/ or the Lower Pliocene. Unusual mineral formations are present, including iron crusts, abundant mondmilch, gypsum crusts and around 200 hollow stalagmites. Hollow stalagmites and rims are encountered in two other caves, together with mondmilch and gypsum in one of them.

Besides, prehistoric representations have been discovered in several caves, dating possibly from 2500 to 3500 BP. A cave with 229 Buddha images, discovered in 2004 by a villager, was studied by us in detail, together with the tens of cave shields it contains. Additional activity concerned, among others, ethnospéologie and cave biology. This paper presents some of the main results.

Résumé

Les explorations 2001-2005 sur le karst du Khammouane ont permis de topographier 55 kilomètres, qui participent aux 130 kilomètres levés depuis 1991. Le grotte la plus longue dépasse 24 kilomètres et la plus grande dénivelée est de + 465 mètres. Des grottes pentues sur de longues distances ont été explorées, dont une de plus de 12 kilomètres (Tham Phiseua). Son origine est phréatique et elle a pu se former au Miocène supérieur et/ ou au Pliocène inférieur. Des formations minérales inhabituelles y sont présentes, comme des croûtes ferrugineuses sur les parois, du mondmilch en grande quantité, des croûtes de gypse et environ 200 stalagmites creuses. De telles stalagmites et des rims existent dans deux autres grottes, associés à du mondmilch et du gypse dans l'une d'elles.

Des figurations préhistoriques ont été décrites dans plusieurs autres grottes et attribuées à un âge possible de 500 à 1500 av. J.C. Une grotte avec 229 statues de Bouddha, découverte en 2004 par un villageois (et que nous avons expertisée), contient aussi de nombreux disques de calcite. D'autres résultats proviennent, notamment, de recherches ethnospéologiques et biospéologiques. Cet article présente plusieurs résultats marquants.

The karst of Khammouane is 290 x 40 km large and made up of around 1100 metre-thick Permo-carboniferous carbonate. It has a two-season dry and wet tropical climate. All the flows go to the Mekong River.

Long caves

All together, we organised 14 exploration campaigns and three reconnaissance trips in Khammouane, leading, among many results, to the mapping of 130 kilometres of passages. Following our 1991-2000 research, further cave exploration has led to the mapping of an additional 55 km of caves passages, bringing the longest single cave development to more than 24 km in the Nam Non Cave, and the highest one to + 465 m in Tham Phiseua.

Now, we have explored 1 cave longer than 20 km, 3 caves between 10 and 15 km, 5 between 5 and 10 km and many shorter ones. A large part of these caves is still under exploration. One cave entrance is around 215 m wide and a 9 km long river cave (Xé Bang Fai) has one of the largest

average flows in the world (Mouret, 2001). Many large chambers have been discovered as well.

Hydrogeological karst features

Our explorations have greatly helped in clarifying hydrogeological relations. The best example is the Nam Bout-Nam Pagan Rivers system (nam = river), that topographic maps were indicating as two rivers flowing out of the karst, in opposite directions (the first towards the Mekong, the second towards the opposite karst edge). This was theoretically possible within the regional setting, though not so likely. The exploration of the remote Nam Bout valley (on the upstream side of the karst) has proved that the Nam Bout and its main tributaries originate from alloctonous formations. The Nam Bout follows the karst edge without sinking, then it enters a narrow 12 kilometres long blind valley and Tham Boumlou at the end (tham = cave). The water flows throughout the karst massif down to the polje of Ban Boumlou, where it takes the name of Nam Pagan. It crosses the polje and sinks again to re-appear in the Mekong valley. This setting is more simple and in good agreement with the regional hydrogeological organisation: the main direction of flow towards the Mekong is parallel to the maximum hydrogeological gradient.

The lack of sinking of the Nam Bout along the karst is surprising, but it is not the only river to do so along the upstream edge of the karst in Khammouane. One of its temporary flowing tributaries, the Houay Nadan, enters the border polje of Ban Mouang Louang without sinking significantly. According to the villagers, the water of the polje, when it is flooded, escapes into the Nam Bout. At the dry season, we have observed ponors which show no morphology of sinkhole and temporary karst springs on the edge of the polje (a large part of the polje is like a blind valley perpendicular to the karst edge).

The lack of sinking must be due to a too weak absorption (low permeability) at the beginning of the rainy season and/or probably to water emission from the karst itself. Flow inversion may exist between some ponors when the water level is rising in the karst. The aquifer gets quickly full (at best, it absorbs little water) and this creates a fast flooding of the polje (a few metres of water depth over several square kilometres), largely fed by the Houay Nadan water income and karst spring flows. In this way, alloctonous waters are forced to escape along the karst edge. This setting is, in the detail, rather complex and more work on it is planned.

Oblique cave networks along dipping strata

For long, only subhorizontal caves were known in Khammouane. Most of them are located close to the present day elevation of poljes and karst plains. A few short ones were known 10 to 15 m below polje surface and a few fossil ones were known up to + 140 m, relative elevation (RE), with cave openings up to + 260 m RE above poljes and karst plains. Besides, a few oblique caves were known: the short Tham Nam Thieng, which opens at + 260 m RE (Mouret, 2001) and a few sunk caves explored by divers: spring of Nam Kongleng : - 47 m (Benoit, 1998) ; spring of Nam Kham : - 48 m (Morieux, 2000).

In 2000, we reached + 96 m in Tham Phiseua, a cave located 15 km to the North-East of Thakhek (Mouret et al, 2001), then + 315 m in 2002, + 379 m in 2004 and + 465 m in February 2005. In 2005, we also reached nearly + 200 m in Tham Houay Sai-Koun Dôn. The two cave systems,

both longer than 10 km each, are located in the same part of the karst and perhaps connect each other (a possibility that we will further investigate very soon).

Tham Phiseua

General organisation of the cave

Tham Phiseua is comprised of two parts: a nearly rectilinear, subhorizontal, passage (Gregory, 1996a & b), controlled by fractures, flowing at the rainy season (Fig. 1), and a complex system of fossil passages, which are nearly all following stratification surfaces (Fig. 2). These fossil passages are locally rejuvenated by present day flows at the rainy season, which result from infiltration in different upper parts of the cave. This is due to the fact that the cave develops in a karst hill which has a limited extension, though at the base it connects larger karst areas. The fossil passages are oblique and dip around 18 degrees, broadly towards the lower spring entrance. The main entrance is a side passage besides the spring and it is located to the West of the hill. The fossil passages rise toward the Northeast and pierce the northern flank of the hill in no less than four openings between around + 250 m and + 465 m RE. The highest one is close to the top of the hill.

This setting is extremely interesting, as the cave has (at least in the explored part) a nearly constant overall slope (Fig. 2), related to an almost regular structural dip: the cave gently rises between the active lower passage and the upper openings and it shows no vertical part, except a few younger pitches that have cut through fossil passages. The slope of the passages varies according to their direction along the bedding surfaces: it is equal to the dip value where the cave follows the dip direction and to a few degrees where it follows the strike. These two directions make up a framework which controls the cave pattern and generate a complex setting.

Main passages (around 15 x 10 m or 20 x 6-8 m) are commonly connected by extremely dense mazes of smaller galleries (around 4 x 3 m). There are also lesser dense mazes with larger passages and very large, low, passages along strata surfaces, which are tens of metres wide and 1 to 3 metres high: some of the latter connect other passages through false, bottomless, eversion hollows, which are subcylindrical holes between the end of an upper passage and the roof of the lower, large and low, passage.

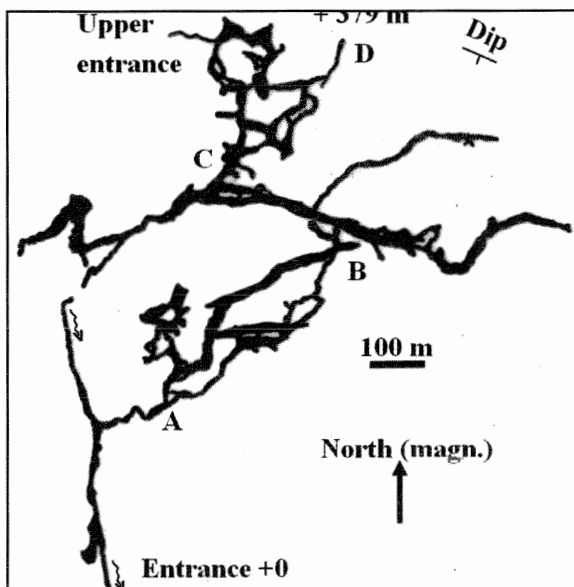


Fig. 1: Tham Phiseua; mapping status after 2004 exploration (now +465 m).

The passages are usually much larger than high, specially where they follow the dip. They tend to be more squared in passages following the strike. Passages form a continuous network and show very numerous, thousands of, cupolas. These cupolas are densely distributed in the mid-elevation part of the cave, in passages following the dip and along their continuation more parallel to the strike. Main passages with a low slope often show a much lower density of cupolas. Cupolas are commonly one metre large, but some reach more than 10 m long. Their height is usually 0.3 to 0.8 m. They are commonly oblique, with a somewhat flat sloping surface parallel to the passage. Their size is clearly larger and higher in larger passages at the junction with smaller ones: these "junction cupolas" are very clearly drawn, larger, and located immediately next to a passage junction.

Moderately developed floor incisions are observed in a number of passages. They have a regular size and do not look like typical vadose features. They are distinct from the late vadose incisions, which have a more irregular long profile and different proportions. They mainly occur in the sloping passages in the dip direction. In addition, in the upper part of the cave, they are sealed by mondmilch and gypsum crusts.

A limited number of potholes exist in the cave. Besides many false ones, as explained above, some erode old, several metres thick, thinly and regularly bedded calcite deposits.

Cave detrital sediments are overall not so abundant. They make up rather regular deposits with a pale brown to yellowish colour, made up of mainly silt-sized to fine-grained grains. Trough cross-bedding is locally visible but, overall, observed sedimentary features do not corroborate a high energy setting: the grain size, the continuity of the facies, the regularity of the deposits. Locally, at the top of the sediments, some coarser grains exist, but they are different, richer in iron pebbles and probably result from late reworking.

Such characteristics clearly indicate a phreatic cave formation and, so far, we have observed no indication of allochthonous sediment input (no allochthonous pebble or gravel ...). Regional setting is probably not favourable to them, as Tham Phiseua is located close to the Mekong River (the regional base level, but since when does it exist as such?), i.e. far from the sources of allochthonous sediments. Obliquity of cupolas indicate a gently flowing water body when the cave was active (hydrodynamism).

Given the difference of elevation in the cave, more than 400 m, and considering the average (we have no more detailed possibility) regional uplift and denudation (it started around 50 million years ago and the denudation is around 3 to 4 km (Mouret, 1994, 2001), it took more than 5 million years for the area to be uplifted enough to make the cave completely dry. So the cave was probably active during the Early Pliocene and/or the Upper Miocene, but how it dried up is less clear. We do not observe any clear rejuvenation under vadose conditions, except recent flows in secondary passages during the rainy season and exceptional heavy rains during the dry season (as in 2004). We do not know the modalities of denudation, but we observe the present day morphology with a karst plain at the bottom and the isolated hill as described above.

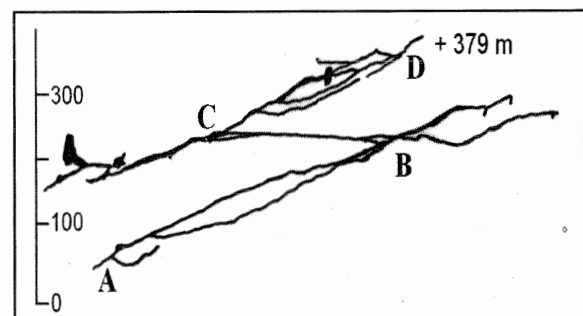


Fig. 2: Tham Phiseua; long section, status after 2004 exploration

Cave mineralogical deposits

Cave mineralogy, under investigation, is extremely interesting. A number of passages are covered with a crust of iron oxide and/ or hydroxide, mainly along the walls, but also at the roof and even inside cupolas. The crusts are "plastered" on cave walls and covered with some porous calcite (?) deposits (under analysis), themselves unconformably sealed by overlapping gypsum crusts on the cave floor. This gypsum also covers thick powdery *mondmilch*. Iron crusts are one to several millimetres thick. Wall calcite is commonly 10 to 20 cm thick. Gypsum is a few centimetres and *mondmilch* can reach more than 50 cm.

Iron crusts are well developed in the upper part of the cave, but not only. They are encountered also in steep passages in the mid-elevation part of the cave, where they preferentially "plaster" the lower half of the walls. In other passages at lower elevation, they are still found at the roof of some passages. Clearly, there seems to be more iron oxide/ hydroxide in the upper part of the cave, as seen also, for instance, on the cave floor, where dark blood-red sediments are well present. The lower parts of the cave seem to show much less of these iron oxides/ hydroxides. At around + 230 m, in a spacious low slope passage, there was in February 2004, just after several days of heavy rains during the dry season, a strong smell much alike the smell of sulphide mine deposits stored outside. This suggests the presence of sulphides in the cave floor sediments of this blackish-coloured passage.

Hollow stalagmites, very unusual in caves, are many (and we have discovered more of them in two other caves) and encountered above + 250 m RE. There are around 200 of them, which are mainly located on flat and marginally sloping grounds. They are commonly around 80 cm high and can reach up to 1.75 m. In another cave, Tham Lô, they are associated with gypsum crusts and *mondmilch* powdery sediments, as in Tham Phiseua. Tham Lô shows several large rims. In the third cave, Tham Houay Sai-Koun Dôn, they are associated with vents and rims in specific locations.

Phiseua stalagmites have a central channel over the whole length, which even enters the floor. Because of this characteristic and the lack of stalactite in at least 95 % of the cases, because the axial hole may be covered at the top by stalagmite minerals, and because this axial hole is sometimes largely deviated from the vertical (and in these cases it cannot be due to dropping water), it was initially thought that such stalagmites are fed from ascending fluids from below the floor. However, several stalagmites were found on large size boulders and there is no hole below the boulder. However, things are probably not so simple: some stalagmites show morphologies that would exist if they were flowing at the top (Fig. 3, d).

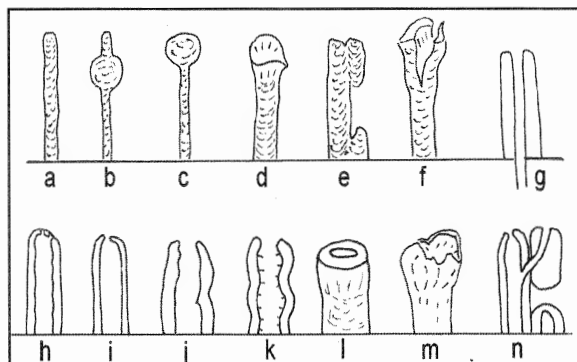


Fig. 3: Hollow stalagmites from Tham Phiseua. a to f: external shape, regular (a), bigger near or at the top (b, c), open and shaped like a pourer-spout (d), composite (e), open, like cracked (f); g: the internal channel goes down into the ground; h to k: internal shape, almost closed on top (h), narrow hole on top (i), top hole smaller than the channel (j), same with internal radial crystals (k); l: elliptical channel and top opening; m: top enlargement of the channel; n: view of the composite internal channels of stalagmite (e) showing both the vertical and oblique channels.

Are there several ways of formation? The rarity of stalactites (Fig. 4) suggests rather unusual conditions of formation. Stalagmites are not uncommonly aligned below crests separating broadly featured cupolas: gravity-related phenomenon only?

Stalagmites mineralogy often shows a case of oxidised iron minerals between other minerals (and iron is more abundant in the upper part of the cave). The central channel, not always cylindrical, looks like corroded in many stalagmites, so there a clear effect of corrosion in the formation of the hollow stalagmites, but the unusual mineralogy (under study) and the lack of stalactites must play a role. We are dealing with an unusual setting.

In the same area as the stalagmites, but not in "stalagmite fields", there are large masses of stalactites (up to 1m large) with flat stalagmites below.

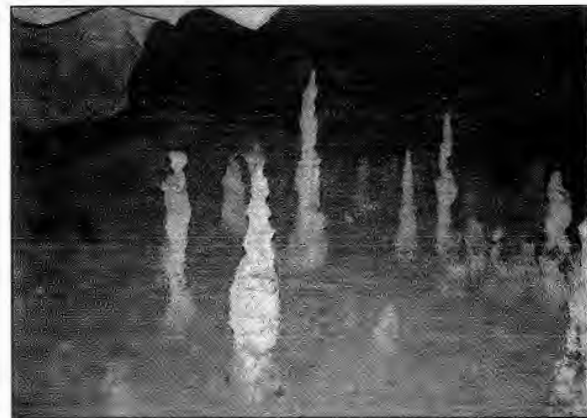


Fig. 4: Some hollow stalagmites (height is around 0.8 m) in the upper part of Tham Phiseua. Note the absence of stalactite. Photo by H  l  ne Frume.

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Hypotheses on cave origin

The age of the cave, the unusual mineral associations, the existence of hollow stalagmites rich in iron, the smell of sulphides and associated black colours in the passage, the existence of cupolas, the fine grain size of sediments and the phreatic nature of the cave, suggest - but it remains to be confirmed - the possibility of a hydrothermal, H_2S driven, speleogenesis. Ongoing analyses will help in solving the problem. In the present status of the knowledge, such a speleogenesis is compatible with the regional geological setting.

Tham Houay Say-Koun D  n

This cave has three entrances on the downstream, southern, side (Mouret, 1998), which are located near the end of an elongated karst plain. One is the spring of the large Nam D  n (a river which has highly contrasted flow rates), the sump of which was dived in 1998 over around 240 m (end at - 12 m), with a low point at - 23 m along the way (Espinasse, 1999). Another one (Tham Houay Sai) is a cave with a temporary flow. The last one is nearly fossil, though it is partly invaded by dormant (?) water in the rainy season. The two latter entrances are located on different sides of the Nam D  n and they are connected by a more than 4 kilometres long loop.

Our team discovered and started exploring the cave in 1997. We went again in 2000, 2003 and February 2005.

The cave shows two areas with respect to the slope of passages: first, a downstream area behind the three outlets; it is around one kilometre large and the slope is small, a few degrees, as is the structural dip. The area behind the above mentioned loop has a steeper, around 20 degrees, slope (though this varies a bit) and a dense network of passages along dip and

strike. The relative elevation reached in 2005 is close to + 200 m and an exit in a topographic, valley-like, low opposite to the entrances has been discovered.

To the West, the cave massif is bounded by a valley which is higher than the karst plain of Nam Dôn and an additional set of three openings to the outside was found in fossil galleries. The part of the cave which is lining the eastern cliff of the valley shows hollow stalagmites and small rims. The cave floor shows common calcite cover through which the stalagmites are set. Some hollow stalagmites are associated with rims up to 15 cm in diameter. Some thin-walled speleothems intermediate between rims and hollow stalagmites are present as well. One area shows a hollow speleothem diverging upward from the vertical then curving down and a nearly horizontal one. No *mondmilch* is observed in this part of the cave.

Tham Lô

This fossil cave surveyed over more than five kilometres is located around 100 m above the surrounding polje of Ban Vieng. It shows a major main passage, which reaches up to a 70 metres width and a 60 metres height, and side galleries. Besides the main gallery which is subhorizontal, many of the side galleries are significantly sloping along the structural dip, with differences in elevation up to 85 metres recorded.

Tham Lô shows several large rims which are located no further than 50 metres from the main entrance (twin openings in the passage wall), though they are distant of nearly one kilometre from the end of the passage, cut through by a karst valley. The bottom of a side shaft is also covered with *mondmilch* and gypsum crusts. More rims are found on sloping flowstones and in the boulders of a large chamber around 250 m from the main entrance (each of them displays a cemented, sealed on the side, chimney). Further away, *mondmilch* covered with a gypsum crust is encountered near a major sloping passage. At some distance again, there are rimstone dams made up of a soft mineral assemblage under study. Then hollow stalagmites are found further inside the cave, on the side of the large passage.

Archaeological discoveries, biology, ethnospeleology

Prehistoric cave art was discovered in 2000, 2002 (Ostermann & Mouret, 2004) and 2004, in rock shelters and cave entrance areas in the Xé Bang Fai Valley (a route between Vietnam and the Mekong River valley) and to the South of it. One set of is isolated in the polje of Ban Vieng, beyond a high limestone ridge. Drawings and paintings represent human beings alone, human beings pulling animals (domesticated animals and one dead animal), animals such as elephants (one with a load on the back), geometric patterns and figurations difficult to interpret because of their alteration. The colour is red or black. A part of the figurations is estimated to be 500 to 1500 BC, but there is more than one generation of cave art.

A major archaeological discovery was made by a villager in April 2004 in Tham Pafa, a cave located several kilometres to the NE of Thakhek, the provincial capital. The previously unknown fossil passage was found 15 metres above ground level, above a large entrance sheltering a permanent lake. There, down a narrow opening, an enlargement revealed 229 Buddha statues, pottery and old writings in two large trunks, dating probably back to the 18th Century. These treasures were likely hidden during the Thai invasions at the end of the 18th or the beginning of the 19th Century, then their knowledge was lost until 2004. We made an expertise of the cave for the authorities and we advised them on its conservation and its geological stability. Indeed, the place where worshippers place themselves to pray is largely located on a less than one metre thick calcite deposit (which may bear some silt or clay horizons) and this part of the cave is above the lake. It has a thin wall with the cliff (locally less than one metre) and fractures exist. Tens of cave shields are also present in the cave.

Cave biology has been largely carried out by our team, including the

study of microfauna and macrofauna, giant spiders specially. Finally, a lot of image acquisition was made, including movies.

Acknowledgements

To our Laotian friends, especially MM Vannivong Soumpholphakdy, Souksane, Kham Nyang, Khamsone Khamlasy, Ky, our policeman friend, our drivers, cooks, guides and the villagers.

Nothing would have been possible without them and without my European colleagues: Ph. Bence, O. Bonnet, J. Chambard, Y. Dreibrögt, H. de Heltdorf, H. Frume, B. Giai-Checa, C. Ghommhid, L. et M. Grillères, E. Guichard, F. Guillot, P. Jaëger, N. Le Teurtre, J. Lordon, X. Noguès, C. Noiriël, H. de Picon-Heltdorf, J. Rolin, J.M. Ostermann, P. Sans, H. Steiner and J.F. Vacquie.

Many thanks also to our friend Jan Burrows for his helpfulness and to the Laotian authorities who kindly provided us with the necessary authorizations and who nicely welcomed us in Khammouane.

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Specific conductivity in karst waters - what can we learn from it ?

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*University of Silesia, Sosnowiec, Poland; McMaster University, Hamilton, Canada***Abstract**

Under field conditions modern digital conductivity meters give standardized, rapid and reproducible measurements. Here we investigate the accuracy of their estimates of the composition of karst waters, as total hardness (TH, as mg/L CaCO₃) for limestone and dolomite and as meq/L for gypsum. PHREEQC theoretical curves for the dissolution of pure calcite/aragonite and dolomite in water at 25°C are compared with water analyses from karst studies worldwide. Other principal ions encountered are sulphates, nitrates and chlorides (the "SNC" group). From carbonate karsts, 2309 spring, well and stream samples were divided into uncontaminated (SNC<10%), moderately contaminated (10<SNC20%) classes.

Where specific conductivity (SpC) is less than 600 mS/cm, a clear statistical distinction can be drawn between waters having little contamination and substantially contaminated waters with SNC>20%. As sometimes claimed in manufacturers' literature, in "clean" limestone waters TH is close to 1/2 SpC, with a standard error of only 2-3 mg/L. The slope of the best-fit line for 1949 samples covering all SNC classes where SpC<600 mS/cm, is 1.86, very close to the 1.88 obtained for clean limestone waters; however, the value of the intercept is ten times higher. The regression line for clean limestone waters where SpC>600 mS/cm helps to distinguish polluted waters from clean waters with possible endogenic sources of CO₂. In the range 250<SPC

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Phenomenon of the underwater caves of Riviera Maya, Mexico

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Czech Speleological Society

Riviera Maya is a part of eastern coast of Mexican semiisland Yucatan by the Caribbean, in state of Quintana Roo.

The area of carbonates is about 190000 km². They are essentially pure, deposited from Paleocen till Pliocen. Uplift of peninsula in Pleistocene predisposed karst platform to dynamics speleogenesis. Oft rains penetrated through the porous surface and created the shallow systems that led the water to the sea. In the next period there was another drop of the sea level and it caused the erosion broadened existing caves while eroding deeper passages. In the meantime the process of secondary karstification and collapsing of thin cave ceilings was running through and the cenotes occurred. 18000 years ago the sea started to rise to the contemporary level and these caves were flooded.

Today the surface is absolutely flat, covered with a jungle. There are no rivers, only lagunas and cenotes. Lagunas are big lakes, while cenotes can be small, often hidden behind the rocks. At the seaside there are calets where the fresh water flows to the ocean. Thanks to its attractive

location it also became a favourite tourist destination.

The cenotes and caves are the really unique ecosystem. Hundrets species of animals were described in last century.

The first bigger system Nohoch Nach Chich was discovered in 1986 by the team of Mike Madden. It was the beginning of the invasion of divers and many other cenotes and kilometers of corridors were discovered. At the present there are more than 140 cave systems where 580km of underwater cave corridors were discovered. System Ox Bel Ha is the longest cave system in the world with 134km of corridors. The exploration of cenotes continues up to now by many projects. One of them in second longest underwater cave system of the world called Sac Aktun. The Members of SAET (Sak Aktun exploration team) led by Robert Schmittner and Steave Boegards establish that this system is now 77 183 m long.

In 1990 The Quintana Roo Speleological Survey was established by Jim Coke to collect all dates about caves in Riviera Maya.



Fig. 1 View on a Riviera Maya surface, covered with jungle. Photo by: Zdenek Motycka

	Cave Name	Length in Meters	Depth in Meters	No. of Cenotes in System	Explored	Last up date
					By	
1	Sistema Ox Bel Ha	134048	-33.5	87	Devos/LeMaillot	01/2005
2	Sistema Sac Actun	77183	-25.0	61	SAET	05/2005
3	Nohoch Nah Chich	63073	-71.6	34 (?)	M. Madden	05/2005
4	Sistema Dos Ojos	56671	-119.1	24	Jasper/Turgeon	08/2001
5	Sistema Naranjal	21525	-34.7	8	B. Phillips	09/2004
6	Sistema Ponderosa	15019	-16.5	18	S. Gerrard	02/2000
7	Sist. Yaxchen East	13090	-16.5	29	K./G. Walten	10/2003
8	Sistema Chac-Mol	9193	-28.3	9	A. Matthes	01/2000
9	Cueva Quebrada	9000	-10.7	5 (?)	S. Ormeroid	1993
10	Sistema Zapote	7697	-27.4	3	R. Wejski-Wol.	02/2005
11	Sistema Camilo	7397	-19.5	4	Cambrian Fnd.	04/2004
12	Sistema Xel-Ha Norte	6652	-13.4	4	Bogaerts/Phillips	09/2004
13	Cueva Aerolito	6100	-27.4	3 (?)	S. Ormeroid	1993
14	Sistema Toh Ha	5818	-10.4	3	Berni/Sieff	03/2005
15	Sistema Actun Chen	5435	-25.0	9	Birnbach/LeMaillot	01/2001
16	Sistema Taj Mahal	5361	-24.4	8	Carnahan/Phillips	04/2004
17	Sistema Actun Koh	5156	-16.5	5	F. Devos	01/2001
18	Sistema Tortuga	4900	-27.4	2	R. Wejski-Wol.	12/2004
19	Sistema Tux Kupaxa	4777	-14.6	5	Schnittger/Phillips	05/2005
20	Dzonot Took	4736	-16.5	5	Lins/Matthes	08/2000
21	Sistema Burrodromo	3962	-14.3	2	W. Skiles	09/1988
22	Cenote Chan-hol	3938	-11.6	1	K. Davidsson	05/2005
23	Sistema K'oox Baal	3838	-17.7	7	Labarthe/Phillips	04/2005
24	Sistema Dos Pisos	3704	-25.9	3	Dotchon/Schmittner	08/2003
25	Sistema Joolis	3636	-20.1	5	Czech Speleo. Soc.	05/2005
26	Sistema Dos Pies	3516	-13.1	5	F. Devos	01/2001
27	Sistema Ich Tunich	3343	-15.8	6	Schmittner/Dovland	04/2003
28	Sistema Sac Be Ha	3303	-11.3	3	Berni/Sieff	05/2005
29	Sistema Crustacea	3163	-18.9	2	Meacham/Madden	01/2003
30	Sistema Minotauro	3118	-14.6	5	Birnbach/LeMaillot	01/2001

Fig. 2 List of longest caves in Riviera Maya, Quintana Roo, Mexico

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The formations of the grutas del palmito, (Bustamante, Nuevo León, Mexico), Preliminary Results

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Abstract

The formations found in the "Grutas del Palmito" confirm the existence of different climatic situations occurred in the cave. Among the more common formations this cave is characterised by a number of limestone pools, sometimes very large. In some of them big cave pearls (up to more than 10 cm diameter) are found. Physical chemical analysis of the material of the rimstone pools show a very fast deposition rate with the presence of thermal water.

Key words: Palmito, formations, rimstone, cave pearls speleogenesis.

Introduction

The cave environment can be divided into three parts (Fig. 1 and 2):

- 1 First part, already used as a show cave: Salon de Baile (about 150 m)
- 2 Middle part: from Paso de la Muerte to Grandes Desniveles (about 160 m)
- 3 Last part: Salon de los Gigantes, Catedral, Cueva de Nieve, etc.

The first part is peculiar for many rimstone pools, often rather large,

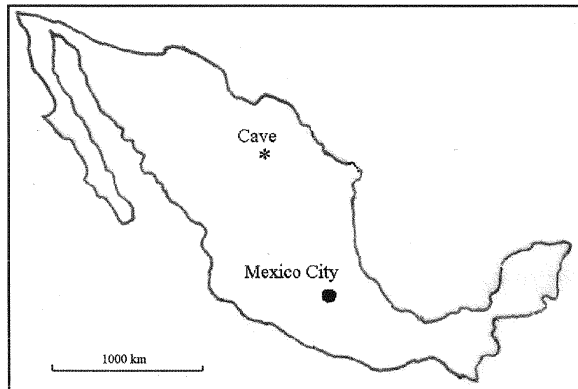


Fig. 1 - Location of the «Grutas del Palmito»

in addition to stalactites, stalagmites and column. In some rimstone pools there are big cave pearls (up to 10 cm in diameter). In the second part, close to the western side (on the right when entering) there is a room of some ten of square metres with very nice helictites rather well preserved.

In the last part many columns are found, some of them fallen down in the past and, successively, other stalagmites grew on them.

From the point of view of formations, this cave has an exceptional abundance of cave powder (Hill & Forti 1997), which is the main constituent of the rimstone pools and is also found in some rocks, being probably the remnants of ancient pools. For this reason some small samples were taken to study their composition and possibly define their origin. In this note, after the geological and climatological characteristics of the cave have been summarised, the samples of cave powder are described with reference to their morphology and mineralogy, and eventually a genetical interpretation is reported.

Geology

Grutas del Palmito (also called Grutas de Bustamante) formed in the Cupido Limestone, which was deposited 115 million years ago as sedi-

ment on the bottom of a shallow sea. Other sediments were deposited on the limestone, until about 60 million years ago when geologic forces pushed up the rocks to form the Sierra Madre Oriental. Successively such rocks have slowly been eroded to expose the limestone and to cut the Bustamante Valley over 500 m deep.

Physical features of the cave

This cave probably developed under hydrothermal conditions since there is evidence of gypsum in some formations. On the other hand, thermal waters have been observed in the area (Ojo del agua, with a temperature above 26°C, source S. Lorenzo with a temperature around 25°C, with the outside temperature around 13°C).

Important cycles of deposition and corrosion may be observed in the cave; concerning both the formations and the rock. In addition, close to the entrance, many stalactites have an evident bent toward the entrance itself, due to an air flow entering the cave when such stalactites developed. For this reason the cave had another entrance at a lower altitude, which later was closed by the growth of formation or collapse.

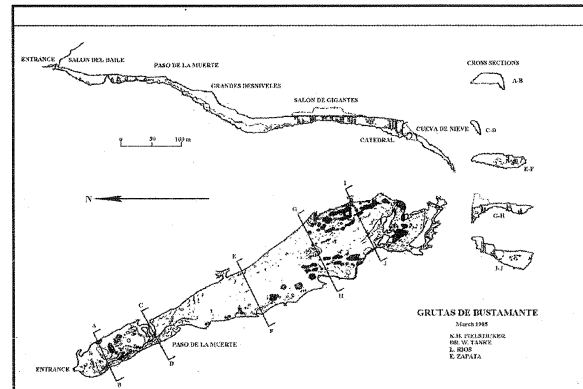


Fig. 2 - Map of "Grutas de Bustamante" ("Grutas del Palmito")

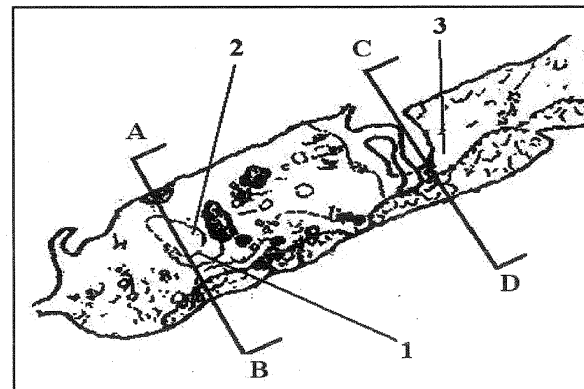


Fig. 3 - Sampling points

Since the present entrance was the "warm entrance" of the karst system, the airflow entered during the Summer time. Therefore this fact agrees with the season of the faster development of the stalactites which occurred during the Summer, a rainy time in this region. Presently very weak air

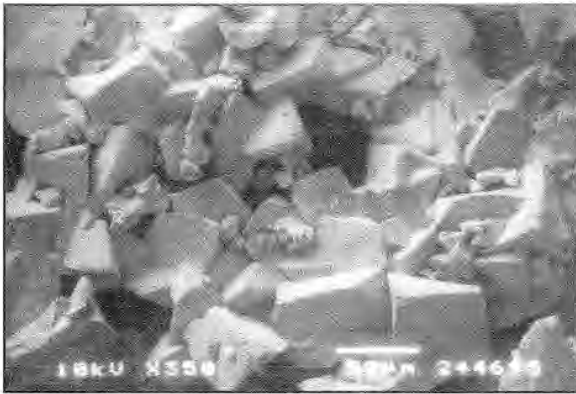


Fig. 4 - SEM image of a characteristic calcite aggregate from sample 1

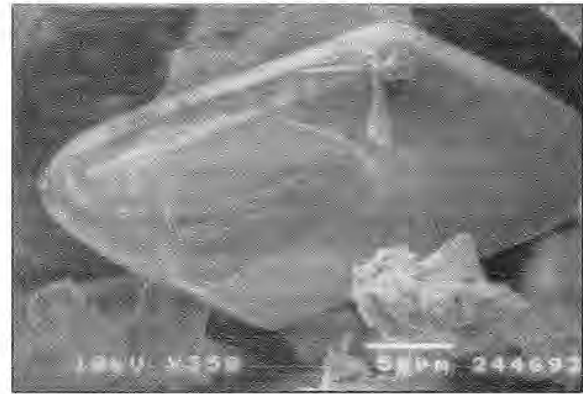


Fig. 5 - SEM image of a "gigantic" calcite crystal from sample 3

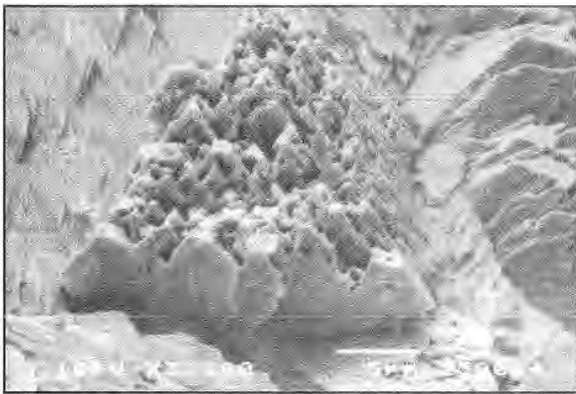


Fig. 6 - SEM image of a vertex of a crystal characterized by holes induced by insufficient crystallisation energy

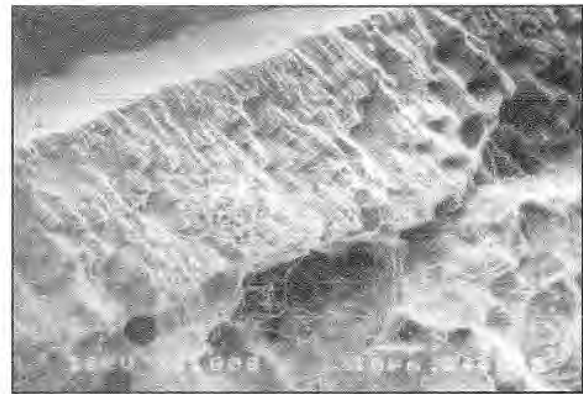


Fig. 7 - SEM image of an aggregate of calcite crystals of sample 3 partially covered by a thin fractured crust

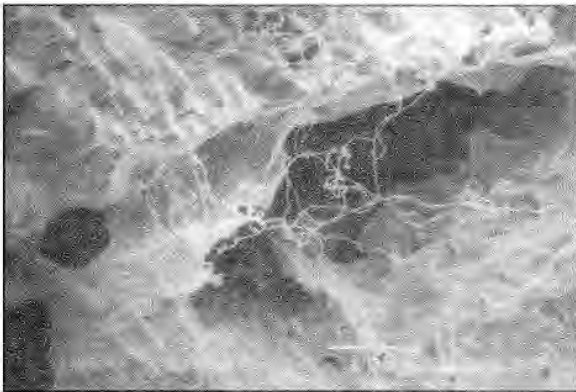


Fig. 8 - SEM image of filaments growing over the crust covering calcite crystals of sample 3

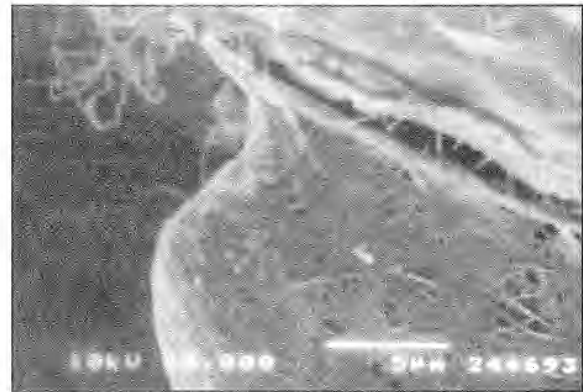


Fig. 9 - SEM image of a "biogenic nest" in sample 3

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flow were detected (below 1 cm/s) at the entrance, sometimes directed inside and outside the cave. Such a flow may be due either to a "barometric cave" (i.e. the air moves inside or outside according the change of the atmospheric pressure outside) or to a chimney effect with a lower entrance is due to small fractures or the porosity itself of the rock. The phenomenon of the acoustic resonance was excluded because the time interval between the change of direction (inflow or outflow) of the air was too long with respect to the intervals (some minutes) due to this phenomenon.

A series of thermometric measurements inside the cave resulted in a uniform air temperature around 19.5°C all over the cave, sometimes with local changes around one tenth of Celsius degree. Such uniformity also

in the vicinity of the entrance is a proof of a rather stable equilibrium of the cave from the energy balance point of view. Therefore the presence of visitors and the lighting system should not alter such equilibrium.

Experimental

Three samples have been collected in the cave (Fig. 3):

- 1 From the remnant of a ridge in the middle of the main flat chamber.
- 2 From the ridge of the rimstone pool in the same chamber, towards West.
- 3 From a whitish rock towards the "Paso de la Muerte"

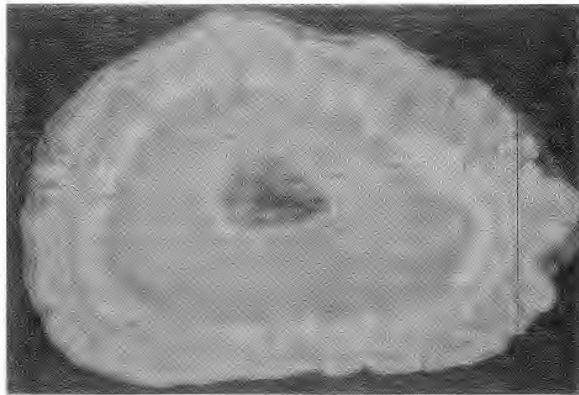


Fig. 10 - Cave pearl with a serpentine nucleus (size 13 mm)

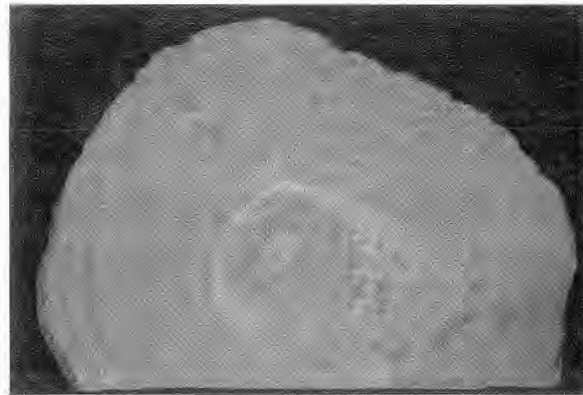


Fig. 11- Cave pearl is composed by the coalescence of at least three pearls.

These samples are quite similar and normally consist of small aggregates of eudral crystal of calcite (Fig. 4), even if larger isolated calcite crystals have been rarely observed (Fig. 5). Under a higher enlargement it is possible to see that many vertices of the crystals in samples 1 and 2 have a "skeleton" structure (Fig. 6) with many triangular cavities suggesting an extremely fast growth without the possibility of keeping a eudral structure. In sample 3 such structures if not absent are much rarer. In sample 3, unlike the previous ones, a thin crust is observed. Such a crust, characterised by dry up fractures, covers many calcite crystals (Fig. 7). In addition this crust supported biogenic activities as confirmed by filaments (Fig. 8) and complex structures (Fig. 9) having an evident bacterial origin. X-ray analysis confirmed that samples 1 and 2 are composed exclusively by calcite, while in sample 3 also traces of gypsum were found.

In point 4 of Fig. 3 two calcite cave pearls were collected in two different rimstone pools. They are whitish with a botryoidal structure with diameter around 7 cm. After having been sectioned and polished, one has a serpentine nucleus (size 13 mm) while the others is composed by the coalescence of at least three pearls possibly with nuclei smaller than 1 mm. Both pearls' calcite layers are alternately "thin and compact" and "thick and porous", sometimes botryoidal without any sign of successive solution or erosion.

Discussion

The experimental results show that the cave powder samples 1 and 2 are quite identical and therefore also their origin should have been the same. Sample 3, on account of the presence of larger crystals, of gypsum traces and organic material, and the absence of "skeleton" structures, implies an evolution different from those of the previous samples. The purity, size and imperfection of the crystals of samples 1 and 2 support the hypothesis of a growth by a fast deposition due to a fast release of CO₂ in the atmosphere from water with a relative high concentration of CO₂, probably of thermal origin. The precipitation was due to physical chemical processes only, which justifies the purity of the deposited calcite.

The evolution of sample 3 should have been slower and more complex. Larger sizes of the crystals, together with the absence of "skeleton" structures support the hypothesis of a slow deposition under a low supersaturation. Accordingly the processes of crystal growth (bi-dimensional) were more frequent than the processes of formation of new nuclei (three-dimensional). Therefore this cave powder was formed probably for evaporation than for the diffusion of CO₂. The presence of a thin crust with traces of gypsum above many calcite crystals shows that, after the deposition of calcite, the evolution continued for a short time under dif-

ferent conditions. In fact, the calcite (also if in small amounts) was solved and re-deposited as gypsum.

Some biogenic process, as supported by the presence of hyphae and globules forms this crust, and the consequent deposition of gypsum probably implies that such reactions could have developed within the cycle of sulphur (Forti, 1989). Thus, the environmental conditions of the evolution of the cave powder should have developed in an aerial environment with the powder slightly wet by condensation water and the presence of small amounts of organic material. Then some micro-organisms could develop and produce a small amount of sulphuric acid, which corroded the calcite and covered it partially with a thin crust having some gypsum inside.

From the analysis of the two cave pearls described above it is possible to obtain some information on the paleo-environmental and paleo-hydrological evolution of the cave. The existence of very large cave pearls (up to 15 cm) is due to a very high "prompt" energy inside the rimstone pools. On the other hand the pearls did not rotate or knocked heavily among them due to the absence of erosion. Therefore the water flow in the cave should have had few but important floods to avoid that the pearls could attach to the floor but not enough strong to develop any evident erosion. The presence of rather large nuclei (Fig. 10) together with very small nuclei (Fig. 11) agrees with the hypothesis of a water flow rate reported above. In fact, during the few floods some gravel could be transported by the flowing water into the pools where, however, for rather long time intervals, small and very small nuclei would prevail on account of the low energy of the whole system. The coalescence of some pearls into a larger one is probably due to some local condition, as the shape of the pool, but it is not possible to describe any more detailed process on the basis of the present data.

The inside structure of the cave pearls is more interesting: the abundance of porous layers (sometimes quite botryoidal) is due to long intervals of partial or total emersion of the cave pearls with the development of structures resulting from the evaporation and not the diffusion of CO₂. Instead, the presence of thin and compact layers is due to intervals when the water supply of the pools was continuous and constant longer than one year.

Therefore, during the growth of the cave pearls, the hydrology of the cave was characterised by few floods and long intervals of dryness when water in the pools evaporated totally. Anyway, periods of more abundant rainfall (few years or few tens of years each) should have existed resulting in the growth of more compact layers of the cave pearls. Presently the water flow in the upper part of cave is connected to heavy rains as a consequence of more dry climate.

Conclusion

The first results of the investigations here reported support the hydrothermal origin of the cave, with a good agreement with the cave morphology. The existence of hydrothermal sources in the vicinity confirms this evidence. The cave itself shows a number of different conditions, which probably followed one after the other. In fact, successive conditions of deposition and corrosion can be observed on many formations, particularly in the part of the cave closer to the entrance.

Further researches both on the hydrothermal sources of the region and cave formations will provide more details on the processes here described.

Acknowledgements

The authors are very grateful to Orion Knox for his support and particularly for having supplied the map of the cave, and to the Corporación para el desarrollo turístico de Nuevo León which funded the visit to the cave.

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The hydrodynamic Behaviour of Cretaceous and Oligomiocene karstic aquifers of Boroujerd (West of Iran)

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In this study the development of karst in the Cretaceous limestone and Oligomiocene limestone have been compared. Both the karstic aquifers are situated in the high Zagros zone of Iran. The analyses of the recession curves of the springs of Zoorabad and Aziz bad which originate from the cretaceous limestone indicate that due to the development of the secondary

fractures the flow regime is of turbulent type. The analyses of the springs of Sarab-e- Absardeh and Sarab-e-Golumsoz which discharge from the Oligomiocene limestone due to the low karstic development is of laminar flow

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Recent exploration undertaken by S.E.L.A.S. club in the "Dersios" sink-hole at Paleochora, Arcadia

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S.E.L.A.S Club

Between the years 2003 and 2005, cavers of SELAS club have been extending the exploration done by a French team in the 1970's in the "Dersios" sinkhole of Arkadia. The sinkhole is at about 750m altitude and presents technical difficulties as there are many parallel passages ending in flooded sections. These have been explored by emptying the sumps or by

cave-diving. The expeditions of S.E.L.A.S. have doubled the depth of the explored cave and more than tripled its length. The cave presents a perfect opportunity to test and perfect techniques at relatively small depths which can then be applied in deeper caves and it is these techniques which will form the focal point of our presentation.

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ENVIRONMENT STUDY IN ORDER TO USE POTENTIAL THERAPEUTIC FACTORS EXISTING IN THE CAVITY OF ONE SALT MINE FOR THE ACHIEVEMENT OF SOME PERSPECTIVES OF SPELEOTHERAPY DEVELOPMENT IN ROMANIA.

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Health and environment problems, of allergic people and of persistence of some inflammatory broncho-pulmonary chronic diseases present a special interest in world. Both OMS and international scientific community, in previous years (1998, 2000, 2003) remarked a substantial increase of allergic people. According to the report signed by Prof. Dr.Richard Beasley (Geneva) at worldwide level are about 300 millions patients with bronchial asthma (BA). Same, the Balkan Congress of Allergology and Clinic Immunology (Bucharest, 25 May 2000) remarked a substantial increase of allergic people.

Practicing in Europe of some new directions in bronchial asthma (BA) present interest such as using of some salt mines and caves with therapeutic properties- speleotherapy. This therapy method is preponderant practiced in Central and East Europe, but also in West Europe (Beamon S, Falkenbach A, Fainburg G, Linde K, 2003). At the present moment are

about 53 underground cavities in salt mines and caves used for speleotherapy, out of which: 17- in Germany, 4- in Hungary, 3- in Czechia, 5- in Slovakia, 4- in Austria, 3- in Ukraina and 1-2 in other countries. In the salt mines with the temperature 9-24° C operate 15, in karstic caves with 9-18° C -34, and in the thermal with 27-38° C- 4 such speleotherapeutic centers (Tab.1).

It was experimental stated that the salt effect on bronchial system is of stimulation of secretion, elimination of viscous secretion, inflammation inhibition, decreasing of the irritation with produce the cough, cleaning of the mucous membrane cillium (Eberhard J.Wormer, 1999). After speleotherapy treatment an increasing of T lymphocytes number and of their functional activity, normalizing of lymphocytes B number, level increasing IgA, decreasing IgM (Simionca Iu and others 1998-2002) were remarked. It was stated that at patients with BA, in speleotherapy result

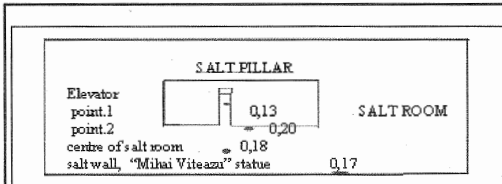


Fig.1. The beta – gamma dose debit / $\mu\text{Gy/h}$ (TLD) in elevator area, entry in salt mine

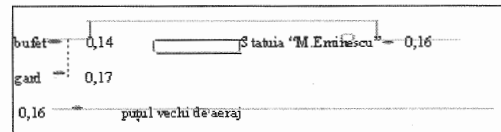


Fig.2. The beta – gamma dose debit / $\mu\text{Gy/h}$ (TLD - were located at 2 m above the salt floor) in "Old Well" area of aeration from salt mine

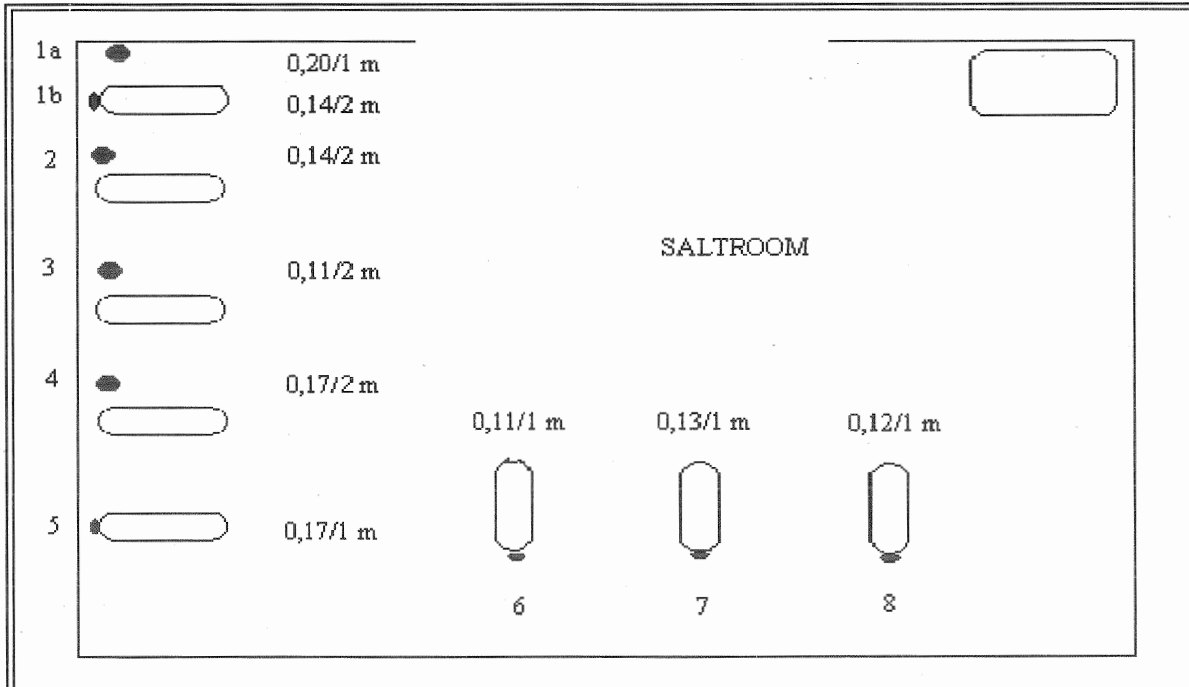


Fig.3 The beta – gamma dose debit / $\mu\text{Gy/h}$ (TLD) in "Sanatorium" area in salt mine TLD- were located at 1 m and 2 m above the salt floor

appear rarely modifications of concentration by CIC, complement and Ig (Simionca Iu and others, 1990-1998; Mohapl J, Bohac S, Weigl E, 1991).

In the last decade, through increased therapeutic efficiency of microclimatic factors from salt mines and caves, ST is used on higher scale for prophylaxis, therapy and preponderant recovery of the patients with bronchial asthma, chronic bronchitis, but also sinusitis, allergic dermatitis, psoriasis. The ST efficiency is certain at re-convalescences with burns. Experimental, ST is proved utile also in wounds therapy, including of infected and inflamed ones (Gorbenko V.P, Simionca Iu.M and others, 1985-1998; Simionca Iu.M and others, 1985-1993).

As a result of some complex scientific researches, achieved in some speleotherapeutic centers from Europe, it was established that the speleotherapy in some salt mines comprises mucolitic, anti-microbial, anti-inflammatory effect of purifying for respiratory ways and tegument, of activation the mechanisms that assure anti-infectious resistance and also (in the last 3-5 years) the hipo-sensitizer and immuno-modulator effect. Obviously that benefic effect is not the same in different salt mines and caves. This depends on the old and gravity of disease, of speleotherapeutic effect and mechanism of reminded curative factors that at its turn depends on different geo-physic, microclimatic and sanitary parameters of underground environment, of specific methodology for speleotherapeutic treatment of some diseases.

Results of analysis of underground factors from salt mine in absence of the patients and tourists and in their presence in order to determine the inter-system activities of underground environment components which form speleotherapeutic curative factors.

The salt mines from Romania is found between the hills with relative low altitudes, of 500-700 m, with a continental climate moderate of hill, with a relaxant bio-climate, sedative-indifferent, of take care. Aero-ionization with a tendency to negative ions predominance. Concentration of aerosol particles is high, with a percent of particles below 3 μm .

In medicine the salt mines Slănic Prahova and Târgu Ocna are used. In the salt mines Cacica, Praid and Turda the "tourism" is practiced. At the present, in Romania new researching and development of range is put into evidence (VIASAN,2004).

Slănic prahova resort, slănic salt mine, mine "unirea"

Slănic is situated in central-north part of Prahova county, nearby some big urban centers: at 40 km North of Ploiesti, 100 km of Bucharest, was documentary attested in year 1532 and 1685. The opening works of "Unirea" mine began in February 1938 and the operation between 1943-1970. "Unirea" salt mine presents an underground complex of galleries and rooms from rock salt (NaCl) - 14 rooms wit trapezoidal profile, 10 m opening at ceil and 32 m at base, height 54 m, with walls slope of 60 degrees. Difference of level between the surface and mine area is of 208 m. After 1970 the mine becomes touristic objective with adequate arrangements for recreation and treatment of respiratory diseases. The access in "Unirea" mine is achieved with elevator inside the well corresponding arranged for persons transport.

The environment investigations from "Unirea" mine were achieved by specialists of the National Institute of Rehabilitation, Physical Medicine and Balneoclimatology (INRMFB), in more locations.

Aero-ionization measurements were achieved after classic method, with aid of register Ebert type, based on the principle of discharging the condenser as consequence of the transport of one air volume with specific flow. The sensible element is a bifilar electrometer, Leybold type, without auxiliary field, connected with a suction device. Aerosol concentration and salt particles measurements were achieved by suction method of one air volume with adjustable pump and forced sedimentation of aerosol particles with subsequent numbering of these by microscopy with aid of ocular micrometer.

Chemical composition investigations of rock salt from "Unirea" mine were achieved by Slănic salt mine personnel through specific physical-chemical and chemical methods. The investigations of pollutant gases - through air volume suction method with adjustable pump and subsequent determination by analyze of specific colorimetric tubes (REI and SENSIDIN).

The samples for microbiologic investigations were collected at the levels 1,5 m, 70 cm and 20 cm height from "saline soil". At the collecting of air samples, Krotov apparatus was used with suction properties of the volume established by air through forced sedimentation of aerosol method with particles of 1-10 and more μm . As culture mediums for air sampling were used as follows; Simple agar-agar (G), Agar-agar-Blood 5% (GS), Sabourand Agar-agar (Gsab), Agar-agar with 6,5 % NaCl and yolk egg, Agar-agar-methylene blue (GEAM). At same levels from "saline soil", from a surface of 100 cm^2 on salt walls from the above mentioned locations, samples were collected in simple bullion and glucose for determination of microorganisms concentrations and microbiologic purity of saline surfaces.

Radiation investigations were achieved by researchers of Engineering Institute and Nuclear Physics "Horia Hulubei" (IFIN-HH), by analyze the beta-gamma flow dose measured with detectors with thermo-luminescence (TLD), the results that were read with high resolution gamma spectrometry with portable detector.

On investigations period in "Unirea" Mine, the collective was accompanied and helped by specialized personnel of Slănic Salt Mine and geology engineers - representatives of SNS "SALROM" S.A.

Results of investigations

The obtained results prove the fact that the majority of evaluated micro-climatic parameters are characteristics of salt mines from Romania. So, the temperature is relative stable in the above mentioned locations between 11,6 - 12,8°C, relative humidity - about 50 - 52 % and atmospheric pressure is different with 18 mmHg in comparison with that from outside. The speed of air currents is extremely low, in some locations - un-dosage. As consequence in "Unirea" Mine a relative cold microclimate prevails. The aeroions concentration is presenting in table 2.

Both concentration of negative ions and those positive is relatively low in comparison with the bibliographic data from other salt mines from country, single-polarity coefficient (K) being considerable low.

Flows of beta-gamma radiations dose in "Unirea" Salt Mine are lower than these measured without this.

By high resolution gamma spectrometry, radionucleids of telluric origin, as K40 and from natural series Pb214 were put into evidence in quantities below the detection limit, and radionucleid of artificial origin - Cs137, also in quantities below the detection limit. Cs137 presence may be explained by contamination with dust outside the salt mine, a part brought in precinct during the visit. The results is presenting in figure 1, 2, 3.

Investigations indicate a relative low beta - gamma dose debit on mine in comparison with outside (0,21 $\mu\text{Gy/h}$).

According to the data from Quality Department of Slănic Prahova, the salt composition preponderant from sodium chloride is remarked (%): NaCl- 97,12-97,32; MgCL2- 0,04; CaSO4- 1,57-1,64; insoluble substance- 1,03-1,16; humidity - 0,08.

In the air of "Unirea" mine by forced sedimentation method of aerosol phases with particles size of 1-10 μm a very low concentrations of microorganisms is present, with variations of total number of germens between 160 and 560/ m^3 - in elevator area, "old well" of aeration and in space destined to so-called "sanatorium" for the patients with BA.

It is remarked also the minor concentrations or in some cases lack of microorganisms conditioned-pathogen (Staphylococcus, Streptococcus, Enterobacteriaceae) and fungus. A bigger number of germens in the air

from "Genese Hall" is stated and also significant bigger - in the area of sanitary group (600 and 900 germens/m³ respectively).

The fact that the total concentrations of microorganisms is different and depend on locations (the smallest being in "old well" aeration area) and the level in comparison with "saline soil" ("floor") of the investigated air samples (the biggest concentration being at level of 20 cm from "soil") present also interest. Microorganism concentration in underground environment from "Unirea" Mine in lack and in presence of tourists / patients with BA are presented in the tables 3.

Also on saline walls from "Unirea" Mine a minor concentration of micro-organisms in the areas used by tourists and patients is stated, although must be remarked that this and spreading of germens pathogen-conditioned is more significant (Staphylococcus sp., Streptococcus Sp, Enterobacteriaceae) fact that is own to pollution from surface and possible development of some halophytes germens shapes.

Between the identified microorganisms the saprophytes are encountered: Escherichia Coli, Citrobacter sp., Enterobacter aerogenes, Flavobacterium sp, sporophyle bacteria, Staphylococcus sp (saprophyticus, epidermidis) and Micrococcus sp. Representative Saprophytes of Fungiceae were also put into evidence.

As a conclusion, the underground saline aerosol from "Unirea" Mine is a natural aseptic environment, total number of germens being lower as proposed norms for surgery rooms and is framing in the category of salt mines microbiologic values from Europe and from country, used in medical purposes.

Consequently, in the achieved study result and also of bibliographic data analyze the followings components of underground saline environment from "Unirea" Mine possible forming of speleotherapeutic factor are put into evidence:

1. Lack of vegetal allergens and of irritation inhaling noxa agents

2. Extremely low concentration of micro-organisms in saline underground environment, rarity of germens conditioned-pathogen and lack of those pathogen - presence of aseptic environment analogue to surgery room.
3. Constant temperature of air (11,6-12,8°C)
4. Relative humidity of air 50 %
5. Speed of air current is decreased: from 0,1 m/s - at un-dosage, resulting a comfortable climate
6. Low radioactivity
7. Partial pressure of O₂ is with 18 mmHg more than at surface
8. Concentration of natural aerosols with a significant percent of particles with size < 3 µm.
9. The salt mine operates as a FARADAY cavity where atmospheric changes can not penetrate → favorable effect to broncho-obstructive syndrome

The studies and tests of underground environment factors, achieved in "Unirea Salt Mine and analyze of microclimatic studies achieved by IM-FBRM researchers and those of the other institutes from country allow to put into evidence the presence of some therapeutic properties, that may be used for patients recovery with different pathologies and especially with bronchitis asthma and chronic bronchitis and also for possible achievement of correction effect of immunologic modifications at patients with bronchitis asthma - a new perspective of development of speleotherapy in Romania. Data analysis, also, allow elaboration of a complex investigations, necessary for studies of saline underground environment, in order to evaluate the speleotherapy mechanism and subsequent medical using of this.

Table 1. UNDERGROUND CAVITIES FROM EUROPE USED FOR

SPELEOTHERAPY

No.	SALT MINES	CARST CAVES	THERMAL CAVES & MINES
1.	Solbad Saltseiman, Germany, 1955	Klutert hohle, Ennepetal, Westfalia, Germany, 1950 (1946*)	Monsumano Terme, Grotta Guisti, Italia, 1971 (1942*)
2.	Wieliczka, Sanatorium "Kinga", Krakowia, Polska, 1958 (1955*)	Friedenshohle / bakebarlang, Iosvafo/ Nordungarn, Miskoltz, Hungary, 1965 (1959*)	Bad Gastein - Bockstein, Termal Gallery Mine (Rn 222) Salzburg, Osterreich, 1965 (1952*)
3.	Solotvino (Slatina) Salt Mine nr.8. Regional Alergologic Hospital, Transcarpatia Reg., Ukraine, 1968	Tapolca Seehohle (Tavarsbarlang), Hungarn, 1966	Cave of the Wind, Province of the Lucca (Southern Carfagna na (Toskany, Italy, 1990 (1989*))
4.	Slănic Praid, Harghita, România, 1972 (1955*)	Gombasecka Jaskyna, "Slovenski Kras", Slovakia, 1971 (1965*)	Free Enterprise Health Mine (Rn 222), USA, 1975
5.	Slănic Prahova, România, 1972 (1971*)	Abaliget Hohle, Pecs, Hungary, 1971	
6.	Solotvino (Slatina) Salt Mine nr.9. Ukrainian Alergologic Hosp. 1976	Magura Cave, Vidinski Okrug, Bulgaria, 1977 (1970*)	
7.	Berezniki, Perm reg., Russia (K,Na), 1977 (1975*)	Sloupskovska Jeskyna, Czechoslovakia, 1977	
8.	Târgu Ocna, Stațiunea balneoclimatică Slănic Moldova, Bacău, România, 1978 (1974*)	Bystrianska Jaskyna Banska Bystrica (Pediater. & Adolesc. Clin. F.D. Roo sevelt Hospital and SVESAN/Speleo Co.LTD, Slovakia, 1977 (1975*))	
9.	Nahicevan Salt Mine. Physiotherapeutic Hospital, Azerbaidjan, 1984 (1980*)	Oberyeiring Heilstollen, Astmayentrum, Osterreich, 1978 (1973*)	
10.	Chon-Tuz Salt Cave in high altitude (Chol-Pan, Kocikorsk District). Republic of Kyrgystan, 1987 (1980*)	Tetri-Mgvime u. Novz Aphon, Tskhaltubo, Institute of Health-Resort Treatment and Phzsioterapz, Tbilisi, Georgian, 1978 (1973*)	
11.	Bishkek Salt Cave in high altitude, Republic of Kyrgystan, 1987 (1980*)	Cave Cisarska, Ostrov u Macochz (The Children Sanatorium), Cvech Republic, 1980 (1979*)	
12.	Avan Salt Mine, Speleotherapeutic Hospital, Erevan, Armeny, 1988	Zlate Hory (Yuckmantel), Layenska, Tschechische Republic, 1982	
13.	Soligorsk Salt Mines, Republican Speleotherapeutic Hospital, Minsk, Belarus, 1990	Silbergwerkstollen, Neubulach (Nords chwarywald), Luftkurort, Schwarzwald Anzeigen, Deutschland, 1990 (1978*)	
14.	Salt Caves, Dead Sea Reg. in Israel Montain of Sedom, 1993 (1991*)	Eisensteinstolen in Bad Grund (Harz), Deutschland, 1990 (1987*)	
15.	Salzbergwerk Berchtesgaden, Deutschland, 1997	Hajnoczy Barlang, Hungary, 1988	

	Bad Bleiberg, Friedrichstollen, Österreich, 1990 (1978*)	
	Schwabische Alb, Aalen, Deutscher Speläotherapie Verband, 1990	
	Szemio-Hegy Barlang in Buda Moun tains (Szemiohegyer Aragonthohle), Budapest, Hungary, 1990	
	Mladec Jaskina Czech Republic 1990	
	Fairy Caves, (Schaubergwerk, Schmiede feld, Thüringer Schiefer gebirge; Saal felder Feengrotten und Heilstoffen, 1990 (1987*))	
	Bodenmais, Bayrischer Wald, Deutschland, 1990	
	Kurzentrums Pottenstein, Fränkische Schweiz, Luftkurort, Deutschland, 1990 (Verkehrsbüro/ Kurverwaltung)	
	Munsterial, Sudschwarzwald, Deutschland, 1990	
	Sezana Cave, Slovenia, 1991	
	Demanovska Jaskyna, Slobody, Slovakia, 1997	
	Jasovska Jaskyna, Slovakia, 1997	
	Tiefer Stollen, Fairstenzeche, Deutschland, 1998	
	Barbara Stollen, Deutschland, 1999	
	Kiliansstollen, Deutschland, 2000	
	Schindler Stollen, Deutschland, 2000	
	Hellagiack Stollen Deutschland 2000	
	Rudolf Stollen, Deutschland, 2000	
	Besucherbergwerk Prettau, Italy, 2000 (1995*)	
	Freengrotten Deutschland, 2001 (1998*)	

*- publications till the operation of speleotherapy center

Tab. 2. The aeroions concentration in Salt Mine "Unirea"

Aeroions, polarity	Concentration of aeroions on outside	Concentration of aeroions in different salt mine locations		
		Elevator area, entry in salt mine	"Old well" area of aeration from mine	"Sanatorium" area in salt mine
n- / cm ³	367	266	286	184
n+ / cm ³	245	204	143	122
The polarity coefficient (n+/n-)	0,67	0,77	0,50	0,66
Total aeroions / cm ³	612	477	409	306

Table 3. Total concentration of micro-organisms/m³ air in "Unirea" Mine, Slanic Prahova Salt Mine.

Conditions of experiment	Concentrations of micro-organisms outside, in salt mine court	Locations in mines and micro-organisms concentration / m ³ air				
		Elevator area, entry in mine, 15 tourists at distance of 5-20 m	"Old well" area of aeration from mine, 58 tourists/patients at 20 m distance	"Sanatorium" area in mine (without patients presence or tourists)	"Genese Hall" (11 tourists at distance 5-10 m)	Sanitary group (5 tourists at distance of 5-10 m)
In air : were collected at 1,5 m from "saline soil" :	960	240	160	240	600	900
Staphylococcus sp.- β-hemolyticus	4	8	2	3	2	2
Streptococcus sp. - α-hemolyticus	0	2	0	0	1	2
Staphylococcus sp. - lecytinaza (+)	2	4	0	0	2	2
Enterobacteriaceae	6	2	1	0	1	14
Fungi	0	0	0	0	0	2
were collected at 0,7m from "salt soil":	1000	240	160	400	-	-
Staphylococcus sp.- β-hemolyticus	4	10	4	4	-	-
Streptococcus sp. - α-hemolyticus	0	2	0	0	-	-
Staphylococcus sp. - lecytinaza (+)	3	5	1	2	-	-
Enterobacteriaceae	5	6	2	2	-	-
Fungi	0	0	1	0	-	-

were collected at 0,2 m from "salt soil":	1680	400	240	560	-	-
Staphylococcus sp.- β -hemolyticus	5	9	5	4	-	-
Streptococcus sp. - α -hemolyticus	1	2	0	0	-	-
Staphylococcus sp. - lecytinaza (+)	3	5	3	3	-	-
Enterobacteriaceae	9	11	1	5	-	-
Fungi	0	2	0	0	-	-
On salt stratum (ml lichide culture medium / 100 cm ²) : were collected at 1,5 m from "salt soil" :	2340	150	320	30	1600*	
Staphylococcus sp.- β -hemolyticus	24	5	10	0	30	
Streptococcus sp. - α -hemolyticus	12	2	3	0	7	
Staphylococcus sp. - lecytinaza (+)	13	4	4	0	3	
Enterobacteriaceae	127	5	2	1	29	
Fungi	0	1	0	0	7	
were collected at 0,7m from "salt soil" :	2500	180	200	220	-	
Staphylococcus sp.- β -hemolyticus	29	5	9	0	-	
Streptococcus sp. - α -hemolyticus	15	3	3	0	-	
Staphylococcus sp. - lecytinaza (+)	12	3	5	2	-	
Enterobacteriaceae	249	10	5	3	-	
Fungi	0	1	1	0	-	
were collected at 0,2 m from "salt soil":	4670	300	380	400	-	
Staphylococcus sp.- β -hemolyticus	33	11	10	1	-	
Streptococcus sp. - α -hemolyticus	11	4	3	0	-	
Staphylococcus sp. - lecytinaza (+)	21	7	8	2	-	
Enterobacteriaceae	292	20	15	10	-	
Fungi	14	2	1	0	-	

*Humidity flaw on salt stratum (6 m²) In "Old Well" area

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The structure of the therapeutic (speleotherapeutical) factor in the salt mines - primordial element in speleotherapy mechanism and effect

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The anthropic changes and the environment pollution represent some of the factors "trigger" and risk in the bronchial asthma. The environmental factors, this time in the underground environment in caves and salt mines, have the role of reducing the sensitizer effect of the allergens with a therapeutic action for the human body.

Speleotherapy of patients suffering from bronchial asthma and other illnesses - the therapy in the underground environment in some caves and salt mines with curative properties is efficiently practiced in Europe and it succeeded to be impressive in the therapy of some pathologies. We also mention that its effect is different depending on the multitude and quality of underground environment component parts in the cave or salt mine.

In this paper the author presents the point of view concerning the role of the cavities parameters in the salt mine in order to form the curative factor for the underground environment and the speleotherapeutical mechanism.

On the basis of the studies in this domain, effected in many salt mines in Europe (Solotvino-8, Solotvino-9 sub-Carpathian Ukraine; Wieliczka Poland; Cacica and Slanic Prahova Romania) several categories of salt underground parameters were discovered, with an important role in the formation of the environmental factor with curative properties - speleotherapeutical and which allow establishing a concept of efficient and secure structure of the speleotherapy center in different salt mines. These parameters form a complex geophysical-chemical and biological system of the underground environment, among them remarkable are:

1. The existence of some admissible values of the geomechanical, geophysical, rheological, mineralogical and geochemical parameters in the salt mount and excavated cavities for the presence of some groups of patients or tourists, as well as the stability of these parameters.
2. The absence of the underground water in potential destructive quantities, as well as the absence of other geological factors (such as creep phenomena) that could affect the safety of the excavated cavities and could lead to their crash or to other underground disasters.
3. The salt chemical composition, the physical, mechanical and rheological properties, the granulometric structure shouldn't affect stationed people in the mine cavities. The salt should be mostly formed (90-99%) of sodic chloride.
4. The absence of the toxic substances in the salt mounts and excavated cavities, as well as the polluting gases, whose presence could

have a similar effect as the "trigger" factors and which could cause different pathologic reactions of the human body, including allergic reactions with bronchial spasm at the patients suffering from asthma.

5. Microclimatic parameters with values in the "comfort area"; prevalent negative ionization.
6. The absence of pathogen microorganisms, conditioned pathogen microorganisms or the absence of the saprophytic embryos - possible etiological factors of the inflammatory process or possible allergens; the total concentration of microorganisms - up to 1000/m³ air (preferable 100-300 embryos / m³ air). The presence of the antibacterial effect and of the self combing out possibility of the underground environment in cavities.
8. The absence of the allergens with chemical, vegetal and animal origin.
9. The measure of the particles in the salt aerosols - prevalent under 5 mkm (preferable 0.5-3.0 mkm); concentration - 1.5-7.0 mg/m³ air.

The relations between systems: the depth of underground cavities in the salt mine dedicated to speleotherapy - the salt walls of the underground space and their chemical composition - the air chemical composition and the salt aerosols structure - ionization - microclimatic parameters - microflora concentration and variety - the absence of allergens - anthropogenic activity - geomechanical, geophysical, geochemical and microbiological stability in the salt layer and of the cavities in the mine - natural and/or artificial regeneration of the underground salt environment - the presence of the properties useful for speleotherapy and/or touristic scope form, in the author's opinion, the base of the curative (speleotherapeutical) factor in the underground environment of the salt mine.

The existence of these systems' relations between the parameters of the salt underground environment ensures the mechanism of speleotherapy and the clinical, mucilaginous, antimicrobial and anti-inflammatory benefic effects, the effects of cleaning the breathing lines and tegument, the activation of some mechanisms that ensure the resistance anti-infection and appropriate immunity status, the effect of hypersensitizing of the human body and of regeneration of the injured and infected tegument - results obtained clinically and experimentally, most of them disseminated and confirmed through studies of other authors in different speleotherapy centers (in salt mines and caves).

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Natural and artificial air ionization in underground spaces - an environmental factor with therapeutic potentialDr.phys. ENACHE Liviu^{1,2}, Chem. FILIPESCU C.³, Dr.b., Ph.D.SIMIONCA Iu. (Ghe.)^{1,2} Dr.Biol.BOTEA SIMONA³, Biochem.HOTETEU M.¹, Dr.med. KISS Ja.¹, Dr.chem. PETEC CĂLIN Ghe¹, Chem. ROGOJAN Rodica¹.¹ National Institute of Recovery, Physical Medicine and Balneoclimatology, Bucharest, Str. Sf. Dumitru, nr. 2, sect. 3, Romania;² Romanian Permanent Commission of Speleotherapy, Bucharest;³ "Victor Babes" National Institute of Research and Development in Pathology and Biomedical Sciences, Bucharest, Splaiul Independentei nr. 99 - 101, sect. 5, Romania;**Abstract**

The paper makes a review on the aspects regarding the characteristics, the action, the effects, and the importance of the electric climate - the natural and artificial air ionization - on living organisms. The underground

spaces, represented by caves and mines (salt mines, particularly), present some physical characteristics that could be valorized for the treatment of some specific diseases - one of the main speleotherapy purposes.

The paper presents data regarding the natural and artificial air ioniza-

tion characteristics in some salt mines and caves from Romania, some of them with therapeutic destination.

Keywords: air ionization, salt mines, speleotherapy.

Introduction

The environmental situated nearby the soil, there where the majority of living organisms live, is characterized through many characteristics out of which some are of physical-chemical nature and others of biological nature. All these factors are in a closed interdependence and fulfill some specific roles. Any quantitative and qualitative modification of environment characteristics, over some limits, evidences its presence at the level of one living organism as different shapes.

From physical factors of aerial environment, in frame of electric atmosphere for beautiful weather, an important role is given to natural ionization of the air. This aero-electric parameter presents many valences as a consequence of the influence and direct and indirect effects on living world, favorable or unfavorable, depending on the intensity, exposing period, or its characteristic features.

The first remarks regarding the existence of aerial gaseous ions were made since 30's of past century, the researches were taking again and elaborated then after 50's by different collectives, that put into evidence the existing relation between the content of small ions from air and pollution of respective atmosphere, and also the fact that almost daily lack of a sufficient quantity of small negative ions of oxygen in work and rest places is a cause of appearance of one unavoidable disorder, often severe, of health state.

A significant number of researches confirm the existence of connection between this electric parameter of the air and a series of biologic effects shown on different stages of organization of living world, from cellular level up of that of organism.

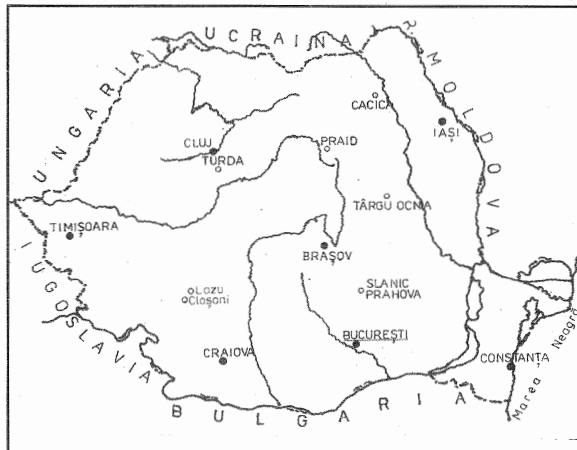


Figure 1 - Location of salt mines and caves on Romanian territory.

The researches achieved in the last decades in Poland, Austria, Ukraine, Slovenia, Slovakia and others, but also in Romania, regarding the physical-chemical characteristics of caves and salt mines microclimate point out the fact that this may carry on favorable effects on organisms and recommend it for its valorization in the treatment of some diseases (speleotherapy).

The features of air ionization from these underground precincts, together with microclimate ones, contribute at defining and completion knowledge of the specific physical conditions of these in order to be used for therapeutic purposes [1, 3, 6].

The paper proposes to present the results regarding some characteristics of underground environment (temperature, humidity, pressure difference, air ionization and others) from some salt mines and caves from Romania (figure 1) in order to use them in balneo- and speleotherapeutic purposes [4, 5, 11, 12].

Theoretical aspects regarding the natural and artificial ionization of the air

Air ionization consists of existence in surrounding atmosphere of different types of ions, gaseous mainly, as shape of some molecules electric loaded (positive and negative), of different dimensions and movement speeds (mobility), that which make possible ions classification in more categories [2, 7, 8].

Ions existence is the result of interaction between the physical factors, generators of aerial ions, on one hand and on the other hand of air molecules. Generators factors for troposphere air are represented of radioactive elements from soil and air, and also of cosmic and solar radiation that through corpuscular radiations (α , β) and electromagnetic (γ , roentgen) released directly or indirectly, assure the energy necessary to neutral molecules of gases and water vapors from atmosphere [9, 10].

Ionization phenomenon of these molecules is complex and is achieved in more successive stages, at its final different categories of aero-ions may be generated.

In initial stage, primary ions are produced, for example the oxygen ones.

If the electrons have sufficient kinetic energy, then others category of ions may appear.

Following to these reactions in atmosphere may appear aerial ions as follow: H^+ (H_2O), $(H_3O)^+$ (H_2O), O^+ (H_2O), OH^+ (H_2O)_n and others.

From secondary ionizing agents, the processes of water fragmenting present especially importance (breaking in micro-particles, spraying through fine jets of water, breaking of the pellicles of air bubbles from water surface, evaporation process, breaking of ice crystals through collision and others), processes and physical phenomenon known in meteorology.

Between the action of generator factors and those which lead at ions recombination (destroying) a balance is established, reflected sometimes in existence of one regime of air ionization and in considered place. In the table 1 some values of negative ions concentrations registered in different places, are presented.

Table 1 - Negative ions concentration (c) in different places.

Place	c (ions/cm ³)
Nearby a cascade	50 000
At mountain	4 500 - 8 000
In some balneal resorts	3 000 - 4 000
After lightning	1 500 - 2 500
Outside the town	500 - 1 000
In town	< 500
Modern typical office	350
Closed vehicle in movement	200

Except natural ionization, through different types of generators apparatus, ions concentrations of both polarities (in limited spaces) that may attain high values, arriving at a few millions ions/cm³ may be obtained.

Materials and method

In order to appreciate local specific characteristics an important role revenue to knowledge of microclimatic conditions from these under-

ground precincts. Microclimatic determinations inside salt mines were achieved with Assmann psychrometer (temperature and relative humidity of air) mechanical anemometers with buckets and pallets (air speed) and with an aneroid barometer (difference of atmospheric pressure because of level difference Δh in comparison with entry in salt mine). Thermal comfort appreciation through °TEE determination (temperature equivalent effective) was made in accordance with corresponding nomographic calculation method.

For the determinations regarding air ionization in the salt mines and caves from Romania the classic method was used (electrometric). The measurements made at Slănic Prahova, Cacica and Târgu Ocna salt mines and also in Lazu, Cloșani and No.2 caves (the remarks were made in the National Institute of Recovery, Physical Medicine and Bioclimatology, Bucharest) were achieved with aid of one ions register of Ebert type, based on the discharging principle of one electric condenser, provided

with a bifilar electrometer, Leybold type, without auxiliary field, connected with a suction air device, with a volume flow corresponding to measured ions category.

The remarks followed stability of small negative and positive ions concentrations (more important as therapeutic aspect) and were made through incidental measurements in different seasons of the year.

Results

Cacica salt mine (old salt mine) from Suceava County, is located in a region with hills with a bio-climate preponderant sedative. In frame of the salt mine some applications climato-medical are carried out.

The microclimatic remarks developed in the course of time in the above-mentioned salt mines, and also in three caves (Mehedinti county) from Romania are summarized in the table 2.

Table 2 - Microclimatic data regarding some salt mines from Romania

Salt mine/ Cave (Δh , in m)	Air temperature (°C)	Relative humidity of air (%)	Air speed (m/s)	Pressure difference in comparison with outside (mmHg)	Thermal comfort (°TEE)	Measurements period
Cacica (-38;-58)	9,5 -10,0	54-55	<0,1	+7 ++8	9,5	III,1979
	10,2-10,4	76	<0,1	+5	9,5	VIII, 1999
Slănic Prahova (-210)	11,6-12,8	61-75	<0,1	+18++20	12,0-12,5	V,IX,1972
	10,0-1,6	50-51	<0,1	+18	7,9-11,2	XII, 2004
Târgu Ocna (-15)	11,7-12,4	67-74	<0,1	<+1	11,5	VI, 1972
	9,0	74-75	0,2-0,3	<+1	10-12	XI, 1993
Praid (-100)	15,6	59	0,07	+12	13,5	1980
	15,2-15,4	70-72	0,47	+8++9	14,3-14,4	X,1989
	15,4-15,8	70-72	0,26-0,50	+8++9	14,5-14,6	VI, 1990
Turda (-60)	7,2-10,5	60-76	0,0-0,4	+1++2 (superior level)	7,1-10,4	III, 1989
	9,5-11,2	72-80	<0,5	+5++6 (Rudolf room)	9,1-11,0	VII, 1989
Lazu	8,9	93	0	-	-	IX,X,1983
	12,0	90	0	-	-	VIII,1984
	7,9	92	0	-	-	VII,1985
Cloșani	11,5	95	0	-	-	VII,1985
Nr.2	17,0	72	0	-	-	VII,1985

The air ionization determinations (in the area of underground lake) achieved with preliminary character, indicate big values (the biggest in ratio with the others underground locations) of ions concentrations: n_+ = 1500 ions/cm³, n_- = 1300 ions/cm³, k = 1,15. The continuation of aero-ionization measurements is imposed.

Measurements of air natural ionization are presented in table 3.

Slănic Prahova salt mine ("Unirea" salt mine) is found in the resort with same name situated on Slănic river valley, at about 45 km North of Ploiești, at an altitude comprises between 380 and 430 m. The locality is characterized by a hills climatic, with small annually amplitudes of main meteorological parameters.

The salt mine for some therapeutic activities is situated at 210 m depth, in frame of some large rooms with a trapezoidal profile (height of 60 m), with walls having smooth surfaces.

The remarks regarding air ionization from the salt mine put into evidence the fact that the values of ions concentrations, although constant, are relatively small and they were modified in time. Thus, positive ions that were presented concentrations over 350 ions/cm³ after measurements from 1972, were decreased at almost half in 2004 and those of negative ions were diminished in a small measure. The lowest concentrations were remarked in the point "Hospital" in comparison with the others measurement points (aeration well, elevator). It was also stated the fact that, in

the remarks from 2004, air ionization was preponderant negative, aspect sustained by single-polarity coefficient, of which size was presented a sub-unitary value.

Târgu Ocna salt mine is situated in the area of Oriental Sub-Carpathians, at an altitude of about 280-400 m, on Meadow Troțuș (at confluence with Slănic river), at about 14 km of Onești city. Under climatic aspect the locality is situated at limits between climate of hills and that of middle mountains.

The spaces destined for speleotherapy have the shape of a series of precincts with dimensions of 8x8x12m³ with unfinished walls (with rough aspect).

The air ionization determinations put into evidence a modification (decreasing) in time of the concentrations for small ions both positive and negative. The measurements from 1972 (the most complete) shown that air ionization from salt mine is comparable with that from surface, with values of 600-800 negative ions/cm³, 450-700 positive ions/cm³ respectively, the ratio between positive and negative ionization is maintained especially constant, at about 1,12, the data presenting a very small spreading.

Praid salt mine (old salt mine) is situated in the locality with same name from Târnava Mică valley, at an altitude of 500-550 m and located in a large depression surrounded of hills with middle heights (600-750m).

The local geographical conditions determine a continental moderate climate of large mountain depression, with relative cold summers and cold winters.

Table 3 - Natural ionization of air from some salt mines and caves from Romania

Locality	n_+ (cm^{-3})	n_- (cm^{-3})	n (cm^{-3})	k	Period
Cacica (Suceava county)	1500	1300	2800	1,15	VIII,1999
Slănic Prahova (Prahova county)	350-450 120-250	275-340 180-270	650-750 300-520	~ 1,3 0,5-0,9	V,IX,1972 XII,2004
Târgu Ocna (Bacau county)	600-800 250-400	450-700 220-330	1050-1500 470-730	1,12-1,48 1,00-1,25	VI,1972 XI,1993
Praid (Harghita county)	-	-	413-610	1,14-1,53	X,1989;VI,1990
Turda (Cluj county)	-	-	450-850	1,0-1,5	II,VII,1989
Lazu (Mehedinți county)	370 450	410 490	780 920	0,89 0,92	IX, X,1983 VII,1985
Cloșani (Mehedinți county)	570	530	1100	1,07	VII,1985
Nr.2 (Mehedinți county)	245	245	590	1,00	VII,1985

Air ionization in different points (entry, central area at intersection, sanitary point) indicates moderate values of total concentrations of ions (positive and negative) comprised between 413-610 ions/cm³ and a coefficient of single-polarity (k) contained between 1,14 and 1,53. Higher concentrations were stated at salt mine entry and the lowest in treatment area.

Turda salt mine is situated in west of Transilvania Depression, with reduced altitude (335 m), characterized by a moderate continental climate, with steppe character, of hills.

Natural total aero-ionization varies between 450-850 ions/cm³, being maxim in the upper area of Rudolf room, at aeration hole 2 and minimum at soil level from Rudolf room. The ratio of single-polarity varies between 1,0 and 1,5, that which prove positive ions predomination.

Air ionization determinations from the three caves indicate values relative average of ions concentrations, comparable with some areas situated in free atmosphere, unpolluted. Smaller values remarked in Lazu caves (season 1983) in comparison with the measurements are because increased humidity of air (93 %).

In some salt mines (Tg. Ocna, Sl. Prahova) studies were also achieved with artificial aeroionization, in therapeutic aims.

Conclusions and recommendations

1. The salt mines from Romania are appreciated as relative cold (10-12°C) with low speeds of air currents (absence of air currents or speeds much below 0,5 m/s), depending on aeration system of salt mine, with relative moderate humidities (60-70 %), higher humidities of air are registered in the three researched caves. Air pressure inside these precincts varies depending on the outside pressure and of level difference in comparison with the surface.

2. The microclimate is, generally, characterized by a big constancy or a very low variation both inside space and in time of meteorological parameters such as the temperature, pressure difference depending on outside and air movement.

3. Air ionization for every salt mine is distinguished through a very small spreading of the concentration values remarkable smaller than at surface.

4. Differences are stated between the values of ions concentrations between different salt mines, especially as consequence of salt mine operation mode. Smaller values of ionization may be owe both to low content of radioactive elements of salt rock and operation mode and also of final processing of these precincts walls. There where the walls are presented with irregular aspect of surfaces (Tg.Ocna and Cacica salt mines) ions

concentrations are higher than in the precincts with walls with smooth surfaces (Slănic Prahova salt mine). Crystals breaking is accompanied of generation of electric load, which arrive then in inside air through evaporation, because of the sharp edges and corners of salt crystals.

5. Continuation of aero-ionization measurements is imposed for measurements completion, data updating and their corroboration with determinations of spatial load, saline aerosols.

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Recent research into Vjetrenica cave (Bosnia-Herzegovina) and the current view of the cave regarding its candidature for the World Heritage ListIvo Lučić¹, Darko Bakšić², Jasminko Mulaomerović³, Roman Ozimec⁴.¹Speleological Society Vjetrenica - Popovo polje, 88370 Ravno, Bosnia & Herzegovina, ivo@vjetrenica.com, ²Speleological Section of University Mountaineering Club Velebit, Radićeva 23, 10000 Zagreb, Hrvatska, baksic@sumfak.hr; ³Speleological Society Speleo-Dodo, Branilca Sarajeva 30 71000 Sarajevo, Bosnia & Herzegovina jasminko_mulaomerovic@hotmail.com ⁴Croatian Biospeleological Society, Demetrova 1, 10000 Zagreb, Hrvatska, roman.ozimec@zg.htnet.hr

Vjetrenica is the largest and most interesting cave in Bosnia and Herzegovina, developed in the deeply marked Karst of the southern Dinarid massif, in the final part of the course of the canyon river Trebišnjica. It has been the subject of research and exploration throughout history. It was proclaimed to be a natural monument in 1950, the first in Bosnia and Herzegovina. After this proclamation, modern exploration followed to draw up plans to make it accessible for tourists. In 1964 a tourist path was opened and electric lighting set up over about 1050 m of the cave, a motel was opened and tourist guides began work. In 1991 war broke out in Bosnia and Herzegovina. Vjetrenica was one of the first places to be affected by the war, all its tourist installations and all the buildings were destroyed, and even the Institute for the Protection of Cultural and Natural Heritage in Sarajevo, where documents on Vjetrenica were destroyed by fire. Over the past five years, after a ten-year break caused by the war in Bosnia and Herzegovina, research into Vjetrenica has been going on, and this has resulted in some important new discoveries related to the picture of the cave. A new speleological plan of Vjetrenica has been made, which has corrected some earlier erroneously defined situations, and this formed the basis for a monograph entitled "Vjetrenica, a glimpse into the Earth's soul" which covered, systematized and presented all the knowledge about Vjetrenica available at that time. This particularly relates to information about fauna, where Vjetrenica is the second in the world in terms of biodiversity. After the monograph the speleological research continued and comprehensive bio-speleological research launched including drawing up an inventory of habitats and fauna, and the recently introduced all year round ecological monitoring. All these events concerning Vjetrenica have been accompanied by enviable publicity in Bosnia and Herzegovina, where there is a need and desire for perspective and more positive news. The basic tourist program has been restored and the idea born of entering Vjetrenica as a candidate for the World Heritage List, and this has been done. Efforts are now being made to gain public support for the building of an institution which would work on this idea in an organized manner, and also the idea of setting up a multi-functional center for Karst, which would organize research, education, tourist activities and environmental protection.

Vjetrenica is the biggest, the most famous and the most explored cave in Bosnia-Herzegovina. It is situated around the middle of the western edge of Popovo Polje, some 12 km from the Adriatic Sea.

«Wind» and the local tradition

Vjetrenica got its name thanks to the fascination of the people with a strong «wind» blowing from cave during the warm season, and with somewhat weaker «wind» blowing into the cave in the winter (vjetrenica = wind cave). Scientists and adventurers were equally fascinated. Here are some examples of visitors' impressions of the «wind»: «The noise is louder than a thousand steam machines» (Ayala 1850); or: «Compared to the hurricane blowing from the cave, the northern wind called bura is but a spring breeze». (Riedel 1888). What the local people thought of the «wind» can be seen from the traditional legends with all sorts of fairies and other creatures supposedly living in the cave. During history, the nobles took the cave over from the fairies. They built a summer residence on its entrance and used the «wind» as a unique cooling system. Anybody

who spent a hot summer day in Herzegovina Karst can confirm the importance of the invention. This is the feeling that has eventually started to attract a completely new kind of visitors - tourists.

The history of exploration

The first known scientific work about Vjetrenica dealt with its unique air circulation. It is *Historia naturalis* by Pliny the Elder, in 77 AD (Plinio Secondo 1884). In his work he mentions a cave in Dalmatia, which could be Vjetrenica. This theory is supported by one of the most famous renaissance biologists Ulisse Aldrovandi from Bologna: on the margins of a letter by the duke of Ston (Dubrovnik seaside) Jakov Sorokočević, (written somewhere between 1580 and 1584), he added the Pliny reference (Grmek, Balabanić 2000). At the same time, the duke of Dubrovnik and philosopher Nikola Gučetić in his *On Aristotle's meteors* (1584) mentions a cave with a strong wind in Popovo polje. This reference is the starting point for the scientific cave exploration in Bosnia-Herzegovian and Croatia.

In 1888 the first modern study of wind was conducted: Austrian engineer Riedel wanted to create a wind-propelled mill. Two years later Hristifor Mihajlović, a monk from the nearby monastery drew the first ground-plan of the cave. Since then, six speleological drawings of Vjetrenica are known have been made.

In the first quarter of the 20th Century the first comprehensive modern research was conducted to discover the Vjetrenica we know today: Czech geographer, biologist and archaeologist Karel Absolon was the first to explore every part of Vjetrenica between 1912th and 1914th (Absolon 1916), later to be measured, described and explained by Mihajlo Radovanović (1929), co-worker of Jovan Cvijić.

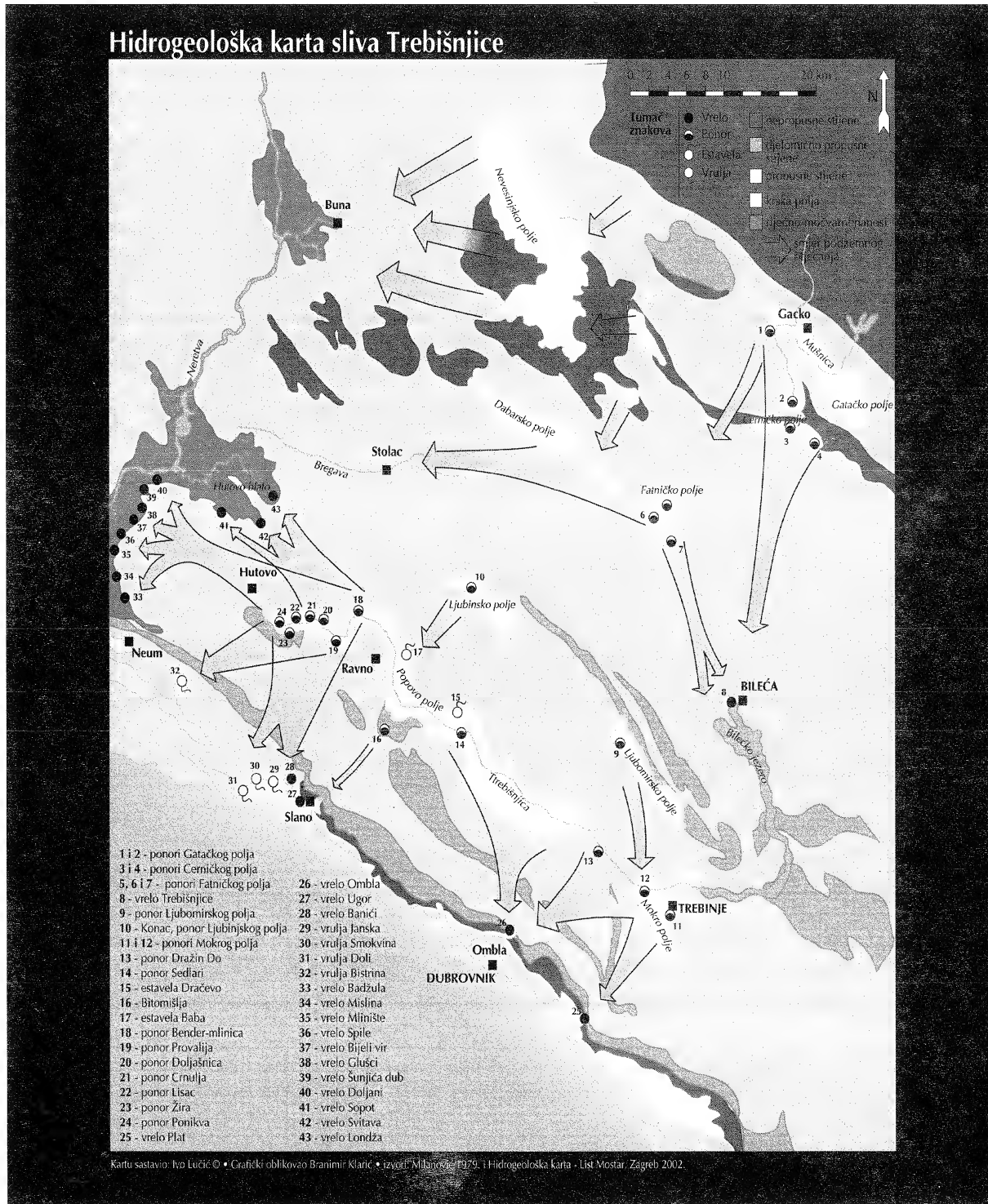
Absolon was especially interested in subterranean fauna: he visited Vjetrenica 27 times and found as many as 47 organisms there. In the nearby Bjelušica he found as many as 51 organisms! (Pretner 1976). His work marked the beginning of a wave of modern biological explorations throughout the 20th Century, the most successful being the research of Stanko Karaman in the thirties and early fifties. Also, the work of a series of Slovene researchers must be mentioned, Egon Pretner and Boris Sket among many others (Lučić 2003). Sket has explored, documented and described Vjetrenica in biospeleological terms, his most recent work was published in a 2003 monograph. Early second half of the 20th Century saw some paleontological exploration in Vjetrenica: bones of some 10 species of prehistoric animals were found, including a complete skeleton of a leopard (*Panthera pardus*) (Malez & Pepeonik 1969), the only such find in the area and scientifically the most interesting.

Karst in the Trebišnjica region

Vjetrenica developed in the deeply marked Karst of the southern Dinarid massif, in the final part of the course of the river Trebišnjica, once the longest underground stream in Europe. The Karst here is made of some 5 km thick blocks of carbonate layers. According to the basic geological map of the Popovo polje area (Čičić, 2003) it was created in Jurassic and Lower Cretaceous limestone layers with interbedded dolo-

mite. In some parts of Popovo polje, limestone is 99 percent calcite. The rocks are exposed to heavy geodynamics: annually they move some 2 cm northwards, which causes change in their compactness, told Croatian geologist Eduard Prelogović. Drainage basin goes almost from the highest peak in Bosnia-Herzegovina, Maglić (2386 m) on the eastern border

of the country, to the Adriatic Sea, to the South. That is why this area is 45 times bigger than Popovo polje (Vlahinić 2004), with Vjetrenica on its edge. If one adds 2500 mm of rain annually, one gets ideal situation for the development of Karst.



Picture 1. Hydrogeologic map of the Trebišnjica river-basin, (Took from «Vjetrenica - pogled u dušu zemlje»)

Explanation of colours/signs on map:

- Brown - impermeable rock
 - Blue - semi-permeable rock
 - Light-blue - permeable rock
 - White - Karst valley
 - Yellow-brown - river and marsh alluvium
 - Arrow - direction of subterranean drainage
 - Ponor - swallow
 - Vrelo - spring
 - Estavela - estavelle
 - Vrulja - submarine spring
- Note: Vjetrenica is near Nr. 16

Vjetrenica and modern hydrology

Experts think that the tectonics and specific hydrology of Popovo polje had the main role in forming this cave. Geomorphologists think that Vjetrenica used to serve as a drain for the water flowing from Popovo polje towards the Adriatic (Radovanović 1929) (Čvijić 1950). Subsequent carstification towards the edge of Popovo polje created a series of ponors with several hundred of kilometers of underground channels that lead to a series of springs and wells in the lower part of Neretva area and in Dubrovnik area on the Adriatic Coast, where they emerge as springs and submarine springs. Further carstification along Trebišnjica river created more than 500 small and big ponors and estavelas (Milovanović 1979)

Table 1. Channel lengths in Vjetrenica

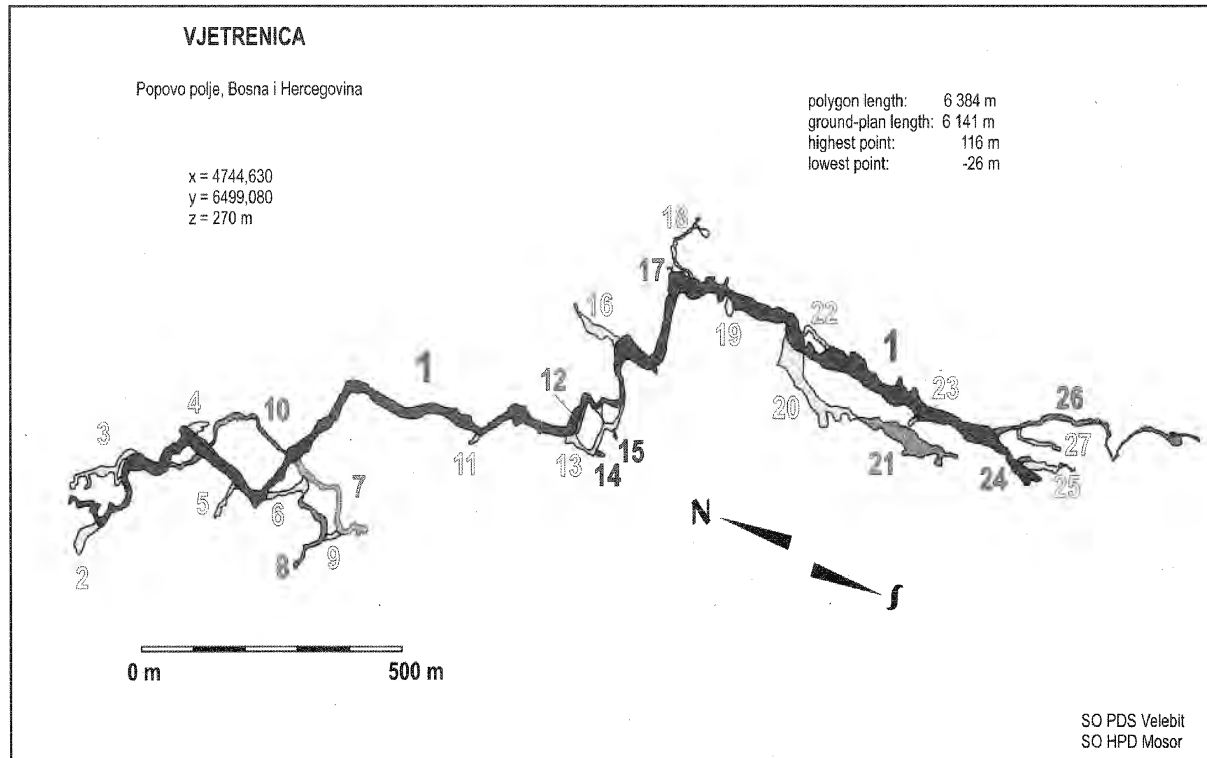
No	Name of channel	Polygon length	Ground-plan length	
1	Glavni kanal	2465,9	2433,0	
2	Vilino gumno	67,3	67,2	
3	Donja Vjetrenica	391,3	371,1	
4	Zlatna dvorana	44,9	43,6	
5	Niski kanal	65,8	65,8	
6	Gašparoviæev kanal	75,3	74,1	
7	Radovanoviæev kanal	234,0	223,0	
8	Gornji Absolonov kanal	180,2	173,0	
9	Spoj Radovanoviæevog i Gornjeg Absolonovog kanala	35,9	34,8	518
10	Donji Absolonov kanal	405,5	396,0	
11	Ržehakov prolaz	16,1	13,9	
12	Makaron galerija	55,4	54,7	
13	Visoki kanal	207,2	204,9	
14	Visoki kanal - Prvi desni odvojak	34,9	31,8	
15	Visoki kanal - Drugi desni odvojak	12,9	12,6	249,3
16	Velika dvorana	129,5	124,7	
17	Lijevi odvojak prije Leopardovog kanala	22,0	18,6	
18	Leopardov kanal	270,6	252,4	
19	Saljev viseæih jezera	21,7	19,6	
20	Požovo brdo - Visoki zasigani kanal do oznake Lou	234,4	209,3	
21	Velški kanal (od oznake Lou)	281,3	273,1	
22	Styx	87,6	81,5	
23	Desni odvojak iza Bijelog saljeva	43,9	38,4	
24	Lijevi odvojak prije Kanala s dubokim jezerom	30,5	30,3	
25	Kanal s dubokim jezerom	129,9	122,9	
26	Ravanjski kanal	736,1	670,9	
27	Ravanjski kanal - desni odvojak	103,9	99,8	770,7
	Sum total	6384,0	6141,0	

which today mostly take the water towards Ombla near Dubrovnik. During this period the side channels of Vjetrenica were formed by dripping of surface water, while Vjetrenica in this period was a spring, bringing water to Popovo polje. (Milojević 1938).

Speleological survey

In recent speleological research conducted in summer of 2002, 2003 and 2004. by Speleological Section of University Mountaineering Society Velebit from Zagreb and Speleological Section of the Mosor Mountaineering Society from Split, a new map of Vjetrenica was drawn up. It is a detailed map, scale 1: 500. As for the ground-plan, the length of the cave is 6141 m, while the polygon length is 6384 m. New measuring showed that the total length is much shorter than 7503 m mentioned by Radovanović (1929). As there is no sufficient data on Radovanović, it is difficult to comparatively analyse the results, but based on a comparison of the ground-plans it seems that no channels have been missed out.

Recent speleological research has shown that Gornji Absolonov kanal and Duboka dvorana are connected. The exact location of the Velški kanal has been defined, while the newly explored Ravanjski kanal has been added to the map. The new map shows a different position of Donji Absolonov kanals with regards to Donja Vjetrenica: Donja Vjetrenica seems to go in the same direction as Donji Absolonov kanal. These two channels create a single hydrological entity: water probably goes from there to Lukavac. The lengths of individual channels have been measured. (Table 1 and Picture 2).



Picture 2. Map of Vjetrenica: channel numbers refer to numbers in Table 1

Morphology of Vjetrenica

In hydrological terms, Vjetrenica has three main parts.

One: the stretch from the entrance to the Četvrti pjati (1460 m from the entrance), from there the watercourse is northbound, goes to the Popovo polje. This part of the cave, some 1000 m from the entrance has a siphon during winter.

Two: From Četvrti pjati to Bijeli Saljev where the watercourse goes underground. The watercourse is South-Westbound, the direction opposite the Popovo Polje.

Three: Ravanjski kanal from which the watercourse is North-Westbound, toward Popovo Polje. It creates an underground stream underneath the blocks of rock in the Main channel, after which the watercourse makes a sharp turn so it is impossible to tell whether it keeps or changes its direction.



Picture 3. The Main channel (Glavni kanal) of Vjetrenica - some 800 m from the main entrance, photo by Ana Opalić

Četvrti pjati is an underground watershed: the watercourse from there is northbound or southbound. It is still unclear whether the watercourse from the Ravanjski channel changes direction once it sinks. The complex situation should be explored further.

The cave was formed on the cracks stretching in NW-SE and N-S directions. The general direction of the cave from the entrance to its furthestmost point in Ravanjski kanal is S-SE (azimuth 157°). Average incline is 1.2° with the cave going up: in the horizontal distance of 2153 m it goes 45.5 m up. But if we look at the Main channel (Glavni kanal) and its furthestmost point, in relation to the entrance, then there is a slight downfall, the incline is -0,3°.

Vjetrenica is easily described as a horizontal speleological object with channels in three levels. The lowest, and hydrologically active level consists of Donja Vjetrenica, Donji and Gornji Absolonov kanal and Radovanovićev kanal. The middle level consists of Glavni kanal with side channels, stretching from the main entrance to Duboko jezero, while the third and highest level consists of Požovo brdo, Visoki zasigani kanal, Velški kanal and the southernmost parts of Ravanjski kanal. The lowest point is in Donja Vjetrenica, 26 metres below the entrance level, while the highest point is in Visoki zasigani kanal, 116 metres above the entrance level.

Majority of the channels in Vjetrenica has a lot of speleothems of various shapes, which contribute to a unique visual experience. There are flowstones, stalactites, stalagmites, curtains and sinter pools. In the oldest and highest parts of the cave one can find even some aragonite formations and crystals.

In autumn and in winter, when the temperature of the atmosphere is lower than in the cave, the air is sucked into the cave, until the temporary siphon closes. When that happens, there is no circulation of air any more. This could mean that there are higher entrances or cracks below the temporary siphon, which in turn could mean that the cave itself is bigger than

we now think The current of air at the entrance measured in August ranged from 5.1 to 9.8 m/s, average speed being 6.1 to 8.5 m/s. The strongest current was measured in the afternoon (at 14.00 hrs) with the biggest difference between temperatures in the cave (11.4 °C) and outside (29.7 °C).

Biospeleological research

Several inventories of fauna have been made so far (Wolf 1934-1937; Buturović 1951; Pretner 1963; and Mikšić 1979). According to Culver and Sket (2000), Vjetrenica with its 60 cave-limited species is the second such cave in the world, rivalled only by Postojna-Planina Cave System in Slovenia, which has 84 such species. The most comprehensive inventory of fauna and habitats of Vjetrenica and the nearby Bjelušica cave and Lukavac spring, the three being parts of a single system, has been published rather recently (Sket 2003). This study found 110 species in the system, 76 troglobionts, 36 of them terrestrial and 40 aquatic.

In August 2004 comprehensive biospeleological research was launched, including microclimate and environmental measuring nad drawing up an inventory of subterranean fauna. The research was conducted by Croatian Biospeleological Society from Zagreb. Scientists such as Gordana Karaman and Božana Karaman from Podgorica also participated in the exploration, while Boris Sket from Ljubljana supervised it all.

First analysis of the recently gathered material and comparison with the most comprehensive list of fauna in this cave system (Sket 2003) showed 17 new taxa, including seven positively and three most likely troglobionts. Three species are probably troglaphils and four are troglaxene.

The most up-to-date inventory of fauna in Vjetrenica, Bjelušica and Lukavac has 128 species, including 85 troglobionts and possible troglionts. Among them, there are 45 terrestrial troglobionts, and 40 aquatic stigmatobionts. More than nine species have been found in Vjetrenica alone, among them two monotypes - snail *Zavalia vjetrenicae* i mysid shrimp *Troglomysis vjetrenicensis*. (Sket 2003). The fauna of Vjetrenica includes



Picture 4. The beetle *Hadesia vasiceki* in its locus typicus, photo by Darko Bakšić

also the only European subterranean vertebrate čovječja ribica (*Proteus anguinus*), the only cave clam *Congerina kusceri*, the only cave serpulid worm *Marifugia cavatiaca*, etc. A rich ecological diversity within the cave includes some very unusual habitats, most especially the cave hygropteric which harbors high specialized coleopterans species, *Hadesia vasiceki* and *Nauticiella stygiva* (Leptodiranae), as well as *Niphargus* (*Amphipoda*) *Typhlogammarus mrazeki*. (Sket 2003). The most numerous are the crabs, especially *Amphipoda*, ten species altogether, (including eight *Niphargus* spp.), and also insects (11 species of *Coleoptera*), snails, etc. Vjetrenica is the locus typicus for as many as 32 troglobiontic species.

As of summer 2005, Vjetrenica will have an all-year-round environmental monitoring. Further research will positively come out with new species for the experts to study

Usage of Vjetrenica

It seems that Vjetrenica was used as a winter and summer shelter but nobody used it for living, the reason being the narrow entrance and strong wind preventing people from entering the cave. Also, one should not forget the very strong psychological effect of the wind. But the local people lived with Vjetrenica, hence the local word «pjat» (Italian for plate) for series of a sinter pools, or «čejrek» (Turkish for a quarter of dried mutton) for series of a small curtains, etc.

The beginning of the protection of Vjetrenica started around 1900, when the metal gate was first made. The same gate, slightly modified in early '60s, is still there (Ržehak 1965). Legal protection of the cave started in 1914, when the authorities issued the first Rule regarding the protection of the cave, and it was proclaimed a natural monument in 1950.

First attempts to make it accessible for tourists were made at the end of 19th Century, by monk Hristifor Mihajlović who, around 1890 managed to draw interest from scientific circles and who, by some sources, expanded the main entrance to the cave. Local ethnologist, writer and politician Ljubo Mićević created a 1250 m long path to Veliko jezero (Ržehak 1965). By the end of 1950s Vjetrenica was for the most part ready for the tourist project realised in 1964: a tourist path was opened and electric lighting set up over 1045 m of the cave, a motel was opened and tourist guides began work. According to available information, Vjetrenica attracted some ten thousand visitors annually.

A new picture of Karst

In 1991 war broke out in Bosnia and Herzegovina. Vjetrenica was one of the first places to be affected by the war, all its tourist installations and all the buildings were destroyed (Lučić 2001), and even the Institute for the Protection of Cultural and Natural Heritage in Sarajevo, where documents on Vjetrenica were kept was destroyed by fire. Over the past five years, after a ten-year break caused by the war in Bosnia and Herzegovina, research into Vjetrenica has been going on, and this has resulted in some important new discoveries related to the picture of the cave. Monograph entitled "Vjetrenica, a glimpse into the soul of the Earth" covered, systematized and presented all the knowledge about Vjetrenica available at that time.

Speleological Society Vjetrenica - Popovo polje has renewed the pre-war tourist programme, but flashlights are used at the moment, instead of electrical lighting. The B-H Academy made initiative to candidate Vjetrenica for the World Heritage List. The idea has got public support and publicity unprecedented in B-H terms when environmental issues are concerned.

What next?

Caving associations together with international experts are trying to establish modern standards for the management of Vjetrenica and other unique Karst phenomena of Bosnia-Herzegovina. A multifunctional Cen-

tre for Karst should be established, with fourfold function: research, education, tourist and protection of the environment. The idea was first heard in the summer of 2004 when Speleological Society Vjetrenica - Popovo polje, together with Ravno Municipality and the Ministry of the environment of the Herzegovina-Neretva County applied for technical cooperation, as announced by the government of Japan. Several months later the initiative was endorsed by SIBIOS, noting that future development must pay special attention to the subterranean fauna. We expect the similar support by UIS.

«SIBIOS enthusiastically endorses the candidacy of Vjetrenica in Bosnia-Herzegovina for the World Heritage list». This is the beginning of their statement which further on describes Vjetrenica as a «remarkable subterranean hydrogeological system, worthy of all of the superlatives one can muster». It stresses the importance of its biodiversity, calling it the very centre of the centre of endemisms, with a large number of cave species.

In order to protect the cave, the Speleological Society Vjetrenica - Popovo polje will be very careful in future dealing with Vjetrenica. Contact was made with the IUCN Task force for Karst and caves, and very soon work in Vjetrenica cave lighting will continue. Neil Kell from Australia describes his lighting approach as one using »as little light as possible for two reasons: firstly, to conserve the cave ecosystem, and, secondly, to reinforce the reality that it is a cave environment where darkness is the natural state».

Conclusion

Data gathered from both previous and recent research show that Vjetrenica is unique in speleological, biological, paleontological, cultural and others terms. That is why it should be included in the World Heritage list: it is not only important for Bosnia-Herzegovina and the countries of Dinaric Karst, but is also universally important for further research and protection of most interesting subterranean habitats. Also, its tourist and educational importance is noted.

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The destructive development of Alistrati Cave (Greece)

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Abstract

Financial and legal factors are related to destructive activities during the development of Alistrati cave. According to decision A1/Φ41/36829/2130/ 6-10-1995 of the Greek Ministry of Culture, the construction of an elevator at the end of the cave's touristic path was strictly forbidden. However, in 1997 and 1998 the Serres Prefecture, through several bureaucratic manoeuvres, proceeded to create a well-hole 7 m wide and installed an elevator. Soon afterwards it was demonstrated that the lift could not be used because rust prevented its function. Furthermore, landslide hazards

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did not permit the construction of a road for visitors to return to the parking lot. As a result, a silo-like tube 42 m high stands as a monument of speleological failure. This failure is due to the following two parameters: First, the enormous financing of the Serres Prefecture at almost 1 million euros was trusted to non-specialists in the field of speleology. Second, the incapability of the State directors supervising the project resulted in an ecological catastrophe for the cave's microclimate. Humidity diminished dramatically and bats may no longer inhabit the Alistrati karstic formation. To this destruction must also be added the construction of a cement

corridor 2 m wide (!) and 1200 m long prepared by an electric bulldozer which flattened the cave's stalagmitic floor. Both: the Anthropological Association of Greece and the Hellenic Speleological Society alerted the authorities to the above facts. Nonetheless the process identifying those responsible for the illegal constructions has still not started. Unfortunately the same applies to the process of restoring the cave and rescuing it from the aforementioned catastrophic interventions.

Alistrati cave was discovered during the 1970's and soon the National Tourism Organization of Greece asked the founder of the Anthropological Association of Greece, Dr Aris Poulianos, to conduct an examination for the purposes of tourist development. In addition to the Poulianos report, other Austrian and Greek speleologists undertook the explorations and provided the State with studies for the same purpose.

The development started during '90s not by a scientific team, but from the local authorities of the Alistrati village. In 26 June 1995 the late Anna Petrocheilou on behalf of the Hellenic Speleological Association addressed a report to the Greek Ministry of Culture, the National Tourism Organization and the Alistrati village. In this report she tried to give advices on how to restore several inadmissible constructions (large corridors, removal of hundreds stalagmitic columns, improper cave lightning etc). The Greek Ministry of Culture sent then an official letter to Alistrati village ordering a permanent supervision of the technical constructions by the scientists of its responsible Department (i.e. of Palaeoanthropology - Speleology). Followed the above mentioned ministerial decision A1/Φ41/36829/ 2130/ 6-10-1995, excluding the construction of an elevator at the end of the touristic corridor, as it was unnecessary for economical reasons and destructive for the cave.

In 20 August 1996 the Alistrati village asked the permission from the Greek Ministry of Culture for future exploitation of the cave. Unfortunately the Ministry replied positively according to a new policy for helping the province, but in a wrong and catastrophic way for the caves. In the meantime the Serres Prefecture got involved and received excellent funding for the works (approaching a sum of 1 million euros). Both Alistrati village and Serres Prefecture insisted for permission of the elevator's construction which proceeded afterwards in a totally illegal manner. Although

the ministerial department was informed, it did not react. Thus, during 1997 and 1998, through several bureaucratic manoeuvres, the opening of a well-hole 7 m wide and the installation of an elevator was initiated.

Soon after it was demonstrated that the lift could not be used because rust prevented its function and a landslide hazard did not permit the construction of a road for visitors to return to the parking lot. As a result, a silo-like tube 42 m high stands as a monument of speleological failure in northern Greece. Humidity diminished dramatically and bats may no longer inhabit the Alistrati karstic formation. To the aforementioned destructions must be added the construction of a cement corridor 2 m wide (!) and 1200 m long - prepared by an electric bulldozer, which flattened the cave's stalagmitic floor.

The above actions and illegal constructions were brought to the attention of the Ministry by three geologists from the Department of Palaeoanthropology - Speleology. The same actions were also denounced by the Hellenic Speleological Association and the Anthropological Association of Greece. The Ministry not only ignored these pleas, but went further and asked its Disciplinary Council to interrogate the author about his examination of the cave in 15 August 1998. The "charge" was that he visited the Alistrati cave without permission, although he had paid for an entrance ticket. Obviously such a charge was dropped, but no other investigation of the destructive development of Alistrati cave was pursued. Because of these negative ministerial actions, the Anthropological Association of Greece applied to the Advocate of the Citizens (independent State authority) which in April 2005 prepared a report admitting that the construction of the elevator was illegal. Media were also interested in the subject. The Athens newspaper KATHIMERINI (29 December 2002) and Thessaloniki TV station MAKEDONIA (24 & 26 March 2004) condemned the above mentioned acts. Nevertheless, the process identifying those responsible for the illegal constructions has still not begun. Unfortunately the same applies to the process of the cave restoration from the above mentioned catastrophic interventions.

Aris Poulianos is ready to appeal to Justice and the assistance of the International and Greek National Speleological Federations may be of a great importance.

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Introduction and tourist development of Postojna cave from 1818 - 2004

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Abstract

Postojna Cave is the longest show cave in Slovenia and one of the country's most recognisable tourist destination. The cave was discovered in 1818 and opened to the public in 1819. Since than more than 30.000.000 people have visited this underground world. The record year to date was 1985 both in the total number (942.256 visitors) and in the number of guests from abroad (757.318). The war for Slovenian's independence and the events that followed in the territory of former Yugoslavia decreased the number of visitors. Situation is getting better, so last year we achieved the number close to 500.000 visitors. In order to improve our

tourist services we decided to start 15 new projects attached to the cave and its surroundings. The cave is easily accessible also due to the unique underground railroad constructed in the distant 1873 - 74. I would like to underline that the Postojna Cave was one of the first caves in the whole world which was illuminated by the electric light already in 1884. Postojna Cave is undoubtedly a cradle of Speleobiology and among more than 80 different cave's animals Proteus Anguinus represents the misterious ruler of Dinaric Karst aquatorium. Key words: history, tourist development, projects, cave's infrastructure, Speleobiology.

Libanese D'Etudes Speleologiques (ALES) re-explored and mapped it (Beayno *et al.*, 1996). They mapped approximately 460 m of passageways.

This cave is actually an iron ore mine that was operational in the 1940's and 1950's, during the iron rush in Lebanon as one of the locals pointed out. The iron extracted was used locally. He added that the cave was used by the Lebanese militias during the Lebanese war as shelter, before it was closed by locals for safety reasons until it was reopened again after the war in 1994.

In 2002 and while the souterrainian group of SCL re-explored this cave they made brilliant discoveries. The iron ore body was found out to be hosted in a palaeocave. The iron body in this mine is in the form of thinly banded layers of hematite and limonite. The host rock is the gently dipping beds of the Sannine - Maameltein Formation of the Cenomanian- Turonain age. Removing the iron ore unraveled the different features of a palaeocave ranging from ripples on the surface of the limestone to pressure conduits. These features were observed over the length of the explored souterrain structure. It was clear that this souterrain structure was originally a cave that developed in the Sannine – Maameltein limestone Formation (Figure 4). Due to tectonic and sedimentary processes the cave was filled with iron rich deposits which were enriched by leaching and digenesis. The iron after enrichment became economically significant but the extent of the ore body was limited to the extent of the cave. Removing the iron resulted in uncovering of such an amazing structure. Finally studying the iron and if possibly dating it will unravel a great deal on the age of the cave and the period in which it developed and will give further clues on the tectonic history of Lebanon.

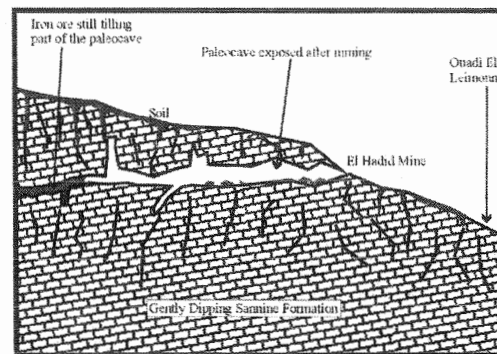


Figure 4: Sketch diagram showing the palaeokarstic cave of Mgharet el Hadid in the Sannine-Maameltein Formation exposed after mining the iron rich deposits from it.

TAR MINES

Besides iron tar was considered in the last century as one of the economically important minerals in Lebanon.

Sohmor Mine

The Sohmor souterrain, more precisely tar mine, is located south of Sohmor Village, close to Tairoun valley in Southern Bekaa. They are located at an elevation of 955 m asl. An unpaved road connects the Sohmor village with these souterrains; which was probably used for the transportation of the raw material and the miners during the production periods.

Sohmor mines were first explored by SCL cavers in 2001. Several pits were discovered probably drilled for exploration purposes. The deepest of these pits reach 15 m. However, the main tar

producing mine has two interconnected shafts approximately 65 m deep. The two shafts are approximately 40 m apart (Figure 5). The shafts are connected at their bottom by a main tunnel.

As early as the Phoenicians the tar was discovered and used for smearing boats and houses. The Romans used it for the same purpose. Digging trenches and small pits to extract such a valuable ore started as early as their discovery. Extraction and usage of such a product was performed during all the periods throughout history of this country. The knowledge of seepages of Asphalet goes back to ancient ages. The Romans referred to them as "Lacus Asphaltites". They used to occur on the surface. However, mining them through drilling of trenches started as earlier as that date and then advancement in the mining techniques lead to extensive exploration and mining in the last century. Locally the tar or bitumen deposits are called el Hommar. The mining technique was developed and exploitation boomed during World War II and mid of the last century. However, the bulk of the production was mostly directed to local use as pointed out by one of the locals.

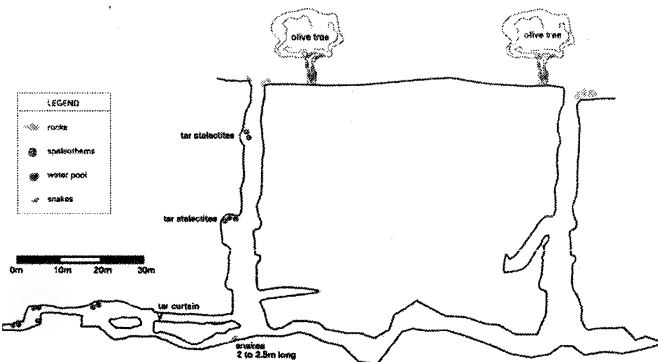


Figure 5: Topographic map of Sohmor Mine (SCL Archive)

Figure 6: The tar curtain discovered in Sohmor mine

The mine is present in the karstic limestone of the Eocene Formation. The mine was developed along an E-W fault for the main tar vein which is approximately 20 cm wide exists along that E-W fault.

Several rare possibly unique types of tar speleothems were observed in the Sohmor mine. A curtain of tar was observed with a beautiful folded base (Figures 6). The curtain is 120 cm in width at the top and 55 cm in width at the bottom. It is 160 cm long and thinner than 0.5 cm. The folded base looks like melted chocolate and has a thickness of 30 cm. This souterrain structure was visited twice during a period of two months in order to document the velocity of movement of such ductile material. For this purpose the curtain was observed to have moved approximately 10 cm in length. One fold was added to the base of this structure. In addition to this curtain a cluster of stalactites reaching 2m in length were documented and popcorn of different shapes and sizes were also observed along with flow like structures on the walls.

CONCLUSION

Southern structures in Lebanon although scarce have great potential. A working group was developed in 2001 for the purpose of exploring, documenting and protecting such structures. This paper documents more than 1 km of these structures. However, their significance also lies in the archeological, speleological and geological findings in them. Other subterranean structures in Lebanon still await identification, exploration and discovery. Examples include the Hasbaya tar mine in south Lebanon which has not unraveled its 1 km drilled tunnels and pits and the Zanoubia archeological tunnel in Hermel northern Bekaa, will continue to enrich the speleological, geological and archeological circle of knowledge in Lebanon and the rest of the world.

ACKNOWLEDGEMENT

I would like to thank all those members of SCL who helped in making this project a fruitful and successful one, especially Rena Karanouh for her help and guidance.

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Le cavit  artificiali del trentino - alto adige: uno sguardo d'insieme

Marco Meneghini

Administrator of the Trentino - Alto Adige Artificial Caves Registry of the Italian Speleological Society and the Tridentine Alpine Society

In Trentino - Alto Adige, la regione pi  settentrionale d'Italia, posta al confine con l'Austria, il fenomeno delle cavit  artificiali ha un'eccezionale diffusione, legata a molteplici fattori storici, economici e geografici. Le opere pi  significative sono senz'altro quelle militari (il Trentino fu uno dei teatri principali della Prima guerra mondiale sul fronte italiano) e le miniere (scavate in particolar modo nel periodo rinascimentale). La speleologia locale, che sinora si era occupata di cavit  artificiali in modo saltuario, sta affrontando studi e ricerche sull'argomento in maniera sempre pi  diffusa e approfondita, soprattutto grazie alla recente istituzione del Catasto regionale delle Cavit  Artificiali, gestito in collaborazione della Societ  Speleologica Italiana e dalla Societ  Alpinisti Tridentini.

The artificial cavities of trentino - alto adige: an overview

In Trentino-Alto Adige, Italy's northernmost region, situated on the border with Austria, the phenomenon of extensively scattered artificial cavities is exceptional and it is tied to various historical, economic and geographic factors. The most significant ones certainly are the military ones (Trentino was one of the main Italian battlefields during the 1st World War) and the mines (dug mainly during the Renaissance). Local speleologists, who were not very active in exploring artificial cavities up until recently, are now performing frequent and intensive studies, especially

thanks to the recent creation of a regional registry designed to record artificial caves and run in cooperation with the Italian Speleological Society and the Tridentine Alpine Society.

Trentino - alto adige: short geographical and historical overview

Trentino - Alto Adige S dtirol^[1] is Italy's northernmost region, and its morphology is mainly characterized by mountains, and in particular by the presence of the central Alps. These reach the highest height at almost four thousand meters on the Ortles - Cevedale mount.

There are small portions of flat land along the valleys of the main rivers, particularly the river Adige (which flows into the Adriatic sea) and the river Isarco (which is one of its tributaries). This is where the main cities of the region are located, i.e.: Trento, Rovereto, Bolzano and Merano. Thanks to the presence of these deep valley tracks, which run along the regional territory, particularly from North to South, Trentino - Alto Adige is an important passageway: this region is situated on the border with Austria to the North (the Brennero Pass is the main link between Central Europe and Italy), with Switzerland to the West, with the region Lombardy to the South and to the West and with the region Veneto to the South and to the East.

The alpine and rural landscapes, and the rich historical and artistic

^[1] The official name of this region is the bilingual one in Italian and German, Trentino - Alto Adige S dtirol.

monuments of the cities make Trentino - Alto Adige a beloved touristic spot.

From an administrative point of view, the region is divided into two provinces having a special autonomy: Trento (Trentino), with an Italian-speaking majority, and Bolzano (Alto Adige - Südtirol), with a German-speaking majority. There are other protected minority groups, and in particular the Ladins, living in both provinces, and the Cymbers and the Mokens (German-speaking people whose presence here is due to the migrations of the past centuries, and connected to the mining activity) in Trentino.

The territory which is now Trentino - Alto Adige was originally inhabited by various populations (Venetian - Illyrian, Retes, Gallic, etc.), and it was finally conquered by the Romans in 15 b.C. After various barbaric invasions, and after the Lombard and Frankish dominations, the Region became part of the Holy Roman Empire. Subsequently, in the 11th century, the Emperor established the Bishop's Principalities of Bressanone (in Alto Adige) and of Trento, with the aim of strengthening his relations with the Church. The Bishop's Principality of Trento, in particular, was destined to influencing the events of the entire area with its economic and political power, up until the arrival of Napoleon Bonaparte.

The Restoration, taking place in 1816, finally assigned Trentino - Alto Adige to Austria, which added it to Tyrol and thus fuelled the Italian irredentist forces. Adding this land to Italy became one of the main aims against Austria, and, during the Third Independence War almost seemed reached, until however the Savoy troupes entered into Trentino only a few kms away from the main city, in 1866, but then retreated.

Right after the end of the First World War, in 1918, Trentino - Alto Adige became part of the Kingdom of Italy under the name of Venezia Tridentina. This, however, caused a series of requests for autonomy from the German-speaking minority. Today's independence of these two provinces is due to a long-lasting negotiation, which at times also became particularly delicate and difficult but which, in time, diminished strongly.

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Artificial caves in trentino-alto adige

In Trentino-Alto Adige, artificial caves are exceptionally widespread, due to a number of economic as well as geographical factors. It is possible to state that there are several thousand caves, though it is almost impossible to calculate their number with any degree of accuracy.

In addition to this, until 2004 the region did not have an organic archive collecting a relevant amount of data and classifying artificial caves in various typologies.

The creation of the Trentino - Alto Adige Artificial Caves Registry, which will be described below, may fill in the gap. The registry will only become a remarkable database in a little while, since the relevant information have only just started being collected: as a matter of fact, in July 2005 twenty-three caves were officially recorded.

Many more are still waiting to be included in the registry, since interesting classification studies, involving artificial caves located in various parts of Trentino Alto-Adige, are taking place but have not been concluded yet. It should also not be forgotten that the classification procedures are new for many speleologists: this results in a series of practical difficulties and in the lengthening of the time requirements, as it invariably happens when a system has not been fully tested and acquired.

The lack of a registry of artificial caves does not mean, however, that no documentation is present. Bibliographical references are countless; the archive documentation is also remarkable, especially the documents concerning extractive activities, which are property of the Mining Service of the Autonomous Province of Trento.

By merely analysing the documentation available, some extremely interesting caves which had fallen into oblivion for decades or even centuries can be identified. It may prove difficult, however, to find these caves,

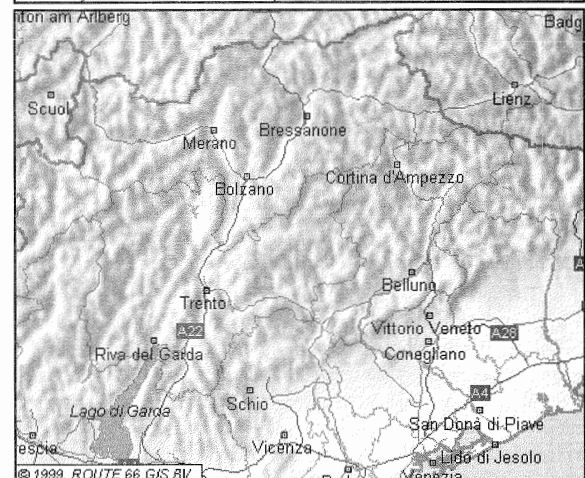


Fig. 1 General and detailed geographic overview of Trentino - Alto Adige Südtirol (Italy)

because of the loss of historical memories, or because the younger generations are less familiar with the local territory, or because some areas have gradually become depopulated. In such cases, a new discovery or the restoration of artificial caves is particularly important in the valorisation of the territory and has beneficial results on tourism.

It is clear then that the current state of the research and data collection does not provide a clear and complete description of the situation. This work aims to be a broad introduction to the phenomenon and will hopefully be followed by more detailed and accurate studies at a later stage.

Hydraulic works

Trentino-Alto Adige is particularly rich of surface and deep water, a precious element for the economic development of the area. There is some

evidence of this typology of caves: a roman well was recently found in Arco (Trento).

From a speleological point of view, however, some more interesting examples date back to the 19th century, namely some interception tunnels created to meet the requirements due to the growth of some towns in Trentino: there is the gallery of the Citàgol aqueduct (CA 2 VT TN) in Mezzolombardo, in the valley of the river Adige, and the 125-metre-long Sperone spring (CA 23 VT TN) in Riva del Garda.

An interesting section is the remarkable network of hydroelectric tunnels, spanning tens of kilometres, dug in the 1950s to produce electric power in order to cope with the increasing requirements of the industries during the economic boom following the end of the Second World War. In that case water proved to be a great source of wealth for a scarcely industrialised region, though it had a particularly traumatic social and environmental backlash: the hard working conditions of the workers, with many tragic accidents, should not be forgotten.



Fig. 2 Interception tunnel in the Citàgol aqueduct (Mezzolombardo - Trento). Pictures by the author.

Mining works

The presence of underground mining works has had remarkable historical, geographical and social effects in Trentino-Alto Adige; the first caves of this type, in all likelihood, date back to the early Middle Ages, there is evidence of them since the end of the 12th century. Their existence is tightly connected to the investitures of the powerful vassals of the Holy Roman Empire, particularly the Bishop Prince of Trento. The power of these feudatories was based on the mines, scattered on the mountains throughout the region, from which metals were extracted (mostly silver, but also copper and lead), making it possible for them to coin money. The importance of the mining activity in Trentino is highlighted by the fact that the first European mining code was issued by the bishop of Trento, Federico Vanga, at the beginning of the 13th century.

Medieval mining works are countless and have formed complex structures. Some of the areas hosting the highest numbers of caves are the mountains north of Trento on the left bank of the river Adige, particularly

Mount Calisio, also called Argentario. There are also many mines in Valsugana and in the Cembra Valley (eastern Trentino).

Alto Adige is rich of this type of caves, too, including the Monteneve and Ridanna structures, recently opened to tourists, in which the highest entrances are located at more than 2000 metres above the sea level.

Mining activities were carried out in the same old structures, through ups and downs, until the second half of the 20th century, although the requirements of the industrial development only focussed on some other materials, like baryta, fluorites and cadmium (in the Ridanna Valley).

Starting from the Middle Ages, mining activities resulted in a series of migrations, especially from northern Italy and central-eastern Europe, which had a deep impact on the local society and culture; these movements continued until the main mines were closed, that is until very few decades ago.

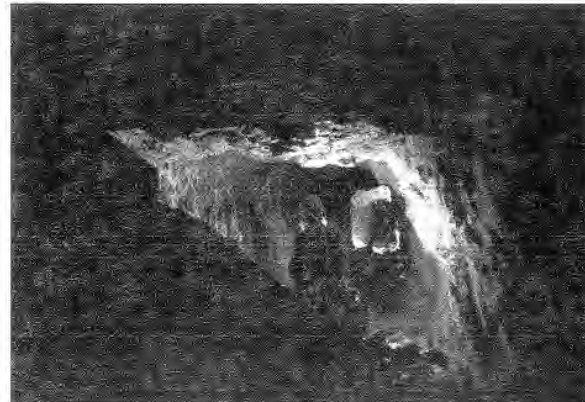


Fig. 3 Inside the mine of Vignola Falesina (Valsugana Valley - Trento). Picture by Daniele Sighel.

Military works

Military works, along with mining works, resulted in the most fascinating caves in Trentino-Alto Adige. This land is the ideal link between north and south, for commerce and for invasions, which have taken place a number of times for thousands of years. The morphology of the territory, which is characterised by mountains and valleys (most of which are closed and easy to control), has favoured the building of countless castles, especially during the Middle Ages and the Renaissance. According to the legends, many of these castles have underground passages, though their existence must obviously be proved.

In any case, underground defensive works reached their heyday in the middle of the 19th century.

Alto Adige and Trentino, belonging to the Austrian Empire, started being threatened by the new Italian state when it obtained full control of the Lombard-Venetian Kingdom. Therefore, the Austrians started a large fortification programme to defend both the boundaries and the towns, especially Trento, by creating a defensive belt on the surrounding hills.

The typologies of defensive works built until 1914, however, did not include any major underground work, but were mostly defences on the ground, at first made of stone, then reinforced concrete (for example, the forts near Trento, like Mattarello and Romagnano). There are some caves, though, used as storage areas or passages, like the entrance tunnel of the Bus de Vela fort, not far from the city of Trento.

When the First World War broke out, the new military techniques resulted in a multiplication of military underground works. The mountains of Trentino and Alto Adige became the battlefields of bloody battles between the Italian and the Austro-Hungarian armies, and for this reason both enemies built artificial caves, often in places so hard to reach that we can hardly believe they could have made such enormous efforts.

To the west, in the area of mount Adamello, close to the boundary with Lombardy, the highest battle in the entire war was fought: it took place on the eternal glaciers, at more than 3,000 metres of height. Very long tunnels were dug, in order to protect soldiers from enemy attacks as well as the inclement weather.

Great fortifications for the artillery were made in the southern sector, for instance a fortified tunnel with areas for the artillery near Riva del Garda, the so-called Tagliata del Ponale (CA 3 VT TN), more than one kilometre long, and the forts of Mount Brione.

In the eastern sector, the Pasubio area, located between Veneto and Trentino, where a long underground battle took place and the most important structures are the Austrian fortified complexes of Corno Battisti and Forte Pozzacchio are located, should be mentioned. While tunnels were being built along the frontline, the defences of the town of Trento were also strengthened, by digging military caves in previously fortified places (Mount Calisio, Mount Celva, Tagliata di Civezzano).

Fortification works did not end at the end of the Great War, in 1918: in the 1930s and 1940s the Italian government implemented a defence programme along the northern boundaries, which also involved Alto Adige, in order to prevent a possible attack from the North.

Along the main valleys, a series of reinforced cement bunkers was developed, occasionally underground, with narrow passages leading to huts and shooting positions for machine guns and small pieces of artillery.

Outline of the development of speleology in the region: trentino alto adige artificial caves registry

Speleology in Trentino developed towards the end of the nineteenth century thanks to some explorers and geographers who were associated to the Tridentine Alpine Society, to which speleologists are still strongly connected today. In the province of Trento there are now seven groups, which are all part of different sections of the Tridentine Alpine Society, which is the Trento section of the Italian Alpine Club.

The situation in the province of Bolzano is the same: there are two speleological associations, and both are connected to Alto Adige Italian Alpine Club.

Many speleological groups have been active for many decades, and their activity was full of explorative and scientific results of great importance. However, up until now they have only dealt with natural cavities, at least officially.

The study of man-made cavities is creating an increasing interest for speleologists in Trentino - Alto Adige, thanks to the widespread presence of caves and to the high historical and anthropological value they hold.

Over the past few years, the situation has further evolved, and speleologists have become more involved in the survey, research and recovery of artificial caves. This, however, did not create occasions for the discussion of this topic and, most of all, this did not involve the creation of a reference database.

A Registry for natural caves was created at the end of the 1920's, but we had to wait until the year 2004 to have something similar for artificial caves. In that year, the Tridentine Alpine Society and the Italian Speleological Society created the Trentino -Alto Adige Artificial Caves Registry. The creation of this registry had strongly been requested by both societies².

The idea of a cooperation between the Tridentine Alpine Society and the Italian Speleological Society was developed keeping into consideration the experience acquired and the good working methods which the Italian Speleological Society had already used for artificial caves (the Ital-

ian Speleological Society national registry dates back to 1981). They also kept into consideration the strong presence of the Tridentine Alpine Society on the territory, as it is an historical society, established in 1872, which has a great prestige locally and which gathers all speleological groups of the province of Trento.

This cooperation includes the Alto Adige section of the Italian Alpine Club for the province of Bolzano, thus allowing territorial continuity of the Artificial Caves Registry in the entire region.

The regional Artificial Caves Registry is part of the National Artificial Caves Registry of the Italian Speleological Society, and it uses the same data acquisition and conservation procedures, in cooperation with the Tridentine Alpine Society for its management and, most of all, with the Registry Work Group (which had already been established to coordinate and catalogue natural cavities) in which take part all the representatives of the speleological groups of the region. The aim of this register is to catalogue all anthropical caves, by collecting the data which determine their extension, their position and which allow their identification according to the models and the procedures defined by the Italian Speleological Society. The person in charge of the Artificial Caves Registry is a member of the National Artificial Caves Commission of the Italian Speleological Society: this allows a local operational autonomy of the Registry and it also allows a direct participation of Trentino - Alto Adige speleologists in projects of wider scale, both national and international.

The job done to start the Registry was excellent, especially considering the speed with which the results were reached and the tools which can now be used. Everyone cooperated at best with each other and with myself, in my role as the administrator and as the person in charge of the Registry.

The Trentino - Alto Adige Artificial Caves Registry is awaiting for the official recognition by local bodies, since it is a precious database for the safeguard of the territory. We hope that this will take place shortly, with the help of the ones who are more involved, such as the region Trentino - Alto Adige Sudtirolo and the Autonomous Provinces of Trento and Bolzano.

At first a lot of time and energy were spent for the creation of the Registry, for the contacts, the technical meetings, the definition and the approval of the rules.

Subsequently, the Registry was advertised on the press and to the people having an interest in it. This included a training and didactic activity to those who can give or use the data in the future. We must bear in mind that for most speleologists from Trentino, artificial caves are a whole new topic: a lot of the people involved are not familiar with the working procedures, with the classification of caves of various kinds, with the technical and historical aspects of cavities. This is the reason why we organized training classes, aiming not only to speleologists.

In fact, in Trentino - Alto Adige artificial caves are of great interest also for amateurs and scholars of other sectors: historians, people interested in the places where the Great War took place, in minerals, and so on, who regularly attend and study military and mining works, and publish works and studies of great interest. Therefore, the Registry must not remain within the speleological field, as it was created to interact with a varied and complex reality, allowing to handle data at best and to coordinate researches and activities at best.

The caves which have been registered until now are scattered in the province of Trento, and can be classified into the following typologies³:

- A - Hydraulic works: 2
- D - Military works: 16

² The Trentino - Alto Adige Artificial Caves Registry has its own regulations, approved by the Central Council of the Tridentine Alpine Society on 18.10.2004 and subsequently endorsed by the Artificial Caves National Commission of the Italian Speleological Society on 30.11.2004 and by the directive council of the Italian Speleological Society on 18.12.2004.

³ The typology classification is the same used by the National Registry of Artificial Caves of the Italian Speleological Society. The typologies can be divided into groups and sub-groups. The groups are indicated by a capital letter, and they are: A - hydraulic works; B - inhabited areas; C - cult works; D - military works; E - mining works; F - transit areas; G - other.

- E - Mining works: 4
- Promiscuous works: 1 (typol. A - D)

Caves were numbered according to the directions of the Italian Speleological Society: each artificial cave is marked by CA followed by a regional progressive number and by the letters indicating the region and the province where the cave is located, and then followed by a progressive number. The letters used by the Artificial Caves Registry of Trentino are VT/TN, and VT/BZ indicates the artificial caves of Alto Adige⁴.

Please note that the regional acronym for Trentino - Alto Adige is VT, which is Venezia Tridantina, deriving from the first official name of the region, dating back to the 1920's, right after the First World War, when Trentino - Alto Adige was annexed to Italy: Venezia Tridantina precisely coincided with the regional territory of today.

We chose VT for artificial caves mostly for historical reasons, and to conform artificial caves data to the data in the Trentino - Alto Adige Natural Cave Registry, which was created when the official name of Trentino - Alto Adige was Venezia Tridantina. The acronym used at the time, VT, is still used today in the Natural Caves Registry.

Thanks

I would like to thank the President of the Speleological Commission of the Tridentine Alpine Society, Marco Ischia; the Administrator of the Trentino - Alto Adige Cave Registry, Riccardo Decarli; the Artificial Caves Commission of the Italian Speleological Society; Arianna Tamburini; Giuseppe Fantauzzi; Enrico Fratnik; Daniele Sighel and the Trentino Speleological Group from Villazzano - Trento for helping me with this report.

⁴ For example: CA 1 VT TN - Cave located North of Romagnano (Trento)

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The stufe di nerone (Nero's Oven): an ancient artificial cave near Naples (Italy).

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Abstract

The earliest known example of a cave plan was published in 1546 in a book by Georg Agricola. It represents a set of branching tunnels called the Stufe di Nerone (Nero's Oven) in the volcanic region of Pozzuoli near Naples. This cave was excavated in the tufa deposits to reach hot springs to be used therapeutically.

This old plan, another one drawn at the end of the 18th century and a modern one are here reported together with some ancient prints of this cave which is just one remnant of the rich cultural- and geo- heritage of this corner of Italy.

Key words: ancient artificial cave, the oldest cave plan, Italy.

Introduction

Agricola (1546) published what can be considered to be the earliest known example of a cave plan. (Fig. 1) as reported by Shaw (1992). In the past it was a large spa developed probably along three levels. The first one at the sea level is presently underwater. The second level opens a few me-

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(Agricola, 1558) the plan is replaced by a cut-away view of the hill (Fig. 2) which is really interesting, even if it cannot be as accurate as a survey.

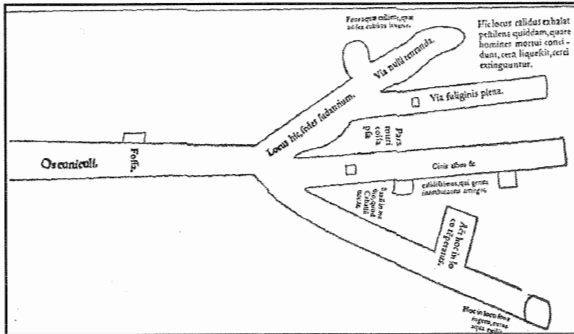


Fig. 1 - The plan published by Agricola (1546) of the Stufe di Nerone (Nero's Oven).

Os cuniculis: tunnel entrance. Fossa: ditch. Locus hic, sedes sudantium: this is the steam room where people sweat. Fons aquae exiliens, quae ad sex cubitos levatur: water source six cubits deep (about 2.7 m) Via nulli tentanda: passage to be avoided by everyone. Hic locus calidus exhalat pestilens quiddam, quare homines mortui concidunt, cera liquefecit, cerei extinguntur: this hot place releases something noxious, for this reason men dye, wax melt, candles extinguish. Via fuliginis plena: passage full of soot. Pars muri collapsa: collapsed part of the wall. Cinis albus & calidissimus, qui genua inambulantis attingit: ash white and very hot, which covers the knees of walking people. Saxu in medio quod Caballu, vocas: rock in the passage, called the Horse. Aer hoc in loco temperatus: in this place the air is temperate. Hoc in loco fons ingens, cuius aqua exilit: in this place there is a large source of water flowing away.

The steam room (literally "Tritoli's sweaty hall") was comprised of some (at least three) rooms excavated in the rock and supplied with stone beds in the walls. The recent transformation into a private house modified the original appearance although the structure is the same. The heat released by a hot aquifer reaches a room (presently used as a kitchen) through two passages, which cannot be easily visited on account of the high temperature and the obstruction by a heap of rubble in one of them. The passages are nearly horizontal, but the main one, towards its end has a slope of about 30° and reaches a pool of water with a temperature of 92°C (Abruzzese Saccardi, 1974-75).



Fig. 2 - The cut-away view of the hill with the Stufe di Nerone (Agricola, 1558).

Sudatorium magnum: Large steam room. Sinus Baianus: Gulf of Baia. Balneae Salveati: Bath of Salveati. GR XLIII: 43 steps. Os cuniculi: tunnel entrance. Sedes sudantium: steam room. Cuniculus: passage. Fons ebulliens: boiling source. Exhalationes lethales: lethal fumes. Via fuliginosa: passage full of soot. Pars muri collapsa: collapsed part of the wall.

Saxum caballum: rock called horse. Cinis albus et calidus: ash white and very hot. Aer temperatus: temperate air.

Panvini's description (18-19th Centuries)

The Abbé Pasquale Panvini, a learned person, doctor of Philosophy and Medicine, member of academies of sciences and art, wrote a book describing a trip lasting three days to look for antiquities in the vicinity of Naples (Panvini, 1818). He used the tables published some years earlier by Paoli (1768) to illustrate his text. The book by Panvini is very rare and now commands a high price. Luckily, this book was reprinted as a facsimile in 1990.

According to his description, along the road from Pozzuoli to Baia, at the sea level there were rooms excavated in the rock, sometimes inundated by the sea. One of these rooms was very hot as was the sand of the near-by seashore. Other rooms had baths inside and in a large one there were the remains of statues with their hands showing the illness to be treated in the corresponding bath. Some inscriptions described in great detail the effects of such baths.

These indications, which could be easily interpreted by ordinary people without any need of instructions by medical doctors, caused three famous physicians from Salerno to go to the place and destroy the statues and the inscriptions! Unfortunately, according to Dionisus from Samo, the small ship carrying these men was wrecked during their return home.

Somewhat higher along the same road, there was a modern (for the 18th Century!) building where the patients from the hospital of Nunziata in Naples (up to 900 per year), could be accommodated, waiting for the treatment in the steam rooms. These halls were found along some passages to reach the source of the hot water (Fig. 3).

According to tradition the passages were excavated by direction of Nero (hence the name Nero's Oven). These "precious baths and steam rooms", to use the very words of Panvini, were described by Alcadino from Syracuse, physician of Frederic II emperor and king of Naples, by Sebastiano Bartoli, under order of the vice-king Pietrantonio of Aragona, in his work "Thermologia Aragoniana" of 1668, and by other illustrious persons.

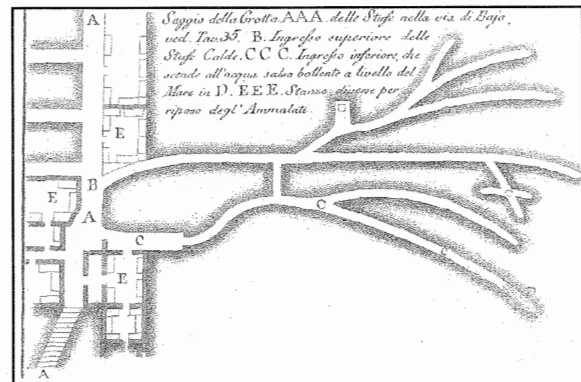


Fig. 3 - The plan published by Paoli (1768) and reported by Panvini (1818). Plan of the Cave AAA of the Oven on the road to Baja, see Tab. 35. B Higher passage of the Hot Oven. CCC. Lower passage reaching the boiling salt water at sea level at D EEE different rooms for patients' rest.

Modern description (20th Century)

In 1974-75 Abruzzese Saccardi published a plan of the cave (Fig. 4) with a short description. This author was particularly interested in the micro-organisms living in a very hot environment. In fact he found some bacteria living in the hot water at 92°C (density 0.980 at 92° and 0.015 at 15°C). Fig. 5 shows the range of some micro-organisms with respect to pH and temperature. Unfortunately no further researches were carried out

at the Stufe by Abruzzese Saccardi (pers. comm. 2004) Such an organism appears to be of particular interest as it can live at a higher temperature than any other.

Conclusions

From a historical point of view this artificial cave is very interesting because of its long existence and the records of it through many centuries. Presently it deserves much more attention from the authorities concerned with cultural heritage. In particular, it should no longer be used as a residence and should be restored to its original state. The people living in it should be provided with a normal house.

On the other hand, the presence of a pool of hot water hosting micro-organisms should be the subject of further research, with the advantage of the site location close to a city where such studies may be conveniently carried out.

So there are at least two avenues for further investigations in this cave, one historical including an accurate exploration of the passages including the parts not normally safely entered due to high temperature and fumes. The other research field concerns the study of life in an extreme environment.

It would be of great benefit if these investigations were taken up by local researchers.

Acknowledgements

The authors are particularly grateful to Dr. Trevor R. Shaw for drawing attention to this interesting site and for his help in retrieving old literature

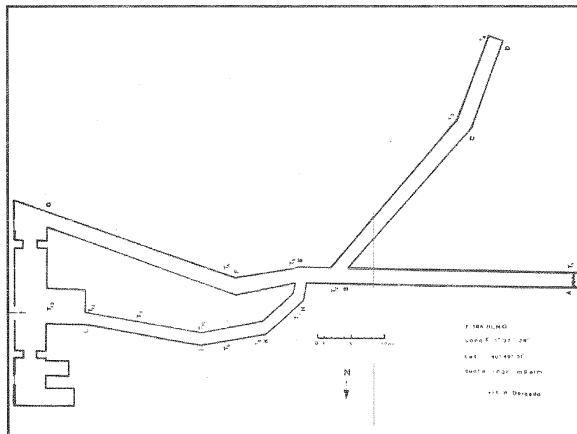


Fig. 4 - Plan of the cave (survey by R. Delgado) (from Panvini, 1974-75).

concerning Nero's Oven.

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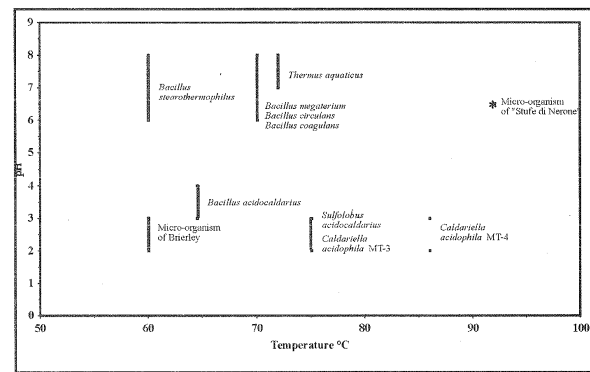


Fig. 5 - Distribution of some micro-organisms, pH vs. Temperature (from Panvini, 1974-75 modified).

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the speleological bibliography of Sardinia (Italy)

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Abstract

The first citation on caves in Sardinia dates back to 1580 when Johannes Francisci Faræ mentions some famous caves such as Grotta Verde (Alghero), Grotta San Giovanni (Domusnovas) and the Su Gologone spring (Oliena). Sixty years have to pass before another author, Salvatore Vitale Marenses (1639) mentions the Ucca 'e Bobois cave (Ussassai), and thirty-four years later Jorge Aleo (1673) describes the

archaeological cave of Bonaria (Cagliari).

During the XVIIIth century only two authors, Francesco Cetti (1771) and Giuseppe Cossu (1799), mention some minor caves for their faunistic (sea-birds) and geographical interest respectively.

In the XIXth century many travellers discover the Island and give descriptions of the most famous caves, especially the Nettuno cave near Alghero. The most interesting speleological observations and descriptions

are given by Alberto La Marmora (1826 and 1860) and Vittorio Angius (1833-1856, in Goffredo Casalis). The first publication on cave dwelling fauna dates back to 1872 when Fairmaire describes the first troglobite species collected by Raffaello Gestro the year before in Su Marmura cave (Ulassai). Important archaeological excavations and discoveries occur towards the end of the century, Giovanni Spano in Sa Rocca Ulari cave, Borutta (1873), Francesco Orsoni in Sant'Elia and San Bartolomeo caves, Cagliari (1876), Arturo Issel, Leon Gouin and A. Baux in s'Oreri cave, Fluminimaggiore (1884) and Filippo Vivant at Genna Luas cave, Iglesias (1891). A couple of years later C.J. Forsyth Major starts studying paleontological materials discovered from caves at Capo Caccia (around 1900).

During the next 35 years many papers written by archaeologists, palaeoanthropologists, biologists or geologists recall several caves for their scientific interest, but the first real speleological contribution, containing a list of 94 caves, is given by Carmelo Maxia in 1936. World War II inhibits the development of real speleological activities until the constitution of the first caving associations in the early 50's (Alghero, Cagliari, Nuoro). In 1955 the National Speleological Congress takes place in Sardinia bringing a strong impulse on caving activities on the Island. The results of these pioneer explorations is resumed in a book written by Antonio Furreddu and Carlo Maxia (1964) that becomes the "bible" for the next generation of Sardinian speleologists.

During the following years results of caving explorations are published in Italian bulletins such as *Rassegna Speleologica Italiana* (Milan), *Grotte* (Torino) and *Sottoterra* (Bologna) until the appearance of *Speleologia Sarda*, the first caving journal of Sardinia published for 18 years by the Gruppo Speleologico PIO XI of Cagliari (1972-1990).

Other important caving journals are founded in 1974 (Grutta e Nurra, Gruppo Grotte Nuorese), 1975 (*Bollettino del Gruppo Speleologico Sassarese*), 1984 (Anthò, Gruppo Speleo-Archeologico Giovanni Spano) and 1992 (*Sardegna Speleologica*, Sardinian Federation of Speleologists).

Since 1995 all bibliographical data on Sardinian caves are inserted in a database (Access) and thanks to the collaboration with four cavers (Guido Bartolo, Giuseppe Graffiti, Mauro Mucedda and Mauro Villani) this database is integrated and completed comprising everything published in the interval 1580-2003.

Introduction

This paper resumes the work carried out by a team of Sardinian cavers (Guido Bartolo, Jo De Waele, Giuseppe Graffiti, Mauro Mucedda and Mauro Villani) in the past 5 years on the speleological bibliography of Sardinian caves. The bibliographic citations have been inserted in a database (Access) together with the caves described and the treated arguments (archaeology, geology, biology etc.) in order to be able to perform complex queries. The entire bibliography will be published in a book together with a CD in order to give a service to all people, cavers and scientists, interested in caves and karst of Sardinia.

The first citations on caves of Sardinia

About 8% of Sardinia's surface is characterised by the outcropping of carbonate rocks of various ages, ranging from Cambrian to Quaternary, and karst phenomena are sometimes well represented, reaching spectacular landforms in many areas (De Waele, 2003a; 2003b). Since the arrival of humans on the Island after the LGM (Late Pleistocene) (Sondaar et al., 1995) caves have been known and used as shelter and/or burial places. But from a bibliographical point of view the first citation on caves of Sardinia appears only in the late XVIIth century, when Johannes Francisci Farac (1580) mentions some famous caves such as Verde (Alghero), San Giovanni (Domusnovas) and the Su Gologone spring (Oliena) (Fig. 1). These very important and easily recognisable karst sites will not be mentioned anymore until the beginning of the XIXth century. Instead, in the XVIIIth

century two more caves are cited in literature, Sa Ucca 'e Is Bobois (Ussassai) (Salvatore Vitale Marenses, 1639), and Bonaria (Cagliari) (Aleo, 1673). In the early XVIIIth century another cave of Cagliari is mentioned for the presence of doves (Cetti F., 1774). Towards the end of the century other 5 caves are reported in the Geographical Dictionary of Sardinia (Cossu, 1799), only one of which, s'Orcu (Dorgali), is important.

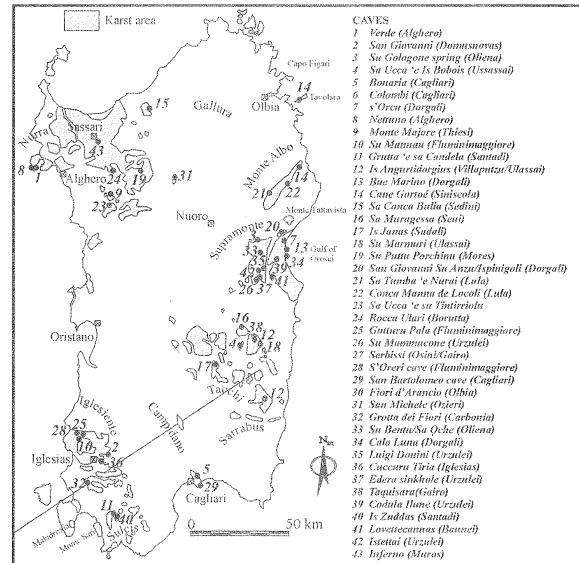


Fig. 1 - Caves and karst areas of Sardinia

The travellers of the XIXth century

During the XIXth century the Island is visited by many Italian and European travellers, and an increasing number of caves are cited in their diaries and books. The first detailed descriptions of important caves are due to Massala who first narrates his visit to Nettuno cave (Alghero) (Massala, 1805), later also reports Monte Majore (Thiesi), San Giovanni (Domusnovas) and Su Mannau caves (Fluminimaggiore) (Massala, 1808). These are the first more or less scientific descriptions of caves in Sardinia. A couple of years later other caves are mentioned and a short description is given of a small cavern close to Santada, Grutta 'e Sa Candela (D'Austrate, 1812). The first sketch map of a cave in Sardinia is published ten years later by Smyth W.H. (1823), representing the Nettuno cave. Many other travellers and authors follow generally reporting the already mentioned caves (Mimaut, 1825; La Marmora A., 1826; Saint-Severin, 1827; Smyth, 1828). New citations can be found in the work of Angius in the monumental work of Casalis in the Kingdom of Sardinia written between 1833 and 1856 (Angius, 1833-56) listing a total of 60 caves, most of which are only small shelters or artificial underground voids. Nevertheless some very important caves are here for the first time reported, such as Angurtidorgius (Villaputzu/Ulassai), Bue Marino (Dorgali), Cane Gortoe (Siniscola), Sa Conca Bulia (Sedini), Is Janas (Sadali), Su Marmuri (Ulassai), Su Puttu Porchinu (Mores), San Giovanni Su Anzu (Dorgali), Tumba 'e Nurai (Lula), Sa Conca Manna 'e Locoli (Lula), Sa Ucca 'e su Tintirriolu (Mara), Gutturu Pala (Fluminimaggiore), Rocca Ulari (Borutta), Su Mammuccone (Urzulei), Serbissi (Osini/Gairo) and many others. Other travellers that have left us interesting descriptions of mostly already cited caves are Valery (1837), Tyndale (1849), Delessert (1855), Miles (1864), Maltzan (1869) and some others. In the same year the first citation on guano deposits in Sardinian caves is published (Aventi, 1869) and some years later also the first Sardinian cave adapted animal, the beetle *Ovobathysciola gestroi* from Su Marmuri, is described (Fairmaire, 1872). Some years later also Magretti (1880) reports some

faunistic observations on the Colombi cave (Cagliari). Important reports on archaeological digs in caves are published in the same years, especially in Sa Rocca Ulari cave (Borutta) (Spano 1873), San Bartolomeo cave (Cagliari) (Orsoni, 1879; 1880; 1881), in s'Oreri cave (Fluminimaggiore) (Baux, 1884; Gouin, 1884; Issel, 1884) and at Genna Luas (Iglesias) (Vivanet, 1891). Very detailed and precise descriptions of caves appear towards the end of the century, such as Nettuno (Alghero) (Costa, 1889) and Su Marmuri (Ulassai) (Businco, 1893). The first description of fossils discovered in cave deposits appears two years later citing Pleistocene bird remains of the Fiori d'Arancio cave on the Tavolara Island (Lydekker, 1891; Shufeldt, 1896). A first ecological description of cave bats is given for the Inferno cave near Muros (Monticelli, 1896), and a second troglobite species, the Chilopod *Lithobius doderoi*, is described from three caves of Ogliastra, comprising the already mentioned Su Marmuri cave near Ulassai (Silvestri, 1898).

Speleology in the early XXth century

The early XXth century is still characterised by the absence of real speleological researches, since the first official caving association will be founded only in the early 50's. Caves are visited by travellers, but an increasing number of scientists (biologists, palaeontologists, archaeologists) start working in a more systematic way in caves. In the beginning of the century many fossil extinct Quaternary animals are discovered in cave deposits, such as the famous *Prolagus sardous* but also other mammals (Forsyth Major, 1900a; 1900b; 1902; 1905; Brandy, 1905; Dehaut, 1911). Also from a biospeleological point of view many articles report cave dwelling fauna of Sardinian caves (Solari & Solari, 1903; Doderò, 1904a; 1904b; Gestro, 1904; Gozo, 1906; Silvestri, 1908; Budde-Lund, 1909; Krausse, 1912; Silvestri, 1912). Many important archaeological findings are carried out in caves in the same period (Ardu-Onnis, 1904; Taramelli, 1904a; 1904b; 1905) with the citation of important historical caves such as San Michele (Ozieri) (Bray, 1906; Porro, 1915; Taramelli, 1915). Important general papers on caves and karst are published in the 20's and 30's (Bertarelli, 1929; Lucchi, 1933; 1934), generally reporting the caves described in the preceding years, but the most important summary on speleology in Sardinia appears a couple of years later (Maxia, 1936), reporting a list of 94 caves.

The birth of Sardinian Speleology

The breakout of World War II inhibits the development of speleology in Sardinia for twenty years and the first caving associations appear only in the 50's. Meanwhile Sardinia is visited by several Italian caving associations and some of these explorations are published in *Rassegna Speleologica Italiana* of the Gruppo Grotte Milano (Barajon, 1949; Sommaruga, 1952, 1955; Barajon, 1955; Balducci et al., 1956) and in the *Notiziario* of the Circolo Speleologico Romano (Patrizi, 1952; Segre, 1952) with the citation of some new caves among which Grotta dei Fiori close to Carbonia. In 1955 the VIIth National Congress of Speleology is held in Sardinia, giving a very importance impulse to the local cavers and new born caving clubs. Slowly also Sardinian cave associations, e.g. the Gruppo Grotte Nuorese, begin to report their first speleological results, with the discovery and the exploration of very important cave systems such as the Su Bentu-Sa Oche system near Oliena (Columbu, 1955; Giacobbe, 1955) and Bue Marino near Dorgali (Columbu, 1956), but also minor but very famous caves (Cala Luna, Dorgali) (Columbu, 1955). In 1955-56 the Gruppo Speleologico PIO XI of Cagliari collaborates with the Commissione Grotte Eugenio Boegan exploring many caves of Monte Albo, and these results are reported in the Proceedings of the VIIIth National Speleological Congress, held at Como (Finocchiaro, 1958). In 1957 one of the most remarkable explorations has been carried out: the descent

of the famous Sterru 'e Golgo, a natural karst pit of 275 meters depth (Furreddu, 1987).

A couple of years later the Gruppo Speleologico Bolognese and Unione Speleologica Bolognese start their explorations in Sardinia (Cantelli, 1962; Altara 1964; Altara & Pavanello, 1964; Altara, 1976) and some years later also the Gruppo Speleologico Piemontese begins to explore some of the most beautiful karst systems of Sardinia, San Giovanni Su Anzu near Dorgali (Gatto, 1964). And 1964 is the year that changes Sardinian speleology: the book "Grotte della Sardegna. Guida al mondo carsico dell'Isola" is published, and this monumental work will guide the new generation of cavers (Furreddu & Maxia, 1964). The cave list of Sardinia has reached about 350 caves (Furreddu, 1964).

The speleological "boom" of the late sixties-seventies

The publication of the "bible" of Sardinian Speleology (Furreddu & Maxia, 1964) causes an explosion of speleological activities in Sardinia in the late 60's and early 70's, with the exploration of well-known and very important cave systems such as San Giovanni Su Anzu (Dorgali) (Balbiano d'Aramengo, 1966) and the discovery of some new and very big caves such as Luigi Donini (Urzulei) (Clò & Donini, 1965), Taquisara (Gairo) (Grimandi, 1967), Edera (Urzulei) (Assorgia et al., 1967; 1973) and Cuccuru Tiria (Iglesias) (Neri, 1969). Many important cave associations are founded immediately after the printing of the "bible", the most important of which are the Speleo Club Cagliari (Cannas, 1967) and the Gruppo Speleologico Sassarese. The first starts publishing monographic issues on several karst areas and caves (Argiolas et al., 1970; Bartolo & Di Paola, 1970; Bartolo & Ferrara, 1971; Sanna et al., 1972; Bartolo et al., 1973; Speleo Club Cagliari, 1975; Bartolo et al., 1980) while the latter prints its own bulletin since 1975. Also the Gruppo Speleologico PIO XI publishes *Speleologia Sarda* since 1972, and two years later the Gruppo Grotte Nuorese starts issuing *Gruttas e Nurras*. This speleological "boom" triplicates the known caves in Sardinia in less than ten years (Catasto delle Grotte della Sardegna, 1974) and greatly enhances biospeleological knowledge (Puddu & Pirodda, 1973).

Modern Speleology

The introduction of modern cave exploration techniques in the late 70's gives a further impulse to speleological activities in Sardinia and allows the exploration of very big cave systems such as Codula Ilune (Chabert, 1980; Gori et al., 1980; Atzori et al., 1982), Edera (Cabras et al., 2003), Su Bentu (Carta et al., 1988), Lovettecannas (De Waele et al., 2002), Istettai (Crobù, 2003) and several others. In the early 80's the Federation of Sardinian Speleologists is founded and other cave bulletins are born, among which "Anthèò" of the Gruppo Speleo-Archeologico Giovanni Spano has to be mentioned. In 1990, with the death of Antonio Furreddu also "Speleologia Sarda" dies and is substituted by the review of the Federation "Sardegna Speleologica". In the last 20 years many important books were published (Mucedda & Pala, 1990; Mucedda et al., 1997; 2002; Bartolo & Fadda, 1998) and the cave register has reached a total number of 3000 natural caves, some of which are among the most important cave systems of Italy, and the Island has become one of the most important biogeographical cave fauna areas of the Mediterranean (Grafitti, 2002).

Conclusions

Since the first citation on caves in Sardinia in 1580 many other papers have been published reaching a total of more than 5000 articles and books. All this bibliographical information on Sardinian caves has been inserted in a database (Access) and thanks to the collaboration with four cavers (Guido Bartolo, Giuseppe Grafitti, Mauro Mucedda and Mauro Villani)

this database has been integrated and completed comprising everything published in the interval 1580-2003. This Sardinian Speleological Bibliography intends to be a useful tool for the Cave Register, for all cavers intending to visit and explore caves and karst areas on the Island and especially to all researchers and scientists of all kinds (geologists, archaeologists, biologists etc.).

Acknowledgements

This paper resumes the work carried out by myself and my caver colleagues Guido Bartolo, Giuseppe Graffiti, Mauro Mucedda and Mauro Villani, without whom this bibliography would have been much poorer.

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L'ardeche souterraine

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Abstract

Le réseau des grottes de Saint Marcel d'Ardèche est l'un des plus grand de France (48,5 km). Son exploration a débuté il y a plus d'un siècle par les grandes galeries du réseau 1, dont une partie est aujourd'hui aménagée. Depuis, et en particulier dans les années 1970, de nombreuses découvertes permirent de connaître les réseaux 2, 3 et 4. En plusieurs points, parfois très éloignés les uns des autres, l'eau était atteinte sans que le niveau noyé ne soit connu. Les mises en charges et les décrues à priori peu cohérentes laissaient imaginer une structure complexe avec une alimentation multiple provenant de l'Ardèche et par plusieurs origines,

des plateaux de Gras. Depuis 1994, les explorations d'AVENS ont porté sur le réseau noyé. Les premières et topographies réalisées en siphon et post siphon à cette occasion dans le système « Saint Marcel, source du Bateau et perte de la Cadière » représentent près de 17 km. Une nouvelle sortie naturelle a été découverte après un parcours de 1,4 km dont 1 km noyé. Plusieurs terminus sont à moins de 500 mètres les uns des autres et laissent espérer de nouvelles jonctions. Saaint Marcel est le plus grand Karst noyé de plateau d'Europe. Video projection de 25 mn. Un texte de 4 pages peut être joint.

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Speleo-discography: a progress report

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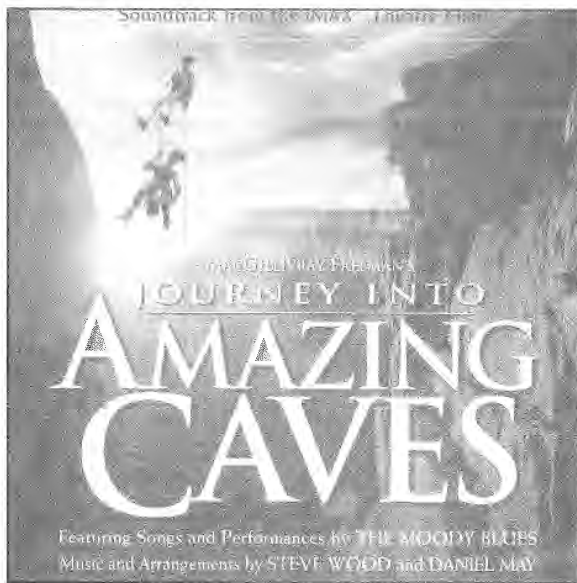
A cave is a natural work of art wrought in stone. What better way to celebrate caves than to create works of art inspired by them? Of all the fine arts, music has a unique power to capture the special magic of caves, that spiritual beauty of caves, which cannot be transmitted in words or images.

Forty years of research has brought to light a considerable treasure of music totally inspired by caves, either real or imaginary. This speleo-discography is a detailed, annotated, international listing of commercially recorded cave music and cave spoken word covering nearly the entire history of recorded sound from 1919 to the present. All categories of music are included: classical, contemporary, film, world, folk, jazz, new age, country, and rock. Opera music has been omitted because in nearly all operas the lyrics rarely mention caves and the cave only appears as a purely theatrical element in the stage settings. A separate part of this discogra-

phy presents spoken word discs, recordings of both fictional works that include significant cave-related incidents and non-fictional documentary recordings about caves.

Each musical entry includes all necessary information concerning the composer, performers, recording company, different releases, and detailed notes about the composition itself plus other pertinent facts followed by a selected bibliography. A serious effort was made to locate or gain information about all the known versions of a particular piece of music or a particular song. For each version of a specific work, all the known record releases of that work are provided; often resulting is a detailed discographic listing of the different countries, labels, and turntable speeds for that particular version under consideration.

In the category of classical music, the most important work is the Fingal's Cave Overture composed by Felix Mendelssohn in 1832. Over 95



different versions of this cave-inspired piece have been recorded, spanning nearly the entire history of recorded music; starting in 1919 with an acoustical Edison recording, through the 78rpm electric recordings, to the 33rpm long-playing records, right up to the recent compact disc releases. In 1963, the world-class Cleveland Orchestra conducted by George Szell recorded a memorable performance. Other important classical works inspired by caves include: La Source du Lyson, a classical guitar piece by Napoleon Coste inspired by this resurgence cave in France; and La Grotte, a poem set to music by Claude Debussy.

Several works of contemporary art music have been recorded ranging from Altamira by the Hungarian composer, Zolt Durkó; In the Cave, in the Light by Keith Jarrett; Sonido en la penumbra, a full synthesizer work by a Spanish caver, Mario Gómez Calderón; and experimental music by Mariolina Zitta, performed by tapping (without damaging) on the formations of caves in Liguria and Sardinia, Italy. The magnificent show cave in Lebanon, Jeita, inspired a major work of concrete music by François Bayle.

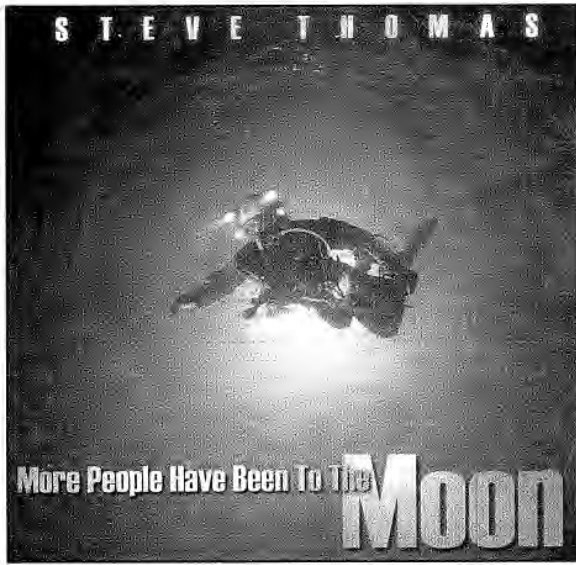
Many contemporary composers of art music have turned to writing film music. The recorded scores for a number of fiction feature films, which include cave scenes, also include musical cues written specially for these cave scenes. Among over 75 entries, a few of the more significant cave film composers are: Alan Silvestri for The Clan of the Cave Bear, Bernard Herrmann's famous score for Journey to the Center of the Earth, Philippe Sarde for Quest for Fire, and John Barry for Swept from the Sea. Steve Wood, Daniel May, and The Moody Blues wrote the music for the IMAX documentary film, Journey into Amazing Caves.

In the category of world and ethnic music many countries have contributed fascinating works inspired by their caves. Australia has five didgeridoo pieces; France offers two popular songs about the Chambre d'Amour cave near Biarritz; Greece has three songs about bats; the Netherlands, Jamaica, the Philippines, and the Tonga Islands each have songs about bats; Spain offers fourteen stimulating pieces dealing with caves on the peninsula and in the Canary Islands including one song by Carlos Núñez celebrating the longest cave in Galacia, Cova do Rei Cintolo. Incorporated within world music are Scottish, Gaelic, and American folk music. Here Scottish music predominates with seven different compositions inspired by seven caves there. American folk music includes one about the Leatherwing Bat and another about the cave-dwelling itinerant, The Leatherman. In this category of folk music a separate section has been added for several recordings of caving ballads composed by American and British cavers. Normally cassette recordings are not included in a discography, however, an exception was made here to include cassette releases of caving ballads since there are so few of them.

The earliest form of country music now called, old time music, started to be recorded in 1924. The tragedy of the trapped Kentucky caver, Floyd Collins, inspired six different old time ballads spanning the months following his death in February 1925 right up to 1929. These were all released on 78rpm records and constitute the first collection of cave-inspired music to be persevered on phonograph records. In 1941, Tommy Magness composed a fiddle piece inspired by the Natural Bridge in Virginia and to date eight versions of it have been recorded. The most successful recent country cave song, Miller's Cave, was written by Jack Clement in 1959 and recorded by over 20 different performers, the popular hit versions being the ones by Hank Snow in 1960 and Bobby Bare in 1963.

From the very beginning, jazz clubs all over the world tended to be located in underground cellars and frequently these cellar clubs were given cave names, such as, El Grotto in Chicago; Bohemian Caverns in Wash-





ington, D.C.; and Beverly Cavern in Los Angeles. Jazz groups that played for extended periods in these clubs would often dedicate a new piece to the club, so recordings appeared of *Cavernism* and *At the El Grotto* by Earl Hines; *The Caves* by The Ramsey Lewis Trio; and *The Purple Grotto* by Herbie Mann. A jazz cellar in France is called "une cave," the French word for cellar, and Sidney Bechet recorded a number called, *Blues in the Cave*. In the Faeroe Islands of the North Atlantic, Kristian Blak, composed, *Concerto Grotto*, a suite of eight cave-inspired jazz pieces that were performed live in a huge tectonic sea cave there.

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The past twenty years has seen the emergence of what has come to be called "new age" music, where musicians improvise on a theme as in jazz but use relaxing rhythms unrelated to jazz. Often directly inspired by nature, new age music has proved to be a fertile source of music inspired by real or imaginary caves. So far over sixty compositions of cave new age music have been recorded, some of them important works with several selections. Andreas Vollenweider composed *Caverna Magica*; David Antony Clark performed six tracks relating to Paleolithic cave artists for *The Man Who Painted in Caves*; the British caver, Steve Thomas, wrote an entire album of fifteen tracks around the experience of cave diving; Romano Serra wrote fifteen selections all dedicated to the *Grottes des Grandes Canalettes* in the French Pyrenees; and Samuel Aguilar composed an album of synthesizer music celebrating the lava tube, *Jameos del Agua*, in the Canary Islands.

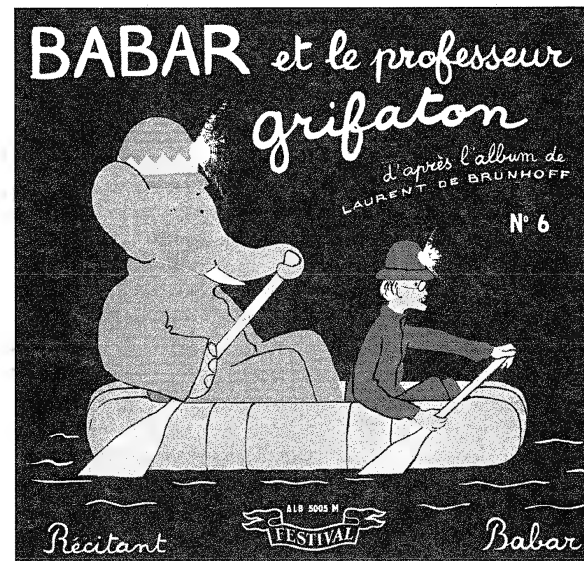
By far the most prolific contributions to cave-inspired music have come from rock music, ranging all the way from rhythm 'n' blues to psychedelic to grunge. Right at the start of the rock 'n' roll movement in 1955, Billy Ward and his Dominoes came out with *Caveman*, which kicked off a long succession of prehistoric caveman rock songs. Tommy Steele, in England, had a hit with *Rock with the Caveman* in 1956; *The Vibrations* cut *Cave Man* in 1960; *The Jimmy Castor Bunch* got a hit with *Troglodyte* in 1972; and *The Cramps* did *Caveman* in 1981. Then there was the monster hit, *Alley Oop*, by *The Hollywood Argyles* in 1960, which was inspired by the caveman comic strip. Down through the years other landmark cave rock songs and compositions by famous groups came in 1956, with *The Majestics* and *Cave man Rock*; in 1963, with *The Big Three* and *Cavern Stomp*; in 1971, *The Pink Floyd* and *Echoes*; in 1974, Rick Wakeman's *Journey to the Centre of the Earth*; in 1988, Lita Ford's *Back to the Cave*; in 1993, *Crash Test Dummies* and *In the Days of the Caveman*; and in 1997, with *Pearl Jam* and *Leatherman*. All told over 200 cave rock songs have been released since 1955.



In an effort to be as complete as possible, an additional section has been included for marginal cave songs, where the lyrics include the word "cave" or "bat" only once, whereas the overall theme and feeling of the songs have little or nothing to do with either caves or bats. Following this, yet another listing was set aside for compositions and songs that have "cave" or "bat" in their titles, but which do not in any way qualify as true cave music.

Another special section was created for music that has been recorded during concerts in natural caves, most importantly, at the *Cango Caves* in South Africa, *Cathedral Cave* in Australia, *Grotte de Han* in Belgium, *Hohler Fels* in Germany, *Cueva de Nerja* and *Cueva del Drach* in Spain, *Postojnska Jama* in Slovenia, and *Luray Caverns* in the United States.

As an important part of this discography, this listing of cave-inspired discs, it was necessary to include a separate section, having nothing to do with music, reserved exclusively for all the spoken word and documentary recordings. Fictional spoken word has been divided into adult and children's fiction. The adult fiction recordings include mostly poetry readings of W. H. Auden's *In Praise of Limestone*; Samuel Coleridge's



The Pleasure Dome of Kubla Khan; and La Fontaine's fable *La Chauve-souris et les deux belettes* (The Bat and the Two Weasels). Spanning both adult and children's fiction, Jules Verne's *Journey to the Center of the Earth*, has been released in French, English, and Spanish. Several charming little children's tales from different countries were recorded: *Babar et le Professeur Grifaton*, where the elephant, Babar, goes caving; *En Jep Espeleòleg*, a Catalan comic tale about exploring a polluted cave; *Randell Jarrell's outstanding The Bat Poet*; and another captivating bat tale by *Janell Cannon, Stلالuna*. Rounding out the children's spoken word records are eight separate recordings of the Cyclops tale from Homer's *The Odyssey* and ten readings of the cave scene from Mark Twain's *The Adventures of Tom Sawyer*.

A complementary section is devoted to non-fiction, documentary spoken word discs. Here some of the more outstanding documents are four recordings of the world-famous French caver, *Norbert Casteret*; one of the equally famous French prehistorian, *Abbé Breuil*; and two flexible discs about cave exploration in Soviet Georgia. There are also three records accompanied with color slides for various show caves in Slovakia, Slovenia, and Australia. A further section was created specially for field recordings of bats and cave-dwelling birds in various parts of the world.

For the connoisseur of phonograph records it has always been an added esthetic pleasure to acquire, along with the recorded music, those beautiful jacket-cover photos, paintings, and illustrations. So it was considered important to include at the end of this discography all known picture covers that depict caves, whether real or imaginary, plus prehistoric cave paintings and bats. There are cave picture covers representing caves all over Europe, Africa, Asia, and North America. Some are 19th Century paintings of caves, others are strikingly dramatic photos of cave entrances or cave interiors, and still others are drawings or paintings of totally imaginary caves. A selected number of cave picture covers even merit being framed and hung on exhibition.

Finally this discography includes an appendix providing the complete lyrics for all the songs from the different categories of recorded music included in the listing. In most cases these lyrics have never been printed anywhere so they had to be transcribed by the author directly from the recordings.

The finished reference work with introductions for each section, fleshed-out entry notes, and four indexes will probably surpass 1200 pages, which would require splitting the work into two volumes. The present format consists of double columns with profuse illustrations, which look good on the printed page. But to save paper, it would perhaps be better to rearrange the page layout for the screen and publish electronically on DVD with the advantage of rapid cross-indexing. Including complete dubs or excerpts of the original cave music recordings would be very desirable and probably entirely feasible for some works where the music copyrights have expired, but, regarding the more recent compositions, it will be necessary to investigate the possibility of obtaining the music rights.

This research on recorded cave music primarily involved searching in numerous record stores, catalogs, set sales, and auction lists. Over the years I have passed in review hundred of thousands of music and song titles to succeed in finding nearly every piece of cave music. The resulting discography is more than a simple listing of cave-inspired works, it is a detailed and dedicated presentation of each work in an effort to open doors, promote this unfamiliar music, and transmit its special appeal.

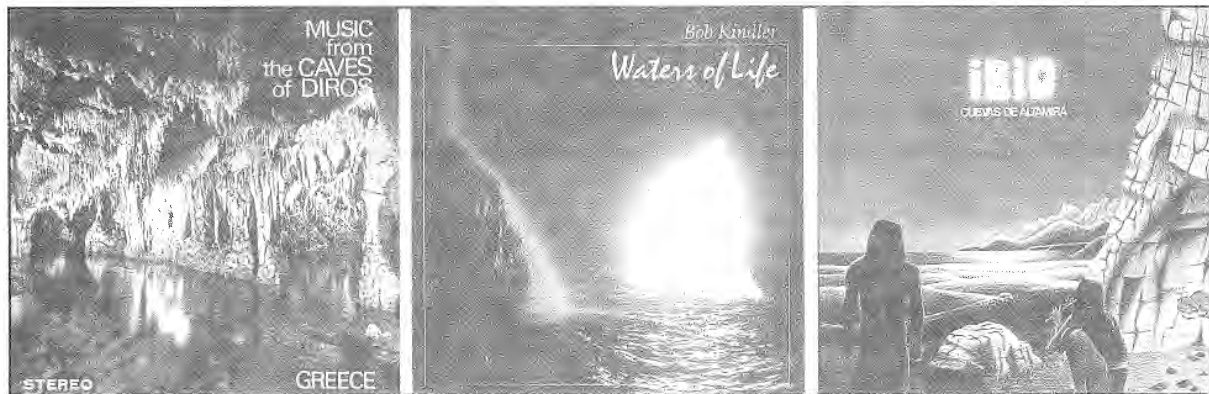
Caves are one of the few places on this planet where total silence can be heard. Music begins with silence, then out of this silence grows an abundance of sound, filling and resonating in space. There is also the image of the composer as explorer. The act of composing music often involves, on the part of the composer, a process of searching, exploring, and discovering the right combination of notes to create pleasurable or desirable sound structures. One of the most powerful of the fine arts for moving the emotions, music can liberate us from tedious moments in life. Cave music has been written and recorded that will take you back spiritually to the cave environment and allow you to recapture some of those emotions of wonder and awe that you felt there.

Acknowledgements:

I would like to thank all the cavers, musicians, and other people who, over the years, have brought to my attention several interesting pieces of cave music and song.

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Title: Advances in computer-aided cave survey data acquisition; the Auriga Palm OS freeware for underground and field use**Section: Cave Surveying****Author: Luc Le Blanc, President, Société québécoise de spéléologie***Address: 5980, rue Saint-André, Montréal, Québec, CANADA, H2S 2K4, Contact: +1 514 277-7897 or lleblanc@cam.org, Web site: www.speleo.qc.ca/Auriga, Keywords: Auriga, Cave surveying, Software, Cave electronics***Abstract**

The underground use of the Auriga software drastically improves the cave surveying process. By trading their traditional paper notebook for a Palm OS PDA (Personal Digital Assistant, i.e. handheld computer) running Auriga for the input of the numerical survey data, cave surveyors benefit from features targeted at yielding better cave maps faster. Survey blunders are rapidly spotted, thanks to the real-time display (as new survey shots are input) of the topographical path of the cave, the display of passage walls and lists of poorly-closed loops and orphan survey shots. Also featured are sketching aids such as a user-configurable map grid, the display of station coordinates using the sketching paper's grid and the display of projected length of survey shots. Cave survey data can be viewed in both graphical and tabular forms, with color cave maps or computed coordinates lists. Supporting the use of geographic locations, either input manually or through a serial link with a GPS, Auriga lets cave explorers immediately know how close they are getting to other known cave passages or surveyed surface features. Auriga's user-friendliness relies on a wealth of user-customizable options as well as a smart user interface well adapted to small PDA screens, even when used underground through the window of a protective case. Acquired survey data can be transmitted via IR to other PDAs, while a software "conduit" handles the bidirectional exchange of data between the PDA and popular PC cave survey software. Already in use in various countries, Auriga undergoes a rapid development, with several new releases a year. Upcoming features include loop closure, blunder detection, electronic links with automated survey devices and, ultimately, the ability to sketch passages walls and features directly on the PDA screen. Auriga is available for free, in 3 languages (English, French and Spanish), and comes with a comprehensive user manual and online help.

Mots-clés: Auriga, Topographie de grottes, Logiciel, Électronique souterraine

Résumé

L'utilisation d'Auriga sous terre améliore considérablement le processus de topographie des grottes. En remplaçant leur traditionnel carnet de papier par un ANP (Assistant Numérique Personnel ou ordinateur de poche) Palm OS exécutant Auriga pour la saisie des données numériques de topographie, les topographes bénéficient de fonctionnalités destinées à produire de meilleures topographies plus rapidement. La détection des erreurs est facilitée grâce à un affichage en temps réel (au gré des visées) du cheminement topographique de la grotte et des dimensions de galeries ainsi que des erreurs de fermeture de boucle et des visées orphelines. Le logiciel offre également des outils d'aide au dessin tels une grille graphique configurable, l'affichage des coordonnées des stations à l'échelle du carnet et l'affichage en continu de la longueur projetée des visées. Les données topographiques peuvent être revues tant en modes graphique que tabulaire, avec une topographie en couleur ou une liste des visées et des coordonnées calculées. Supportant l'utilisation de localisations géographiques, acquises manuellement ou par un GPS connecté via un lien sériel, Auriga permet aux explorateurs de se situer immédiatement par rapport aux galeries déjà topographiées ou aux phénomènes de surface relevés. La convivialité d'Auriga repose sur un éventail d'options et une interface intelligente bien adaptée au petit écran des ANP, même lorsqu'utilisés sous terre à travers la fenêtre d'un étui protecteur. Les données acquises peuvent être transmises par faisceau infrarouge entre les

ANP, tandis qu'un «conduit» logiciel permet l'échange bidirectionnel des données entre l'ANP et plusieurs logiciels de topographie de grottes sur PC. Déjà utilisé dans divers pays, Auriga connaît un développement rapide, avec plusieurs nouvelles versions par année. Parmi les fonctionnalités à venir figurent la fermeture des boucles, la détection des erreurs grossières, des liens électroniques avec des dispositifs d'acquisition de données automatiques et, ultimement, le dessin des galeries directement sur l'écran de l'ANP. Auriga est disponible gratuitement, en trois langues (français, anglais et espagnol), accompagné d'un manuel d'utilisation et d'aide en ligne.

Text

Much has changed over the last 20 years in the field of cave surveying. Most cave surveyors process their numeric data with PC-based programs, while the number of hand-drawn surveys is ever decreasing, thanks to sophisticated drawing programs and the availability of scanners to digitize notebook sketches.

By contrast, the input of survey data has changed very little over that period: the vast majority of cave surveyors still use a measuring tape, a compass and a sighting inclinometer and jot down their measurements into a waterproof paper notebook.

But the times are changing, thanks to the availability of Auriga, a cave survey freeware that runs on Palm OS handheld computers.

Originally created in 1997 by Martin Melzer to help tune his compass/clinomometer electronic sensor box prototype, the Auriga project became dormant around 1998. Luc Le Blanc resumed the software development in 2002, aiming at designing the perfect electronic replacement of the classical survey notebook. Auriga is now a user-friendly almost full-fledged cave survey software, albeit with a strong input interface designed to be used underground.

With universality in mind, pretty much everything is user-customizable:

- naming format and auto-incrementation scheme of survey stations;
- map units (length, angle, and slope 0 reference);
- handling of reverse headings and slopes (backsights);
- handling of passage dimensions;
- handling of unsaved data;
- handling of duplicate shots;
- hardware button use;
- various automated behaviors.

Auriga's target is to suit the needs to survey a complex cave system with several simultaneous teams, possibly with different instruments (e.g. metric tape in small passages and Topofil in collectors) using different measurement units (e.g. a Topofil counting in centimetres) and bearing different calibrations. Of course, all this data must support easy merging once back at camp.

Mixing instruments thanks to sessions

The ability to mix heterogeneous data is made possible with the use of sessions, a concept already present in several Windows/Mac OS cave sur-

vey software. Each survey shot belongs to a session, i.e. an abstract time period (its actual duration is left up to the user) during which survey shots are taken. Each survey session consists of two sets of instruments, calibrations, measurement units, and some default settings. The data read from the instruments can then be input "as is" into Auriga; the surveyor is not bothered by the broken end of his metric tape, the magnetic deviation, or the compass shift; the session takes care of these. When computations are performed, Auriga simply uses the proper session settings to interpret the survey data, without ever altering the original input data. In this respect, Auriga is as faithful as a paper notebook.

Tight storage

Despite an effort to squeeze as much survey information as possible into the meager 54 bytes used for each survey shot record in the Auriga cave databases, limits are few. Length, heading, slopes, reverse headings and slopes and passage dimensions are each stored with two-decimal precision as 16-bit integers, i.e. in hundredths of units. Survey shot length is thus "limited" to 655.33 meters (or feet, depending on user choice), an uncommon span in caves. Since survey data is stored in input units, no rounding error due to meters-feet conversion can occur when presenting the original data. In addition to basic survey data, a note of up to 255 characters (bytes) can be appended to each survey shot and session record, and to the cave database as a whole. Auriga cave databases can hold up to a maximum of 16 384 records (one per survey shot or session), a Palm OS limit. This limit can be pushed several folds by combining cave databases into networks.

Managing passages

Survey stations can be named with up to 8 characters, with user control over the permitted character set (numeric, alphanumeric, punctuation, etc.) The user can choose between a 4.4 format (e.g. "2.6", "A31.74") and an 8-character free format (e.g. "Cascade", "X24-46b"). The 4.4 format allows the use of series, a concept inspired by Toporobot. A series is simply a suite of survey stations and shots sharing a common root (like "A2.0", "A2.2" and "A2.31b") which can be acted upon collectively. As series are usually, and appropriately, made equivalent to passages, their use allows users to selectively hide passages from a crowded cave map, distinctively colorize them in the map, exclude surface shots from total cave development, select the projection direction of a passage in the projected cross-section cave map view, or just navigate between passages when reviewing survey shots. The sole prerequisite to manage survey shots as a series is to have a "series-beginning survey shot", i.e. a virtual survey shot linking the series-beginning virtual station to the rest of the cave (or to itself, starting a new disconnected leg.) The series-beginning station must bear the smallest station number within the series (e.g. station 2.3 cannot be the beginning station of series 2 if there exists a physical station 2.1.) Since series-beginning shots are virtual (zero-length) shots, the unused shot data storage space in their database record can instead hold a geographic location (like the UTM co-ordinates of the cave entrance) or an absolute XYZ co-ordinate - a convenient feature when working with cave subsets.

For those not familiar to the series concept or for compatibility with software that ignore it, most series benefits have been extended to sessions, offering an alternate way to manage passages.

Sharing the data

If several teams are let loose surveying a cave, conflicts are to be expected (...) with regard to station names or session numbers. To circumvent these, Auriga offers various maintenance functions to rename or shift stations names or series numbers, renumber or merge sessions, or move survey shots to another session. Ideally, teams should harmonize their data before merging it, in order to minimize tedious subsequent clean-ups.

Two mechanisms allow sharing survey data between teams: infrared (IR) beaming and the Palm HotSync process.

IR beaming is the common device-to-device Palm OS data sharing mode. Auriga can send a whole cave database, or a subset of it, to another device. In the latter case, every survey shot sent is accompanied by its corresponding session, so as to make the beamed data complete by itself. If the cave database does not already exist on the target device, it is created and filled with the beamed data. Otherwise, a record-by-record merge process is triggered. Similar but different survey shot or session records are duplicated and logged into a text memo for subsequent clean-up by the user. Otherwise, if the beamed records contain a note or other survey data that records on the target device do not have, while start/end survey stations are the same, records on the target device are simply updated with this additional information.

The HotSync process takes place on the target PC (or Mac) through a conduit launched by the HotSync Manager, a software component shipping with every Palm OS device. This process of synchronizing the Auriga cave databases with those present on the PC is a more complex process than IR beaming because it runs between heterogeneous databases (Auriga and non-Auriga) and it is a bidirectional process (insertions, deletions and modifications must be reflected on both sides.)

It is highly unlikely that another PC cave survey software would have its internal data format match Auriga databases field for field. Some software recognize series, some don't; and the same goes for reverse measurements, mixed direct and reverse shots, mixed measurement units, passage dimensions, etc. Thus, in order to transfer the Auriga survey data to the desktop software, the conduit may have to adapt this data to a format the target software can understand. This can mean merging the session calibration with shot data, removing series-beginning virtual shots, inverting reverse shots to make them all forward, etc. In the process, some information could be lost. To prevent this information loss, the conduit performs a two-phase sync: the Auriga data received through the HotSync manager is first stored into a mirror XML database on the PC before being adapted for the target software. This way, if the survey data is modified via the PC software, thus requiring a transfer back to Auriga (data consistency between the PC and the Palm must be maintained if further Auriga surveying is to take place in that cave), the conduit can fetch from the mirror database the previously dropped data and re-attach it back to the synced records before writing them into the Auriga database. Note that this latter step of fully synchronizing both databases is not yet implemented. Of course, the extent of this data removal and recovery depends on the target software, some being more restrictive than others. The Auriga conduit structure supports both the usual single user mode and a multiple user mode where several users can collectively sync their data with the same cave database; this choice is made within Auriga when creating a new cave database.

The current Auriga conduit, developed by Christian Chénier, allows the bi-directional exchange of survey data with Visual Topo and Compass, but support for other desktop cave survey software will be added based on demand.

Surveying with Auriga

Auriga can be used as:

- an electronic notebook to store numeric survey data and instantly view the cave map while in the cave;
- a scientific calculator to convert survey shots into Cartesian co-ordinates while at camp;
- an input device to transfer survey data from the paper notebook to the PC without wasting battery power.

The most common use for Auriga is to input survey data while in the cave. But carrying a Palm underground? Once you accept that you must treat a device as fragile as a Palm (compasses are also fragile) with proper care, it is no problem. In easier caves, wrapping the Palm in a Ziploc bag and carrying it inside the survey notebook (still required for sketching) may be sufficient. Otherwise, Aquacase makes, for US\$ 25, a watertight soft case with a write-through film on the front. Screwed into the cover of a regular survey binder, the setup allows for simultaneous input of numeric data into the Palm and sketching on the usual waterproof paper. This setup was used for my own field testing, and Auriga was improved accordingly to ease data input, up to the point where the usual stylus is not required for most tasks: a field-aware self-adaptive custom alphanumeric keypad with finger-tappable keys was developed for navigation between fields and survey data input.

A configurable input Assistant further increases the user-friendliness of the whole input process by automatically creating survey shots based on the previous one, auto-incrementing station names (with both digits and letters), popping-up the custom keypad when necessary, incrementally computing new survey shots, displaying the revised cave map. Everything is done to prevent mishaps that could result in data loss.

Computing the cave

Auriga performs, automatically and on demand, all the computations required in order to display the cave map and essential statistics. In order to handle every possible survey shot arrangement and to pave the way for a future loop closure algorithm, a full-blown non-oriented graph is internally constructed to represent survey stations (nodes) and survey shots (arcs) between them. An iterative algorithm scans in alternating directions the list of survey shots in the cave database to compute XYZ Cartesian station locations relative to the origin.

Any station can be manually selected as the Cartesian origin (0,0,0) of the cave, or as a point with a known fixed offset from this absolute origin. If the cave does not have a determined origin, the computation process chooses the first survey station (sorted in alphanumeric order) as the origin and assumes a zero offset. It is also possible to assign a pre-determined XYZ co-ordinate to a series-beginning or virtual survey shot (presumably computed somewhere else), thus allowing the computation of "real" co-ordinates from a cave subset that does not include the cave origin.

Likewise, any virtual station owning a geographic location (UTM, with or without altitude) can be manually selected as the geographic reference for the cave; after which any other survey station displayed in the cave map can be queried for its geographic location!

Viewing the cave

Auriga offers a graphical display of the cave map display, with full pan and zoom capability and the ability to graphically poke stations for information, XYZ coordinates or geographic location. The line plot can be displayed in top view or S-N, W-E, extended and projected profile views. One convenient feature is the ability to get the orientation of a passage, the inclination of a slope, or the distance between two points by simply dragging the stylus on the screen. Orientation angles obtained through this feature are automatically copied to the clipboard to allow quick pasting into the projection angle selection dialog.

The cave map is probably the most compelling feature to use Auriga underground: surveying with Auriga allows cavers to see the cave map while the cave is being surveyed. Not only can survey errors be detected faster, but it can orient the exploration process: by knowing right away where the cave is heading to, surveyors can decide which way to take or which passage to survey in priority. If a junction is expected, Auriga can let cavers know how close they are from the other passage and eventually

keep hope... Actually, Auriga could become an incentive to survey while exploring, a good practice in every respect!

Auriga also supports cave networks, where several caves can be logically linked and geographically positioned on a common display. This feature turns out to be very convenient not only to simultaneously view closely located caves but also to display caves so large (in terms of number of survey shots) that they had to be split into several sub-caves (ex. Lechuguilla or Wind Cave.)

A recent addition is the Sketch to Scale dialog where survey station coordinates are displayed according to the selected map scale and the paper grid size, making the in-cave use of the ruler and protractor a thing of the past.

What's next?

The rising activity in the field of electronic data acquisition has allowed Auriga to re-activate its serial link with sensing devices, starting with the compass/clinometer Revolution module from True North Technology - others should come soon. Survey data can be fetched from electronic devices and fed to the data input form in a fully assisted fashion. This should give Auriga a great boost: cavers may be reluctant to bring a Palm underground just to add features to their classic notebook, but the prospect of an affordable electronic cave surveying process may well become irresistible. Furthermore, with the recent addition of GPS support, the tracking of the current surface location against a "moving map" of the cave underneath is just months away!

The next feature to be implemented should be a loop closure algorithm along with blunder (gross errors) detection. This will improve the detection and correction of survey errors while in the cave.

The ultimate future addition to Auriga will be the ability to sketch the cave walls directly onto the Palm screen. This may sound like a heresy to purists, but a full screen of drawing space for every survey shot, in scale with the surveyor's own visual perception, would possibly lead to better sketches. This feature would definitely render the paper notebook useless, while allowing cavers to come back to the surface with an almost finished cave map. But the complexities of this feature, with regards to curve handling, storage and conduit syncing could be the topic of an article by itself.

Trying Auriga

The software can be downloaded from the Auriga homepage, along with sample caves and a complete user manual. Do read the manual at least once. Auriga is not complicated, but complex; the manual should give you a good understanding of the underlying concepts and may help you discover features that are not immediately obvious in the user interface.

If you do not have access to a Palm OS device, you can nonetheless try the software under a free Windows-based emulator. Get the details in the Auriga homepage.

Acknowledgements

Martin Melzer, for starting the Auriga project and thus providing the initial proof of concept that convinced me to jump into this adventure

Christian Chénier, friend, fellow caver and fine beta tester, for his most precious advice on concepts, strategies and user interface, and for writing the data exchange conduit

Annick Normandin, my wife, for her understanding towards all this time spent since 2002

O-168

Use of a non-linear curve fitting program to separate the emission spectra of multiple fluorescent dyes from spectrofluorophotometer analysis used in groundwater dye tracing

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Synchronous scanning spectrofluorophotometric analysis has proven to be the most efficient and effective technique for analyzing fluorescent dyes used for tracing groundwater movement in karst aquifers. Quantitative as well as qualitative results can be obtained providing that the individual spectra created from each fluorescent dye produces emission spectra that do not overlap and thus mask the emission output of other dyes in a sample. Injecting multiple dyes in a groundwater tracer study can result in only qualitative results at best if the spectra from these dyes overlap and/or the spectra of one dye greatly mask the nearby spectra of another dye. With the aid of a non-linear curve-fitting computer program these overlapping emission spectra can be separated and quantified beyond the capabilities of a spectrofluorophotometer alone. This data analysis program can model gaussian curves of varying heights and widths in the data stream produced by the synchronous scanning spectrofluorophotometer.

The data stream is broken down into the individual spectra of fluorescent dye molecules contained in a multi-dye tracer sample. These individually separated gaussian curves are identified by the wavelength of peak locations. The non-linear curve-fitting analysis software is set to then perform integration on each gaussian curve to determine the area bounded by each curve. Calibration curves derived from similar analysis of laboratory standards are then used to calculate the concentration of each fluorescent dye present in a sample. The Center for Cave and Karst Studies has successfully utilized this non-linear curve fitting analysis method for fluorimetric analysis on countless fluorescent dye tracer investigations. Utilizing the non-linear curve-fitting program allows for multiple dyes to be injected simultaneously and effectively provides qualitative and quantitative results. This greatly reduces the number of overall dye trace events that would ordinarily be required if only one or two dyes are used. This method can be performed equally well for both quantitative water analysis and semi-quantitative activated charcoal elutant analysis.

O-169

An Open-source Web-based National Cave Database

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*Thornleigh NSW 2120, Sydney, Australia, MikeL@speleonics.com.au*Peter Matthews, UIS Informatics Commission, +61 (3) 5263-1686, *matthews@melbpc.org.au***Abstract**

Building on its successful experience in 1985 with the Australian Karst Index Database (140 fields, 6600 caves and karst features, 2400 maps, 925 references, and the associated 500-page book [1]), the Australian Speleological Federation teamed up with the Informatics Commission of the International Union of Speleology to expand and convert the KID to a modern, web-based, fully relational database using open-source software. Those responsible for each of Australia's 355 cave areas can keep it up to date and control access to the information using a simple web interface. The read-only KID using the 1985 data has been operational on the web since 2001, and the updateable version since mid 2005 (<http://www.caves.org.au>). ASF produced the software and the installation, while the Informatics Commission (<http://www.uisic.uis-speleo.org>) advised on the field definitions and database structures, for which this installation also acts as a pilot. The Commission invites many more fields from the caving, research and management communities.

The software was professionally written and documented to ASF's detailed specifications, and released under the GNU Public Licence so that it would be freely available to other groups. It runs on a GNU/Linux server, but could also run on other platforms because it uses MySQL, Perl and Apache, all of which are open-source and multi-platform. Though easy to use, it requires reasonable knowledge about computer servers to install and manage. Attention has been paid to ease of conversion of the programs and data to languages other than English, and to ease of adapting the user interface, though there may be internationalisation problems for some languages. It is hoped that its ease, adaptability and economy will lead to wide use, and with its formally defined fields, will facilitate the ready exchange and consolidation of caving and scientific data.

Introduction

The Australian Speleological Federation's national Karst Index Database is accessible on the Internet at <http://www.caves.org.au/> (Click on "Karst Index database"). Most of the information on the 6 600 caves is accessible to anyone via a guest login. The software was written so that it can be used via any Web browser, including text-based browsers, so users with vision impairment can access all functionality of the KID. The database itself consists of approximately 500 fields structured into 69 tables.

The ASF's KID is the first Web-based database to implement the suggested information standards developed by the International Union of Speleology Informatics Commission (UISIC) [3]. These Standards include definitions for the cave and karst data fields, numeric codes for their values, and suggested table structures for cave and related databases.

Functionality Provided by the ASF's KID

Features of the Web-based KID for users include:

- * a web-based interface that is easy to use;
- * works with text based browsers - important for visually impaired users;
- * users can make queries about areas, caves, maps, persons and organisations;
- * updaters can update areas, caves, maps, persons and organisations;
- * users can see what changes have been made to the data so users and State Coordinators can easily identify what data has changed;

- * the software creates Cave and Map Summary Forms for archiving and in-field use in PDF format directly from the database;

- * data attribution keeps track of contributions.

Features for administrators include:

- * web-based user administration system;

- * administrators can create, delete or edit users;

- * administrators can assign user access from state down to cave area level;

- * administrators can restrict user access to individual fields;

Additional features include:

- * UISIC field compatible;

- * open sourced under the GPL licence so others can use it and contribute to it;

- * source code is well documented;

- * scalable to cope with tens of thousands of caves;

Anyone can use the KID to make queries, however updating functions are only available to updaters via a username and password. Screen shots and detailed tutorials for updaters can be viewed by anyone in the documentation section (<http://www.caves.org.au/kid/doc>). This means that anyone in a caving club in Australia wishing to help update caves can see how updating works and overseas organisations wishing to gain an overview of the updating system can also see how updating is done.

The integrity of the data in the KID is of paramount importance and for this reason checking of all updates by independent checkers is part of the KID updating system so that the possibility introducing errors into KID is reduced. Effectively a peer-review system is used; updates go into a staging table, a checker then reviews the changes and only if they are passed do the changes proceed into the main data tables where they can then be seen by users making a query.

This also means that no single user is responsible for errors that get into the database. Errors can still make their way into any database so data history is recorded so that all changes can be traced and mistakes corrected. This also extends to cover the data quality fields.

Data quality for fields is also recorded so that the accuracy of the entered data can be specified (e.g. data quality for the "discovery date" may be "probably correct" while data quality for a cave's length may be "known to be greater than"). There are 27 available data quality fields varying from simple ranges such as "correct" to "wrong" to more complex statements about data accuracy.

Data attribution is also tracked so that data is attributed to the organisation that produced that data.

The ASF KID Licence

The ASF's KID is released under the GNU General Public License [4]. Indeed, one of the requirements of the ASF specification to the programmer was that the software used in the KID was open source and released under the GPL. This means that the ASF did not need to purchase any software or software licences and we can use other people's high quality, open source code in our KID. Because the KID software is released under the GPL it's also available for other speleological groups and individuals to use and hopefully contribute to it.

There is no publically available link on our website for the source code, however you only need to email the KID Administrator and a link from where you can download the latest version can be emailed to you. The complete code is 2.9 MB and some sample data is 200 kB in size.

There is no published link yet because:

- a) The software is developing rapidly and we probably will not keep the link up-to-date with the latest version.

- b) We would like to know who is interested in the software. If you

decide you don't want to use it we'd like to know why, was it too difficult to install? was the interface not what you expected?

- c) It is not client software and cannot be easily installed on Windows machines.

If people do download and use the KID, and make changes to the system, we would like to know. We would prefer if the code does not "fork". Keep track of your changes and if it is possible we will try and incorporate those changes, if applicable, into the KID code so that other countries and ourselves can benefit.

Software and System Requirements

The KID software was written by a professional programmer from our detailed specifications. The software runs on a Debian GNU/Linux server, however any other Linux distribution can be used. With minor changes to the installation procedure it will also install and run under Mac OSX. The database used is MySQL (<http://www.mysql.com>). The web server is Apache 1.3 server with mod_perl. The software is written in the Perl programming language and uses several CPAN modules (Comprehensive Perl Archive Network <http://www.cpan.org>). This perl code runs to over 150 000 lines. We are also using some open source relational database interface modules developed by Praxis for rapid application development. All of this software is available under either the GPL or other open source licence.

There is a detailed Installation Guide and a Maintenance Guide for the KID available on the KID Documentation page. However to install and manage the KID does require a reasonable level of computer knowledge. You will need to know how to setup, configure and run a web server, install software from a tarball, an RPM or Debian package and install Perl modules from CPAN.

Finally, the security of the system was carefully considered throughout during coding. However as with all systems that are connected to the Internet, install and run as few applications and services as possible, keep your system up-to-date with the latest security patches, read your log files regularly, run an intrusion detection system and check it regularly.

UISIC Database Schemas

UISIC aims to facilitate local and international storage, use and exchange of data related to caves and karst by developing and publishing related information-handling standards (<http://www.uisic.uis-speleo.org/exchange/exchprop.html>).

These standards include definitions for cave and karst fields and their values, and suggested table structures for cave-related databases. The ASF's Web-based KID is the first Web-based database to implement these standards. The draft field definitions and most of the suggested table structures are used and the ASF will try to follow these standards as they evolve.

UISIC has identified the following three requirements to allow the valid transfer, comparison and/or consolidation of cave/karst data between independent databases. It is not required that the same software or database structure be used at each end of the transfer. These recommendations are still in draft, and will be discussed via international UISIC working groups before being finalised. All are invited to contribute.

1. **Record Identifier:** Use of a record identifier which is internationally unique and permanent for each cave or karst feature or other entity being transferred. The unique identifier for an entity being transferred consists of the concatenation of an ISO 2-letter country code, a 3-letter organisation code issued within that country, and a serial number issued by that organisation. The identifier is therefore issued locally by the creator of the record, yet is unique internationally.

2. **Field Definitions:** Use of internationally agreed definitions for the data fields and field values to be transferred. The draft fields and definitions can be seen on the above web pages. Fields and their values are designated by numeric codes so that they are independent of any national language yet can be expressed in any language.
3. **Transfer Format:** Export and import of the exchange data from/to the database via an intermediate standard UIS transfer format. A UISIC working group is currently establishing the transfer format using XML. Its name is CaveXML. Use of a standard transfer format means that the various independent database systems need allow for export/import to only one format to be able to transfer data to/from any other participating database system. (See <http://www.cavexml.uis-speleo.org>).

The ASF is trying out the record identifiers, field definitions and values, and suggested table structures in a real-life situation. However the CaveXML transfer format has not yet reached draft stage.

System Documentation

The software is very well documented. There is a detailed Installation Guide and a Maintenance Guide available on the KID Documentation pages. The field definitions used by the ASF are available as HTML pages produced on-the-fly from the KID database itself. The table relationships are also produced on-the-fly.

In addition to the code itself being well commented for every perl module in which object classes are defined the objects and methods are

documented in HTML format.

Updaters require documentation to assist them in understanding the overall KID system, the procedural aspects of field data collection, collection and updating and in understanding the many fields in the KID and their meaning. This documentation is well advanced but much remains to be written.

Future Directions

Internationalisation: The software currently uses the English language. Future versions of the software should be internationalised so that it can be easily adapted by other countries. The KID already has excellent separation of the Perl code from the HTML markup so redesigning the user interface for other speleo groups is not too difficult. However there are areas of code which will present some problems, especially for countries that use non Latin character sets.

Further entities: Other entities we expect to add in the future are lists of articles/papers, lists of biological species, etc etc.

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2. Australian Speleological Federation's Karst Index Database <http://www.caves.org.au>
3. The International Union of Speleology Informatics Commission <http://www.uisic.uis-speleo.org>
4. GNU General Public Licence <http://www.gnu.org/licenses/licenses.html>

O-170

Contribution to the cave origin by mechanical weathering in temperate zone

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Abstract

There are several examples of caves originated by mechanical weathering in various rocks of the Western Carpathians (andesite, basalt, rhyolite and their tuffs, limestones) described in this paper. The mechanical weathering is a physical breakup or disintegration of rocks without changes in their composition. It consists mainly of washing up, temperature oscillations (solar warmth), frost wedging, eolic processes. Cooperation of more components at the same time generally occurs in natural conditions. The mechanical weathering moves forward in appropriate structural and/or lithological environment (fault, gravitational crevice, joint, layer intercalation, xenoliths, tree molds and others). Loose rocks are the most prone to the mechanical weathering (sandstone, aleurite, conglomerate, tuffs etc.).

Key words: pseudokarst caves, mechanical weathering, washing up, temperature oscillations, frost wedging.

Caves originated by mechanical weathering - without chemical dissolution - are not frequent in nature and do not reach larger dimensions. Weathering phenomena originated by the frost wedging and other cryogenic processes occur more frequently in northern and periglacial zone, high mountains (Holler & Holler 1989, Sjöberg 1989) and as Pleistocene remains in temperate zone (Demek 1989).

Several small caves, which originated by mechanical weathering, occur in temperate zone of the Central Europe. This process is caused by following exogenous forces:

1. **Washing up:** raindrops (0.004-8.0 mm of size) infiltrate through fissures (lithoclasts, diaclases), joints, interlayer sheets and pores

of rocks and carry along the smallest particles into the deeper zone. This process is considerable in humid areas. In Central Europe the annual average rainfall is 170-600 mm in continental zone and up to 2,000 mm in mountains and Atlantic zone. The plant cover can delay the infiltration and decrease the washing up. Larger washing up process is known as suffusion (piping, tunneling - Liszkowski 1995, Halliday 2004, sapping, tunnel erosion - Bryan & Jones 1997).

2. **Temperature oscillations:** outer part of rocks is warmed more than the inner one. A stress is generated between them and exfoliation happens. Daily temperature oscillations in summer in temperate zone range between 40-60 °C and are extended to the depth of 0.25-0.6 m. Exfoliation and disintegration happen due to different warming of dark and light minerals (dark minerals increase more their volume than the light ones, some minerals are enlarged only in certain directions). In basic rocks the sonnenbrandt (exfoliation in small rounded forms due to sunshine) is typical.
3. **Frost wedging:** the frozen water - ice - expands its volume down to -22 °C (1 cm³ of water produces 1.0908 cm³ of ice) and, under condition of bottle effect and filling up of all pores with water, it pushes out the surrounding particles of rock. The greatest effect is in rough, schistose, bedded and vesicular rocks, mainly by repeated processes. The depth of the frozen part of rock is 0.4 - 0.9 m in the temperate zone. Frost wedging is effective only in caves entrances in this climate (several caves are known in limestone in the West Carpathians - Mitter 1983).



Fig. 1: The Delta Cave originated by washing up and frost wedging along a gravitational crack in Štiavnické vrchy (Slovakia). Photo: M. Solár

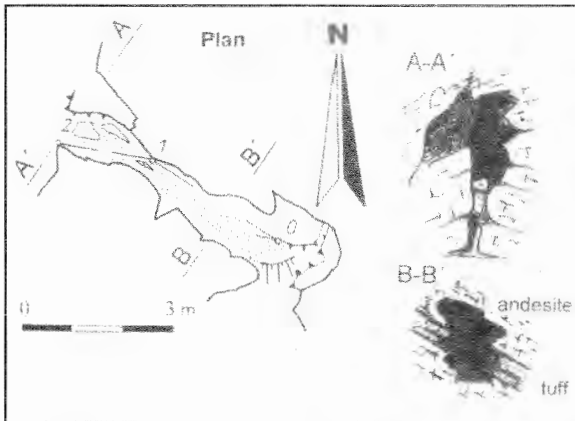


Fig. 2. The Jaskyňa v Budinskej skale Cave. Compiled by L. Gaál.



Fig. 3. Small underground spaces along the bedding plane in sandstone in Český ráj (Czech Republic). Photo: L. Iždinský



Fig.4: The Belinská jaskyňa Cave in Cerová vrchovina (Slovakia). Photo: L. Gaál

4. **Wind erosion:** it was stronger in the temperate zone in the cold periods of Pleistocene, when strong winds in lowlands took along many soft clasts.
5. **Spreading forces of tree roots:** cracks in rock can start by the growth of tree roots, which press the surrounding rock with power of 10-15 kg/cm².
6. **Crystallization of salts:** several salts can spread the surrounding rock; it may have the same effect as frost wedging in cracks.

Particles of rocks loosed by this processes will be fallen down and exfoliated by the gravitation power. However, the majority of the upper mentioned processes generally occur simultaneously in nature. Therefore the classification of weathering caves by the mechanic processes is questionable.

The exogenous powers work in nature conditions generally along sheets of predisposition, i.e. mainly faults, crevices, layers, schistosities, joints, as well as in consequence of different hardness of rocks and weathering of xenoliths. The optimal rocks for mechanical weathering are loose, not much coherent for example as conglomerate, sandstone, claystone, loess, tuffs and so on. However, in appropriate conditions the weathering processes take place also in solid rocks.

The weathering processes proceed the most frequently along the tectonic fissures or gravitational crevices. Some caves of this type occur in Permian-Mesozoic sandstone of Saint-Cross (Świętokrzyskie) Mts. in Poland. Their development consists in widening of vertical fissures by subsurface water with contribution of mechanical weathering and gravitational collapsing (Urban & Kasza 1994). Similar way of origin has several caves of the Czech Cretaceous region, mainly around Broumov (Vítek 1979, Kopecký 1982) and in the upper Triassic sandstones near Bayreuth in Germany (Striebel 1994). Small underground tunnels are known in gneiss of Žďárské vrchy in Czech Republic (Kirchner 1989).

Two small caves occur in the Štiavnické vrchy Mts. in Slovakia (Delta 10,7 m and Buková diera 5,1 m), which originated by washing up and frost wedging along a gravitational crack in relatively weathered rhyolite.

Weathering processes often operate along the bedding plane or stratum intercalations. One example of a bedding cave is the 5 m long cave Jaskyňa v Budinskej skale in the Ostrôžky Mts. in Slovakia, that originated by frost wedging and washing up along the tuff intercalation in andesite.

The other nice example is the Komoniecki Cave in the Beskid Mały in Poland created between sandstone and conglomerate (Waga 1990). Many bedding plane caves occur in sandstones of Czech Cretaceous region (caves in Klokočská skála - Vítek 1987, in Broumov region - Kopecký 1982, caves in marlite - Vítek 1977), Elbsandsteingebirge ("schichthöhlen").

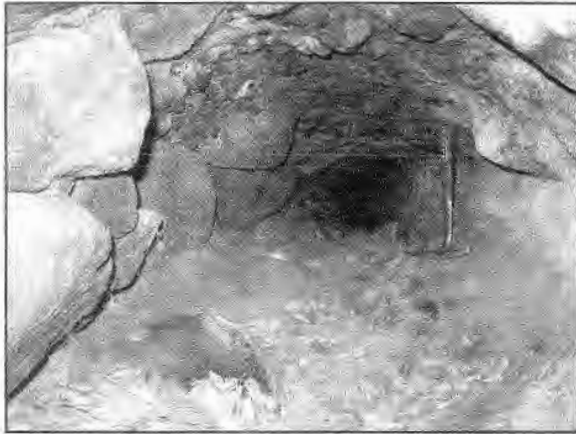


Fig. 5. Underground tube of the Trpasličia jaskyňa tree mold cave in Slovakia.
Photo: P. Bella.

len" - Börner 1989) and Zittauer Gebirge in Germany (Bothe & Winkelhöfer 1989) but also in Paleogene sediments near Sokolov in Czech Republic (Cikánka cave - Kukla 1950).

Weathering processes can proceed along a joint plane in volcanic rocks. Very interesting weathering cave of this type occurs in the Cerová vrchovina Mts. near Fiľakovo in Slovakia. The 4.5 m long Belinská jaskyňa is developed on the plane of columnar jointing of Pliocene basalt by the weathering of sonnenbrandt type by temperature oscillations (Gaál 1996).

Underground cavities can originate also by selective weathering in rocks with different hardness and resistance. The cave Abčina with 12 m of length in Poľana Mts. in Slovakia originated by dropping out of andesite blocks from loose tuffit. Later, it was enlarged by eolic and frost processes.

The event of washing up of sandstone xenolith in basalt neck is known in Salgótarján in the Northern Hungary (Baglyas-kő cave - the opinion of fumarole origin of this cave is known as well - Ozoray 1960). Probably unknown object was washed out in the case of andesite cave Jánošíkova skrýša in Ostrôžky Mts. in Slovakia (Gaál 1996). Arched shape of jointing of andesite and its exfoliation signalized the existence of this object.

Special types of the selective weathering caves are the tree mold caves. In temperate zone they originate by washing up or decay processes of trees usually covered by the volcanoclastic material. The trees were deposited by periodical flows on the volcanic slopes or by debris flows, mud flows as lahar sediments. The first type is represented by caves with the length of about 5-10 m in Miocene volcanoclastic rocks of the Central Slovakia (Jaskyňa pod Jaseným vrchom, Trpasličia jaskyňa, Jaskyňa v tufoch, and Voňáčka).

Mučínska jaskyňa in the Southern Slovakia originated by weathering of totally carbonified tree. The little cave Jaskyňa v maare in the Southern Slovak Basin lies in lapilli tuffs of maar crater's wall. The trees near the crater were probably pulled down by strong volcanic explosions, thrown to the air and their remains (trunks) were consecutively covered with another layer of lapilli tuffs (Gaál, Tachihara & Urata 2004).

The nice example of the tree mold cave in lahar occurs in Doupské vrchy in Czech Republic. The tree mold cave is a compound of 7 trees with the length of 18 m found there among the ca 15 caves named Jeskyně skřítku.

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Infiltration in the dolomitic karstic system of Nerja Cave (Southern Spain)

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Abstract

Hydrogeological studies have been carried out within Nerja Cave since 1991 to characterise the dripwater within the cavity, both chemically and isotopically, and to determine the hydrodynamic functioning of the unsaturated zone of the aquifer in which it lies. Analysis of the natural responses (hydrodynamic, hydrochemical and isotopic) observed at a representative drip point in the cave to variations in the volume of precipitation reveals the existence of two types of infiltration through the marbles overlying the cavity, and enables us to establish the mean residence time of the infiltration water in the unsaturated zone of the aquifer.

Introduction

Nerja Cave is in the province of Malaga (Andalusia, southern Spain), some 5 km east of the coastal resort of Nerja (Fig. 1). It has three entrances, two natural and one artificial, and was opened for tourist visits in 1960 (one year after its discovery). Since then, it has received an average of 500,000 visitors per year. The cavity contains an almost uninterrupted 25,000 year-long archaeological sequence, together with important groups of Palaeolithic and post-Palaeolithic cave paintings.

The cave, with a volume of approximately 300,000 m³, has a practically horizontal development, lying between 123 and 191 m a.s.l. (SEM, 1985). It is divided into two sectors: one is open for tourist visits (the Tourist Galleries) and occupies about a third of the total volume of the cavity; the other area (High Galleries and New Galleries), occupying the remaining two thirds of the total volume, is closed to tourists and is only occasionally visited, by researchers and small groups of speleotourists. The general orientation of the main galleries is N35°E in the tourist zone and N-S in the rest of the cavity (Sanz de Galdeano, 1993).

Outside the cave, the air temperature varies between 8.1°C (January) and 27.8°C (August), with a mean annual value of 17.3°C. The mean precipitation in the area is 490 mm/year (Andreo and Carrasco, 1993a), although it is irregularly distributed over the year, with a well-defined wet season during the months of November to January, and a dry season during the summer.

From a geological viewpoint (Fig. 1), the cave lies within rocks belonging to the Alpujarride Complex of the Betic Cordillera (Andreo et

al., 1993). The stratigraphic series of this Unit is made up of a Palaeozoic lower metapelitic succession and of an overlying carbonate sequence, constituted of dolomitic marbles (in which the cave developed) of Middle Triassic age toward the bottom and calcareous marbles of Upper Triassic age toward the top. These marbles, which are permeable as a result of fracturing and karstification, form part of the Sierra Almajara carbonate aquifer.

Today, the cave is situated in the unsaturated zone of the aquifer, several metres above the piezometric level (Fig. 1), as a consequence of the tectonic lifting of the region during the Pliocene and the Quaternary. The thickness of the marbles above the cavity is highly variable: from 4 to 50 m in the area open to tourism, and exceeding 90 m in the non-visitable area. Rainfall infiltrates through fissures and fractures in the marbles, and drips from the roof of the cave.

The objective of the present study is to describe how infiltration takes place in the unsaturated epikarst zone of the Nerja cave system, on the basis of the results obtained from over a decade of investigation.

Methodology

From 1991 to the present day, a systematic study has been made of the hydrodynamics, the hydrochemistry (principal components), the isotopic content ($\delta^{18}\text{O}$ and $\delta^2\text{H}$) and the physical-chemical characteristics (pH, temperature and electrical conductivity) of the water obtained both outside the cave (rainwater recorded at the weather station) and within it (dripwater). Daily records have been kept of the volume of precipitation above the cave, measured by the pluviometer at the weather station, and the volume of dripwater within the cavity.

Until March 1993, the control network was made up of 10 points where dripwater was monitored. After this data had been analysed (Andreo and Carrasco 1993b; Carrasco and Andreo 1993; Carrasco et al. 1995, 1996), the monitoring was restricted to a single dripwater point in the Cataclysm Chamber, known as the Rincón del Órgano drip point, which was considered to be representative. Sampling periodicity has varied over the years; it was performed monthly from 1991 until December 1993, fortnightly from January 1994 to October 1995, and then weekly from November 1995 to date. The Total Organic Carbon content of the dripwater collected at this point was recorded from April 2000 to August 2001.

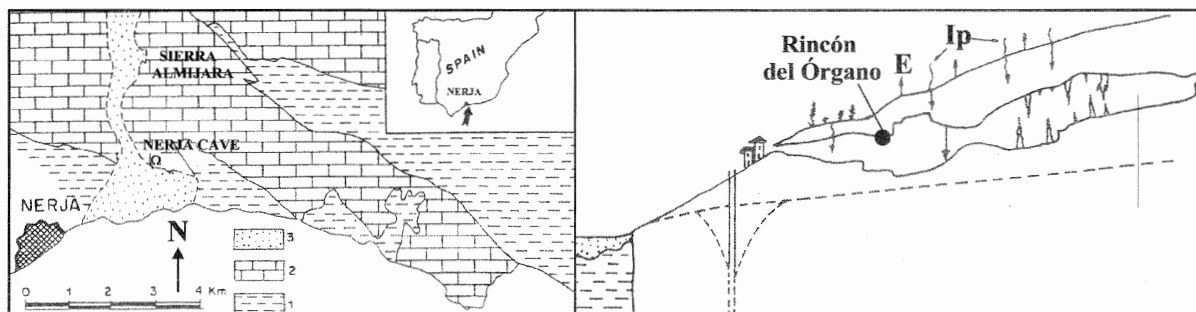


Fig. 1. Location of Nerja Cave and hydrogeological cross-section (not to scale). Key: 1- metapelites; 2- marbles; 3- Pliocene and Quaternary deposits; E- evapotranspiration; Ip- infiltration of rainwater

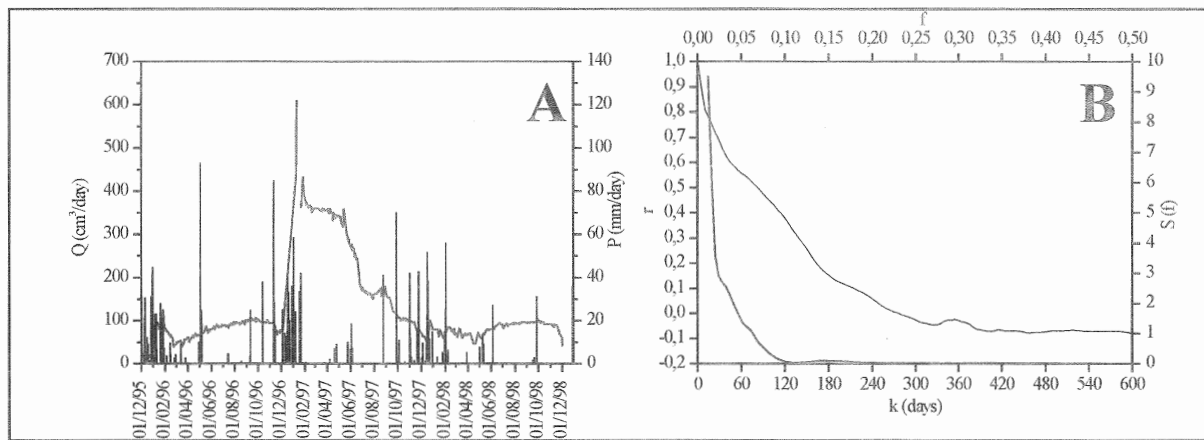


Fig. 2. Temporal evolution of the volume of dripwater flow at Rincón del Órgano, plotted against precipitation (A) and autocorrelograms of the data series for dripwater flow and rainfall (B).

Hydrodynamic of the unsaturated zone

The dripwater flow within the cavity is, in general, very low, at around 10-100 m³/year under average pluviometric conditions. At the Rincón del Órgano drip point, the mean dripwater flow is 90 cm³/day. The temporal evolution of the dripwater flow at this point is wave-shaped, with maximum values during the summer and minimum ones in the winter (Fig. 2). The fissures and fractures in the dolomitic marbles above the cave present only a slight aperture (or width) and, moreover, are partially filled in by clays or carbonates, which means rainwater must infiltrate very slowly through the marbles.

The temporal evolution of the volume of dripwater, with respect to the local pluviometry (Fig. 2A), reflects the existence of two modes of infiltration through the epikarst and through the unsaturated zone (Carrasco et al., 1996, Liñán et al., 1999): one is a slow infiltration, that is predominant throughout the year, and the other is a rapid infiltration that occurs only occasionally. Taking into account the annual distribution of precipitation, the overall evolution of the volume of dripwater, with maximum values in summer/autumn and minimum values in winter/spring, means that rainwater circulates slowly through the aquifer, from its entry until its appearance at the drip points within the cavity. Only during periods of significant recharge, in magnitude or in intensity (for example, in the early months of 1997), is there evidence of rapid infiltration, visible as a marked, rapid increase in the volume of dripwater within the cavity. The magnitude of the latter depends on the quantity of the recharge and on that of the water stored in the epikarst of the cave, before the precipitation occurred. Rapid infiltration takes place in response to high levels of precipitation that produce a faster circulation of water through preferential diaclasses.

The correlatory and spectral analysis of the daily precipitation and dripwater data, corresponding to 5 hydrological years, reveal the inertial behaviour of the unsaturated zone and the strong modulating force of the input signal recorded (Andreo et al., 2002). The correlogram of the dripwater flow displays a slope flattens more slowly with respect to that of the rainfall (Fig. 2B), there is a marked memory effect (about six months), the regulation period is high (85 days), the spectral band is narrow, with a cutoff frequency of 0.10 (10 days) and the entry-exit lag, for events of annual periodicity, is around 6 months. The quantity of water stored in the epikarst before precipitation occurs plays a very important role in the hydrodynamic functioning of the system; the latter factor has been observed to be less inertial during a wet year than during a dry one. Only in periods of high levels of recharge (in magnitude or in intensity) is there a considerable, rapid increase in the volume of dripwater within the cave. The magnitude of this variation depends on the previous hydrodynamic state of the unsaturated zone above the cave, that is, on the greater or lesser quantity of water stored before the precipitation occurred.

Both rainfall and dripwater sporadically present a very high content of K⁺ (up to 49 mg/l in rainfall and up to 92 mg/l in dripwater) and of Cl⁻ (up to 61 mg/l in rainfall and up to 139 mg/l in dripwater). By making use of the K⁺ content as a tracer it has been calculated that the transit time, from the rain falling onto the surface until the dripwater appearing within the cavity, is approximately 2 to 8 months (Fig. 3), depending on the quantity and intensity of recorded precipitation before, during and after the K⁺-rich rainfall, and also on the path this water follows through the fissures of the marbles (Carrasco et al., 1996, Liñán et al., 1999, Andreo et al., 2002b).

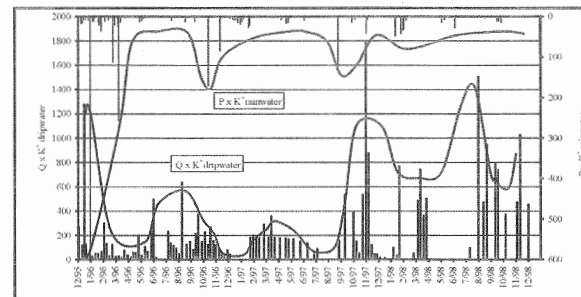


Fig. 3. Entry and exit flows of K⁺

The values of δ¹⁸O in the dripwater are lower during the summer and autumn months, and higher during the winter and spring. Comparison of the entry and exit flows of δ¹⁸O reveal the existence of a slow circulation through the unsaturated epikarst zone (with a duration of some 8 months) together with a faster circulation presenting a transit time of 1-3 months (Andreo et al. 2002b; Liñán et al. 2002).

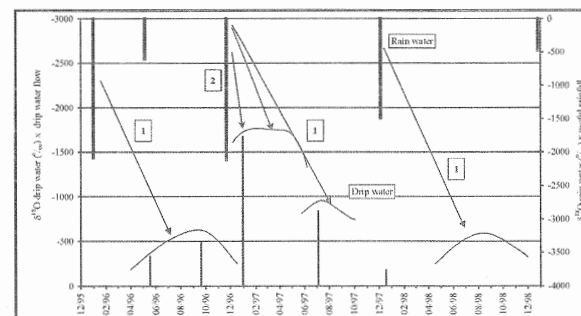


Fig. 4. Entry and exit flows of ¹⁸O. 1- Slow flow; 2- Fast flow

The temporal evolution of the Total Organic Carbon (TOC) content of the dripwater reveals a seasonal variation, with maximum values during the summer and minima during the winter (Fig. 5). The organic matter content in the soil lying above the cavity is higher during the summer because this is when the vegetable matter that falls onto the soil accumulates and decomposes, as part of an adaptation mechanism to the dry conditions prevailing at this time of the year. The rain that falls during the subsequent months of autumn and winter washes the soil and carries this organic matter into the aquifer, and thus into the dripwater that appears in the summer (Batiot et al., 2003). This again illustrates the existence of a seasonal lag between rain falling and its exit through the dripwater points within the cave. The water drained by the drip point contains minimal levels of TOC because the latter is mineralised and because this water falls and infiltrates during the winter and spring, when the organic matter content of the soil is low, the decomposed organic matter having been washed previously by the rain falling in autumn and winter.

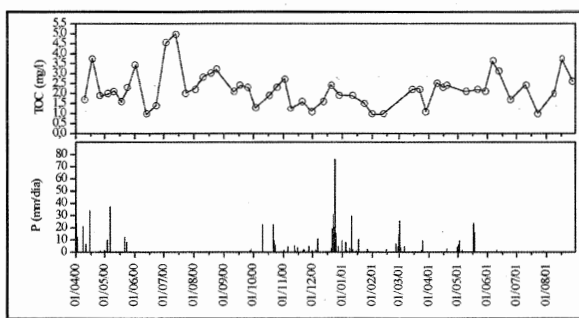


Fig. 5. Temporal evolution of the Total Organic Carbon content of the dripwater registered at Rincón del Órgano, and of the precipitation recorded at the Nerja Cave weather station.

Hydrochemistry of the unsaturated zone

Within the cave there are two main types of water: that which is obtained in the area closest to the entrance, and the samples taken in the rest of the cavity (Andreo et al., 1993a and b). The first type, with a bicarbonated-sulphated calcic-magnesian facies and presenting an average level of electrical conductivity of 1150 $\mu\text{S}/\text{cm}$, has a PCO_2 of 0.43% (0.43×10^{-2} atm). This water is obtained from a nearby borehole and is used to irrigate the garden, after which it seeps into the cave. The second type has a magnesian-calcic bicarbonated facies and a mean electrical conductivity of 468 $\mu\text{S}/\text{cm}$. It is clearly of meteoric origin, as evidenced by its chemical and isotopic composition (Liñán et al., 1999). In general, the mean PCO_2 is 0.15% - 0.15×10^{-2} atm- (Carrasco et al., 1998), which is higher than atmospheric values and, moreover, is higher in summer than in winter (Fig. 6). The water inside the cave is supersaturated in calcite throughout the year, and so produces deposits of calcium carbonate.

On an annual scale, the chemical composition of the meteoric dripwater is mainly influenced by the Ca^{2+} and Alkalinity (TAC) content and, to a lesser degree, by the K^+ and Cl^- content (Fig. 6). In turn, the Alkalinity and the Ca^{2+} and Mg^{2+} contents influence the degree of saturation of calcite and dolomite in the dripwater.

The electrical conductivity of the dripwater increases in summer, when the volume of dripwater is greater, when the water is less supersaturated, has a lower $\text{Mg}^{2+}/\text{Ca}^{2+}$ ratio and a higher Ca^{2+} and TAC content, and presents higher PCO_2 values. The electrical conductivity decreases progressively during the autumn, coinciding with the progressive reduction in the dripwater flow. These seasonal variations in the electrical conductivity of the dripwater are related to the degree of saturation in calcite and

dolomite which, in turn, is related to the PCO_2 of the dripwater; in winter, the water is more supersaturated in calcite and dolomite, there is a greater precipitation of calcium carbonate, the $\text{Mg}^{2+}/\text{Ca}^{2+}$ ratio increases, and so the electrical conductivity decreases. In summer, the water is less supersaturated in calcite and dolomite, there is less precipitation of calcium carbonate, the $\text{Mg}^{2+}/\text{Ca}^{2+}$ ratio decreases and the electrical conductivity increases.

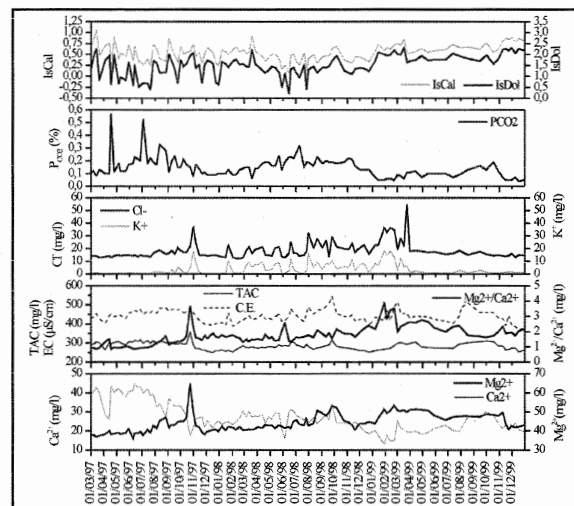


Fig. 6. Temporal evolution of the electrical conductivity, the chemical composition and the parameters of the calcium-carbonic system of the dripwater at Rincón del Órgano.

Conclusions

The hydrogeological studies carried out in Nerja Cave have enabled us to characterise the hydrodynamic functioning of the unsaturated zone of the aquifer in which it lies. Analysis of the natural responses (hydrodynamic, hydrochemical and isotopic) at one of the drip points in the cavity, with respect to variations in precipitation, reveals the existence of two types of infiltration through the epikarst and the unsaturated zone: one is slow, and predominates throughout the year, while the other is rapid (or, rather, less slow) and only occurs sporadically, when recharge levels are very important in magnitude or in intensity.

The residence time of the rainwater in the epikarst and in the unsaturated zone, until its appearance at the drip points in the cave, is 2-8 months ("rapid" and slow infiltration, respectively), as calculated from the hydrogram obtained at the drip point, from the results of correlatory and spectral analysis, from the time lag between entry and exit flows of K^+ and $\delta^{18}\text{O}$ and from the temporal evolution of the TOC content.

The chemical composition of the dripwater is mainly determined by the Ca^{2+} and TAC content, and to a lesser degree by the K^+ and Cl^- content. There are seasonal differences in the electrical conductivity of the dripwater, which are related to differences in the degree of saturation in calcite and dolomite, and therefore in the PCO_2 of the dripwater. When the latter is low, the water is more supersaturated, there is a greater precipitation of calcium carbonate and the electrical conductivity of the dripwater decreases; when the PCO_2 is higher, the water is less supersaturated, the precipitation of calcium carbonate is reduced and the electrical conductivity of the dripwater is higher.

Acknowledgements

To the Nerja Cave Foundation for the financial assistance. This work is a contribution to the Spanish-French Integrated Action HF02-158, to the

Research Group RNM-308 of the Junta de Andalucía and to the projects REN2002-1797/HID of the DGI and IGCP-513 of UNESCO.

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O-172

Unusual subaqueous speleothems from Zlomísk Cave (Low Tatra Mountains, Slovakia)

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Abstract

Speleothems growing continuously bathed by standing water in perched pools are commonly composed of macroscopically visible crystals of calcite or aragonite. In Zlomísk Cave (Jaskyňa zlomísk) another type of subaqueous speleothems has been encountered (Hochmuth & Holúbek, 1998; Gradziński & Holúbek, 2005). They are similar to the speleothems called cottonballs, which were known from Cataract Cave (Hill & Forti, 1997). Zlomísk Cave (Jaskyňa zlomísk) lies in the Janska Valley (Jánska dolina) in the northern part of the Low Tatra Mountains (Nízke Tatry). The cave is developed in Gutenstein limestone and dolomites (Middle Triassic) which are thrust over Mesozoic autochthonous cover of the crystalline core of the Low Tatra Mountains. The cottonballs occur in the perennial pools located in the main passage in southern part of the cave at 815 m a.s.l. and ca. 70 m below the surface. The water temperature in the pool equalled 6.0 °C and pH was 7.8. The cottonballs form whitish to pale orange globular bodies up to 12 cm in diameter covering almost all the bottom of the pool. Their consistency is soft, gelatinous and resembles that of the fresh cottage cheese. In some places there are some clusters of organic mould attached to the particular cottonballs. They contain more than 92 wt.% of water. Calcite is their dominant mineral. It builds minute crystals, which together with organic filaments, probably of fungal origin,

form dense irregular mat. The consistency and co-occurrence of micro-organisms with needle shaped calcite crystals strongly resemble moonmilk speleothems (see Gradziński et al., 1997). Although the cottonballs from Zlomísk Cave have some common characteristics with moonmilk, they differ in several points such as a lack of bacteria in the studied samples and small needle-fibre calcite crystals, which both are typical of moonmilk. The morphology of calcite crystals proves that calcite building the cottonballs is an autochthonous mineral phase. The role of micro-organisms in the formation of cottonballs still remains an open question. One may only suppose that the presence of living fungi influences the calcite precipitation. References Gradziński, M. & Holúbek, P., 2005. Cottonballs - peculiar speleothems from Zlomísk Cave (Low Tatra Mountains, Slovakia) - pilot results. *Slovenský Kras*, 32 (in press) Gradziński, M., Szulc, J. & Smyk, B., 1997. Microbial agents of moonmilk calcification. In: Jeannin, P.-Y. (ed.), *Proceedings of the 12th International Congress of Speleology*, vol. 1. International Union of Speleology, Basel, 275-278. Hill, C. & Forti, P., 1997. *Cave Minerals of the World*. National Speleological Society, Huntsville, 463 pp. Hochmuth, Z. & Holúbek P., 1998. *Geomorfologické pomery a topografia novoobjavených častí Jaskyne zlomísk v Jánskej doline v Nízkyh Tatráh*. *Slovenský Kras*, 36: 59-80.

0-173

Cueva Charles Brewer (Chimantá)**Cueva Ojos de Cristal (Roraima) the greatest quartzite caves of the world (table-mountains, Venezuela)**Branislav Šmída¹ - Marek Audy² - Hernán Bior³ - Federico Mayor⁴¹Slovak speleological society (SSS), Hodžova 11, 031 01 Liptovský Mikuláš, Slovakia; sandia@nextra.sk;²Czech speleological society (ČSS), Tyršova 332, 679 06 Jedovnice, Bohemia; audy@speleo.cz;³Grupo Espeleológico de la Sociedad Venezolana de Ciencias Naturales (SVCN), Calle Cumacho con Arichuna El Marqués, Caracas, Venezuela; svcn@cantv.net;⁴Miami or Caracas, Venezuela; fmayoralp@cantv.net**Abstract**

This contribution-article discusses about quite new discoveries (2002-2004) of the most extensive quartzite caves of the world by leading cavers and scientists from Venezuela, Slovakia and Czech, who in 2004 created common numerous international South American-Middle European working team, specialized in the research of the subterranean portion of plateaus of Venezuela (so called tepuy). Because of the limited possibility of the length of this article does not allow the authors to write broader about the latest findings and explorations of the spaces, already longer than 13 km (on the massifs Chimantá and Roraima), so fresh and diversified, that it would take (and it will) whole compendia, we will struggle in the next lines to point only to the most substantial part for now, what touches to the history of the discoveries about the morphology of the quartzite caves discovered by us and to mention expressively couple of curiosities around it. People who are interested in this specific, however exceptionally valuable knowledge of the problem, can find more in already published articles in world speleo-magazines (as Spelunca, NSS News, Descent, Regards, Speleofórum, Journal of Sydney Speleological Society and so on), or in the monographs already published, or being prepared by us.

Introduction

The modern speleological research in the area of Venezuela's tepuy is of very young data. Great progress to the knowledge about this fascinating table-mountains was provided by the photographic pictures from the air and by the possibility to use a helicopter. The expeditions there however remain relatively expensive and difficult in logistics: plateaus, like Cerro Duida, Marahuaca, or the very Chimantá, are deeply inside the country, and they are isolated from the surrounding impenetrable jungle and from the savannas by vertical (or overhanging) walls of hundreds of meters. Expeditions to here therefore are still not numerous.

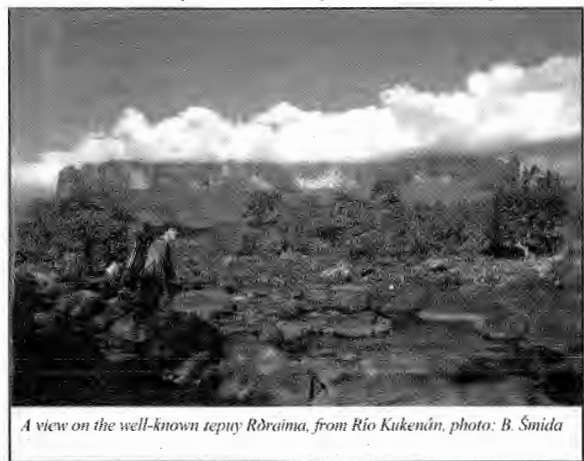
The first such known legendary action was performed to known Cerro Autana, by the well-known researcher Charles Brewer-Carías. In mountain climbing way he got to the wall about 150 m under the top, he found in this marvelous, about one kilometer high tower, caves and tunnels of the same name, already in 1971, crossing the massif in the length of 653 m

(Brewer-Carías, 1976a). Basically it was the discovery of the first quartzite cave, additionally with evident fluvial modeling. In 1974 then, the also by him, in the cooperation with the scientists from SVCN, the giant abyss at the plateau Sarisariñama was the first time explored, known as Sima Mayor, with the depth -314 m and with monstrous oval mouth, 350 m in diameter, which had the internal volume 18 million cubic meters (Brewer-Carías, 1976b). Other remarkable discovery at this area was performed at the plateau Auyantepui: the dimensional abyss Sima Aonda (-383 m) was explored by the Venezuelan cavers from SVE (Galán, 1983). At the same massif, later (1992-1996), the Italian cavers from the association La Venta (for example Bernabei et al., 1994), were exploring here the system in quartzite Sima Auyantepui Noroeste (2950 m/-370 m) which was not long ago the biggest one, or other dimensional collapses, crevices and collectors (Sima Churun and so on).

By this article we would like to introduce to you, at least briefly, the last important period of the speleological research in the area of tepuy (or of the Lost World, how it was poetically named in the famous novel by Sir A. C. Doyle, 1912). Since 2002 we discovered at the mountains Roraima and Chimantá the greatest quartzite caves of the world, which are immensely interesting, not only by the parameters of the length, or of the volume, but also for its unique genesis, spectacular fillings of biogenic origin, or by the endemic fauna.

Cueva ojos de cristal

During short tourist visit of the famous plateau Roraima (40 km²), at the borders of Venezuela, Brazil and Guayana, on 4th February 2002, Marek Audy and Zoltán Ágh, by the logical disappearing of water (but otherwise in fact accidentally) found the entrance to the subhorizontal inflow cave. Because they were also excellent cavers, they entered to its trace, in the length of about the first 300 m, where they found smaller waterfalls and quite dimensional passages with an underground river. For the further exploration of the underground they were not ready in the time. The had



A view on the well-known tepuy Roraima, from Río Kukenán, photo: B. Šmída



Typical passage of the cave Cueva Ojos de Cristal, photo: M. Audy



Speleothemes "carrots" from Cueva Ojos de Cristal, photo: M. Audy

just basic headlamps and no mapping tools (Audy, Šmída, 2003).

Because it seemed that the cave could continue, they organized a serious speleological expedition to there one year later. During the expedition in the days 8th-15th January 2003, we explored here in the group of five: M. Audy, B. Šmída, E. Kapucian, M. Griflík and L. Vlček (members of SSS and ČSS, Slovak speleological society and Czech speleological society) not only the cave named as Cueva Ojos de Cristal (in Slovak or in Czech Kryštalové oči, in English Crystal eyes), in precise scaled map (scale 1:500) the length 2410 m, but also other new caves, with the total length of underground discoveries 3,7 km (Audy, Šmída, 2003; Šmída et al., 2003; Šmída, 2004; Vlček, 2004).

During the next expedition in the days from 20th to 28th February 2005, we continued in the speleological exploration of this area, already in the cooperation with the speleologists from SVCN (Grupo espeleológico de la Sociedad Venezolana de Ciencias Naturales). The system Cueva Ojos de Cristal is formed by the three evident main lines: Mischel, Cueva del Hotel Guácharos, and the first known Ojos de Cristal, which were connected into one complex with the length of 3164 m and with the elevation -48 m (Šmída, 2005).

Their main passages are 4-7 m wide and 2-3 m high in average. Locally however they reach the width 15-20 m, and maximum 10-12 m of height. The greatest known space is Sala con catarata (40 x 20-25 m). The inflow rivers flow through the branches Ojos and Mischel, at the circumstances when the passages are comfortable for the exploration (during relatively dry season January-March), with water flow 0,5-3 l/sec. (In the time of rain, the flow can increase to tens of l/sec.) Only slight increase of the water flow during raining will cause flooding of wide and relatively very low passages, which are not available for crawling then at the ends of the branches, which are, though relatively wide, but they are just 0,5 m high in the profile. Cueva del Hotel Guácharos is the one with the higher position, originally surely the older branch of the hollow basin depression (100 x 180 m), where as if blind end of the valley is in fact the main entrance to the branch Ojos. The passages of the system are connected by some mutually parallel passages which are smaller in dimensions, they are separated from each other often only by narrow rocky barriers and connected to the labyrinth. Their direction is much subhorizontal, as if little bit oblique, but otherwise almost without remarkable steps (the highest is about 4 m high, the other steps are about up to 0,5 m high) - the average cadence in the straightened cut is only about 2-3 %. The cave tunnels go subparallel with the surface, not deep below the surface (20-30 m). The passages have mostly quite flat rocky floor, with micro-cuts, deepening, or somewhere with turbulent hollows (diameter up to 40 cm) and with swirl holes (so called "ojos de cristal"), which were engraved by quartz pebbles (originally crystals of pure quartz brought from the surface) - the name of the

cave is by this phenomenon. The passages are otherwise mostly without sediments, somewhere there are rocky bridges, or fallen pieces of ceiling (by the plate separation or the separation of ashlar shapes). In the fossil levels, or in the wider passages it is evident side "plastic" separation of the lengthy quartzite plates. The passages are generally significantly wider than high, commonly in the ratio of the width to the height 4:1 (somewhere it is at the edge of being available, and the ratio is 40-60:1!!!). The speleothemes are rare, however if they are present, they have often lovely shapes, they are directed by relatively strong drafts: no once they are concentrated nests of dark very solid stalactites in the shape of spiky carrots up to 0,5 m long. Some speleothemes appeared here by the decay of moulds or by unique decomposition and lithological hardening of some down from the little birds of *Zonotrichia* genus.

The cave was created by the secondary corrosion of the layers, which are the least resistant of the almost 98 % ortho-quartzite (mainly at inter-layer discontinuities, and on the planes of hiatus), which is caused by the sophisticated enrichment of the water in organic materials, coming from the products of metabolism and from the decay of special endemic flora at the surface (for example also carnivorous plants). The repeating inflows of the water, during enormous rain seasons (the most of the year), apply significantly at the removal of the material from the block areas.

The cave has five entrances discovered till today, 3 of them are standard and 2 are in the form of remodeled vertical crevices (the deeper of them is about 100 m long and -18 m deep).

The discovery of the cave is unambiguous and undoubtable, because we did not find any traces of human activity inside Cueva Ojos de Cristal neither in 2002 (what was possible to verify also in the fossil passages, where there are very creep untouched little crusts developing thousands of years). The entrance to Cueva del Hotel Guácharos was known to the local indians Pemons, however even they did not enter to the tract deeper than the first 100 m, where we found their pictogram - further the sandy floor of the passages was untouched and the rocky floor was quite clean (Audy, Šmída, 2003; Šmída et al., 2003).

Cueva de los pemones and another discoveries in the karst at roraima

The cave Cueva Ojos de Cristal likely has some genetic and hydrological connection with the next interesting cave in the close area named as Cueva de los Pemones (for the tribute of already mentioned indians - Pemons). These locations were not connected in the time of our research in February 2005, by physical personal passing through them.

One of the entrances to this second biggest system at Roraima, called as Pokemon 2, we had known already in 2003, it had been found by the duo B. Šmída and L. Vlček, on 14th January 2003 (Šmída et al., 2003). Other potential entrances to this genetic subsystem we also partially explored in 2003 (Cueva de Gilberto, Cueva Asfixiadora). The location, which was visited by the cavers from Oxford(?) just before us (not by very clean and ethical way, using our knowledge), we mapped precisely in the days from 20th to 28th February 2005, in the scale 1:500, while we discovered here some great extent of passages not visited by anyone and ever (again by the not existing footprints) and also some crevice entrances, mainly in the South-East ascending tract.

The passages of the main line Cueva de los Pemones, descending in the direction to the West, are 10 m wide in average, somewhere however even 15 or 20 m (or even more). Their height is also 2-3 m. The connection of the crossings and passages here also forms locally almost chaotic labyrinth of disorientation (mainly in the middle part of the cave). The main passage of the system is more compact, in the middle part (analogically as in Ojos de Cristal) with oval, also with ashlar shapes, and also with deeper lake pools, which must be passed around, by the several meters higher situated fossil parallel passages. (There are nice hollow pits in

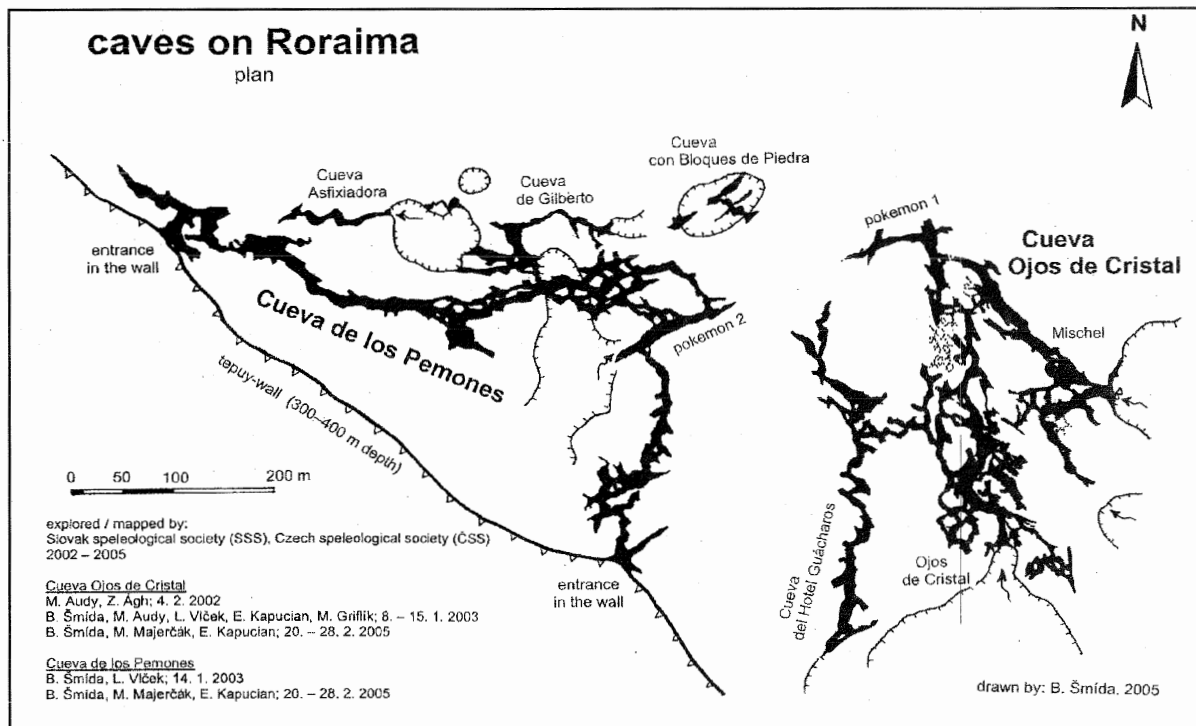
them.) There are also some collapsed little domes here. The biggest of the spaces is the lengthy passage-like hall, the dimensions are about 20 x 30 m and the height is 8-9 m. Two of the entrances are formed by about 100 m long collapsible crevices, about 25 m deep. Further similar, but little bit more shallow crevices (covered by high-mountain jungle) create the entrances to the South-ascending branch of the system.

In the cave several smaller inflows connect together in the shape of delta, to one concentrated little river, with the minimal flow about 30-100 l/sec. (In the monsoon season, or at intensive rain, the flow can increase at least to several hundreds l/sec.) This river disappears in the cave in the

floor with collapsed boulders, only some 80 meters from the vertical wall of the plateau. The most probably it feeds some strong spring at the heel of this wall, called by the indians Tuná Deutá, which is approximately 350-400 m lower (at the beginning of the access ramp to Roraima). The way to this remarkably vertical hydrological system unfortunately was not found yet.

Cueva de los Pemones has the mapped length of 2070 m for now (200 m of less significant branches and spurs are drawn only for the orientation for now). The elevation of the cave is -73 m (Šmída, 2005).

All the remarkable genetic system of the caves at Roraima has 13



known entrances for now (in the altitudes around 2600 m above the sea level): two of them are heading directly to 300-400 m high wall at the South edge of Roraima, about 30-50 m below the top plateau. (They were found by the exploration from inside and they are beautiful places, with impressive view from some kind of amphitheatres, with special flora.) The other 8 entrances are collapse crevices remodeled by the water (relatively direct, or only slightly curving), which are up to 25 m deep, from 1 to 3-5 m wide, and even more than 100 m long. Because they are by their characteristics different from the others and from the common "not cave creating" crevices at Roraima, we use for them not genetic term, so called pokémon (Šmída et al., 2003). These are oriented roughly in the directions WSW-ENE, and if they did not collapse to the underground totally there are higher longer halls created under them in the caves, with the falls of with the surface water in the form of dispersed drops falling down.

The length of the common genetic system of the caves Cueva Ojos de Cristal and Cueva de los Pemones, which could be later connected into one location, is 5,3 km now. At the close area of the plateau (roughly 500 x 1000 m) there is not impossible even to discover other less visible sub-branches and labyrinths, after the precise mapping of the branches maybe another kilometer of the length could be reached. Even the connection with the other close locations here is possible, for example with the cave

Cueva de Gilberto (505 m long for now), Cueva Asfixiadora (125 m), Cueva Fragmento Marginal (78 m), or Cueva con Bloques de Piedra 2 (75 m). Beside these, we discovered bigger number of another caves at Roraima, 80-150 m long for now. Already in 2003 we explored some of the huge crevices, for example Grieta de Diablitos Volantes (-120 m), where some numerous colony of the blind birds live "guácharos" (Steatornis caripensis), or Cueva con Puente (-80 m).

Cueva Charles Brewer - the greatest quartzite cave of the world

The entrance to this unique, directly monstrous quartzite cave by its dimensions, was observed by it's discoverer, Mr. Charles Brewer-Carías, the best expert on the research of tepuy in Venezuela (he performed about 150 expeditions here!), for the first time on 11th January 2002, during the flight above one of the plateau of the dismantled massif of Chimantá (1470 km²). After the analysis of the flight photographs by stereoscope and after another position determining flight, then they finally entered on 27th February 2004, together with a group of 11 friends, as the first humans in the history at all, to a giant cave, and then (on 28th February) they passed approximately the first two kilometers, where they were stopped, as they were not prepared for such dimensions of the cave, the



Gran Galería de los Guácharos
has volume 320 000 cubics, photo: M. Audy

40 m long and relatively deeper lake (Lago Chayo) stopped them in further proceeding. In the group under the leadership of Ch. Brewer-Carias, there were: Ch. Brewer-Capriles, F. Mayoral, A. Tovar, L. A. Carnicero, F. Tamayo, A. Chumaceiro, E. Wallis, A. Chacón, C. Barrio, R. Guerrero and F. Delascio.

The next already very well organized and unusually successful action was performed here not much later, in the days from 28th May to 2nd June 2004, while at this action when Cueva Charles Brewer completely mapped in the length of 4482 m and with the altitude difference 110 m (Šmída et al., 2004, 2005a, b, f), again under the leadership of Ch. Brewer-Carias also participated: Ch. Brewer-Capriles, F. Mayoral, L. A. Carnicero, J. Brewer, photographer M. Audy and B. Šmída.

For now the latest, this time very numerous, 25 member multi-disciplinary Venezuela, Slovak, Czech natural-science and speleological expedition was performed to this area (again under the leadership of Ch. Brewer-Carias and B. Šmída) relatively not long ago, in the days from 6th-17th February 2005. Also this was exceptionally successful and we are just processing now the wide results, knowledge and the samples obtained.

Cueva Charles Brewer is a spring in fact, with the entrance that has enormous dimensions (30 x 120 m!) in some kind of amphitheater valley. The main branch of the cave is up to 50 m wide, already at the beginning. However in spite of that (from the reason of barrier of huge blocks being at the entrance) in the time of strong rains during few hours a lake can appear here up to 200 m long, 7-8 m deep, which is like half-siphon (or a real siphon?). The entrance to the cave is closed then, and it is better to be outside in the time... At the time of absolutely dry weather at least 300 l/sec. flows through the cave, otherwise however commonly 500-800 l/s. We suppose that at the sudden inflows of water the capacity of the river floor can take much more (maybe up to 20-30 m³ sec.!), the traces of corrosion at the walls from water, and the first speleothemes preserved and growing (also in wide passages!) show, that the level is even 8-10 m above the basic flow level. Because of the huge dams formed by the fallen blocks, surely big and deep lakes are created along the whole cave passage in that time.

In the cave two types of galleries appear and they repeat relatively regularly: 1. dome-like (width 40-100 m! height is 10-40 m, with huge

Waterfall Cascada Vanessa
in Cueva Charles Brewer, photo: M. Audy



asymmetrical debris areas; they are hard to pass, the walk through the cave to the end and back with some light equipment can take several hours), 2. canyon-like (width 10-15 m, height 15-20 m, which have the river flow in the whole width; therefore these are dangerous places during sudden water inflows). There are some super-dome widening areas, with the volume commonly more than 50 000 m³, and more places with above 100 000 m³ (for example enormous oval hollow Planetario, 90 x 150 m). The biggest space of the cave is 355 m long, and up to 70 m wide portion of the passage Gran Galería Karen y Fanny, with the calculated volume of about 400 000 m³. It is the biggest natural underground space in Venezuela, and the biggest underground quartzite chamber in the world. (For the comparison even the smallest passage profile in Cueva Charles Brewer reaches 5 x 15 m!)

There are turbulent waterfalls in the cave (the highest, Cascada de Eslovaquia, is 5 m high), and all the forms of the underground quartzite corrosion which are possible to imagine (mantels, lake dishes and cave "pokemons", rock bridges, selectively separated columns, "ojos de cristal", lateral flood floors), as well as various fillings (for example sandy beaches). There is a unique diversity of the speleothemes: Champignons, Muñecos (Puppets), Carrots, Guácimos... (Brewer-Carias, 2005, in press). This classification and typology has its reason, because each of the mentioned types was created in a different way. For example, the big hard white balls (diameter up to 15-30 cm), in the form as if "mushrooms" or "footballs" are created as alive(!) accumulations of Cyanobacteria (Aubrecht et al., 2005, in press), creating in aphotic conditions big wall colonies (after the lithological hardening of their growth layers opal stromatolith appears). Another researcher (Marcano et al., 2005, in press) has found other autotroph and undescribed symbiotal organisms... Other speleothemes of coral shapes appear as a result of drafts, with heavy aerosol and at the same time there are places with culmination of the organic material by spiders building their webs everywhere.

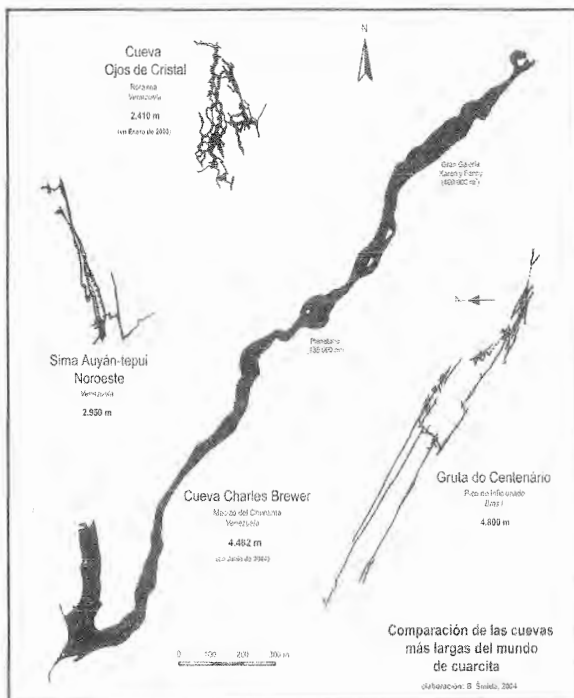
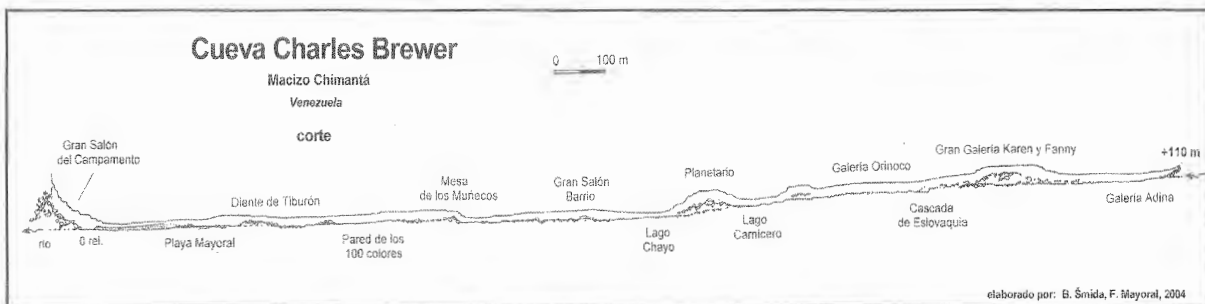
Also the initial proto-channels of the cave Cueva Charles Brewer were created at interlayer and hiatus predisposition (for example the old beach scallop surfaces) of the quartzite sandstones. These could be created at least from the Cretaceous period, so it is a very old cave. So, it is in fact accidental connection of two big hydrological drainage areas and at the



Typical gallery of the Cueva Charles Brewer, 40 m width, 15 m height, photo: M. Audy



Opal biospeleothems named as "Champignons", photo: M. Audy



The perspectives

By our discoveries at the plateaus Chimantá and Roraima the view on the style of karst creation in the quartzite and on the underground potential of similar massifs of table-mountains is changed principally.

The cave Cueva Charles Brewer was prolonged to 4732 m by some short progress against the flow at the end of the main gallery, as well as by

finding of the continuation through the collapsible end of Gran Galería de los Guácharos connected with the surface.

But in the potential underground hydrological drained area of Cueva Charles Brewer it was explored by us altogether more than 8 km of the cave passages, crevices and abysses (Šmída et al., 2005). By connecting them, which is really supposed, plus by the discoveries and explorations of the new caves, which have entrances (and mainly some access to them) that we already know, it will appear unprecedentedly and for long time the biggest known karst system in quartzite. It depends on the next expeditions how fast we will get to it, and we are already planning them.

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O-174

Velika klisura (Gryka e Madhe) in Kosovo - the discovery and exploration of one of the biggest cave systems at Balkan

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Abstract

At the foothill of the massif Prokletije, at the border of Čierna hora and Kosovo (republics of former Yugoslavia), in the wild limestone canyon Rugovska klisura, with the walls up to 800 m high, there is the entrance to the well branched cave system, the length of which is today, after 7 performed expeditions of the members of the Slovak Speleological Society (SSS), almost 10 kilometers. Its entrance was localised and estimated as a perspective one in 1992 by five Slovak cavers, who at the first moment considered it to be not penetrable spring. Just in 1995, at the repeated visit of the locality, the water level dropped, and four Slovaks found the higher-flood entrance to the incredible, ascensive cave. The first kilometers of the subhorizontal tunnels and cascades with wild river (in the time of rain more than 1-2 cubics per second, 100 liters per second in average) were absolutely free then, the explorers were stopped by muddy half-siphon. After digging through it in the 1996, during the winter expedition,

there was found so called "New Cave", fabtastically decorated with various speleothemes and with lake dishes with unique macrocrystalline surface. The next exploration was oriented to climbing and in the numerous higher levels, which are in fact fossil siphons, and in the spiral chimney-like inflows, there was reached the whole amplitude of the cave up to 310 m (+296 m, -14 m). It is in a way the "highest" cave at Balkan, explored from downside, by pretensive speleoalpinistic climbing. In this several-level cave which is after the year 2002 explored and mapped by Slovak cavers, already in the cooperation with the local ones, Kosovian explorers from the city Pejë (Peč), there are several siphons and beautiful blue-green lakes, some of them were partially explored by cave divers. The autochthonous system of the main underground river and of some of its feeders has the potential of the high to plus almost 1,5 km and the cave has very similar ascensive character, as the well-known cave Lamprechtsoe in Austria. The exploration of this longest cave of Kosovo is continuing.

O-175

Karst protection and conservation in Venezuela; Inventory of caves in Natural Parks and protected areas using GIS techniques

C. Silva Aguilera

Abstract

Venezuela presents a considerable karst areas development and with more than 600 caves reported. Cave and karst system are important besides other reasons by the source of fresh water resources and groundwater until now unexploited in Venezuela. The protection and management of these vital water resources are critical concerning the public health and to sustainable development. Actually there are two figures of natural protection in Venezuela: the 43 natural parks and 36 natural monuments. National parks in Venezuela cover a total area of 13.6 ha and natural monuments 4.3 ha which represents 19% of the country surface. Until the

present is not clear the amount of caves located within the area of the National parks and most of these are not considered inside the inventory of the features of the park. A data base of the Venezuelan caves was created using the information of the Venezuela Society of Speleology and others speleological group like Speleo-USV and GEO-UCV besides others. A review literature a source of information about National parks, Digital Elevation Models and geology, thematic map were created and processed using GIS techniques. The results show that 252 caves are within the protected areas mentioned, from these only few are considered within the Park features. Some actions for included this caves in the Natural Parks are proposed and discussed

O-176

Potential Impacts of Acid Mine Drainage on the Hydrogeologic System of Russell Cave National Monument, Alabama, USA

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Russell Cave National Monument is a 310-acre federally protected area located in Alabama at the base of the Cumberland Plateau Escarpment in Doran Cove. This preserve protects an Alabama Treasured Forest on the surface and Russell Cave below it. Until recently, no attempts had been made to study the hydrogeology and source waters of Russell Cave. The Center for Cave and Karst Studies and Hoffman Environmental Research Institute, in conjunction with the National Park Service, have now completed a hydrologic study and karst inventory of the area which includes underground flow routes determined by dye tracing. Fieldwork as part of the project has identified a cause of concern in this region of the Cumberland Plateau Escarpment because of the potential for Acid Mine Drainage (AMD) from the inactive coal mines located at the head of Doran Cove. Drainage from these mines flows into sinking streams which have been dye traced to Russell Cave. The goals of this study are to investigate how pH, water temperature, and bedrock composition affect dissolved metals that are common in AMD, to determine how, if at all, these metals affect the water quality of Russell Cave, and to indicate if land use activities other than AMD were negatively affecting the water quality of Russell Cave. To complete this study, samples were taken from coal mine efflu-

ent, effluent-containing surface streams before they sank underground, streams located in the cave, and from the main spring that drains the cave system. Lab analyses were conducted by the WATERS Lab, a laboratory consortium comprised of resources from Western Kentucky University and Mammoth Cave National Park. In addition to water sampling the physical parameters of pH, dissolved oxygen (DO), temperature and conductivity were measured in the field. Observations of iron oxyhydroxide flocculents (locally called "yellow boy") and other cation accumulations, indicators of acidic waters and especially AMD, were also recorded. Preliminary measurements indicate that acidic effluent from the coal mines at the head of Doran Cove is naturally attenuated by the limestone bedrock on/in which the effluent/streams flow before sinking underground. The pH at selected resurgences in the area ranged from 7.4 - 8.1. Readings within Russell Cave ranged from 7.8-8.0. Samples from these locations and from inside Russell Cave will help determine the effect AMD has on this karst environment. Further analyses are being conducted at this time. The integration of this water chemistry/quality data will illustrate which areas of the watershed are most vulnerable to acid mine drainage and to the negative affects of current land use. Project results will allow better understanding and protection the of Russell Cave System.

O-177

Underground beauty show without destruction

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Presentation of special technical informations based on our own design, installation and maintenance of 15 cave lighting equipments (CLE's) in the last 20 years and on study of CLE's in a lot of others showcaves recently. They shoul'd help us to know the light influence on growing the lampsflora in the caves better and to plan the new CLE's more friendly and inoffensiv to the caves enviroment in the future.

Some recommendations for design of CLE's followed from our work. Recommended and "forbidden" lamps, suitable luminaires, design, installation, control and operation of CLE's. Something about the use of colours and the light effects.

The fight against old lampsflora.

Introduction

The cave lighting equipment (CLE) is one of the most important technical equipment in the cave. It enables the visitors to observe the beauty and dimensions of rooms, variety of colours and shapes and safe move through the cave.

Really do we need the light in the cave ?

The caves alone don't need any light and any visitors too !!!

YES or NO, open for the visitors or visible only for the speleologist?

The answer for the showcaves is very simple, in the others very difficult.

To prepare a cave to a showcave it is quite complicated and it is always drastic interference into her ecosystem. To avoid full destruction, we must work extremely sensitively so that way we avoid the bad light influence.

We collected special technical informations from a lot of showcaves during last 2 years. These helped us to make some decisions about the light influence on the lampsflora (LF) growing in the caves and will help us to plan the new CLE more better and inoffensiv to the caves enviroment.

The most important informations collected :

Quantity of luminaires

Total power of CLE [kW]

Number of switched circuits

Type of lamps used in CLE

Average operation time of CLE [hours/day]

Length of visitorspath with CLE

Number of visitors in a year

Average temperature [°C]

How much lampsflora is in the cave : none - less - medium - a lot

And some others additional questions

1st RESULTS

We've got the informations from :

	Caves with incandescent lamps	Length of visitors paths [m]	Caves with discharge lamps	Length of visitors paths [m]
CLEs planed by COMLUX	15	12000	1	360
Other CLEs	40	30000	14	8030

Also altogether from 70 caves with 50000 m visitors paths.

The answers were mostly usefull, some quite poor too - depending from the skill of the persons and his

knowledge about the CLE. Unfortunately the datas of about 15 caves aren't completely. We know, it wasn't easy to fill our questionnaire, we achieved the best results in the caves visited by ourself.

What did we see ?

Quality of CLE	incandescent lamps	discharge lamps
Excellent	9	1
Good	16	4
Medium	20	3
Bad	3	2
Awfull	2	4

As we can see, only 10 % CLEs with incandescent lamps are bad or awfull, while 43 % CLEs with discharge lamps failed into this categorie!

The result is, that it is necessary to pay higher attention to plan and install of CLEs with discharge lamps !

PRINCIPAL RULES of ESTHETIC is TO SHOW THE NATUR

and it means :

- **NO FUNNY COLOURLIGHT,**
- **we HANDLE CAREFULLY with LIGHT and SOUND EFFECTS.**

Important are
ESTHETIC NEEDS on ROOM and OBJECT LIGHTING,
TECHNOLOGICAL EQUIPMENT,
FINISHING TAUCH of INSTALLATION.

ENVIROMENT PROTECTION (ECOLOGIE)
during the installation (destruction of cave),
while at work of CLE (light and heat).

SAFETY of persons and objects.
sensitiv INSTALLATIONS and OPERATING KOST.
easy CONTROL and MAINTENANCE.

THERE IS NO STANDARDS OR RESTRICTIONS
about the light quality and quantity in the showcaves.

PRACTICAL EXPERIENCE :
ILLUMINANCE of SHOWOBJECTS,
like in stagelighting lies between 10 and several 100 lx - mostly directlight .

For the SAFETY on the PATHS and DANGEROUS POINTS
(steps, low profile, ...) are suitable about 2 lx (minimum 0,1 lx) - mostly indirect, sometimes with special luminaires.

EMERGENCY LIGHT,
mostly with guide carrying the torch, (seldom with special luminaires).

“WHITE” v.s. “COLOURLIGHT “

WHITE !!!
If we'd like to show to visitors the beauty of natur, we need the light with very good Ra and Tc :

- karst caves Tc max. till 4000 K (neutral white)
optimum 3000 K (warm white)
Ra minimum 80
- ice caves Tc optimum 4000 K, sometimes til 6000 K (day white).
Ra minimum 80

COLOUR
only if we'd like to make a SHOW in the cave, but for this reason we don't need the cave indeed !!!

What has the positive influence on growing of LF ?

1. LIGHT EXPOSITION = $\Phi \times t$
2. HEAT but isn't enough alone (can only dried the cave)
3. LIGHT and HEAT EXPOSITION² = EXPOSITION x K or + K
4. 1 and/or 3 combinate with something else (humidity, etc.) ??? There must be a limit value of

EXPOSITION , under which the LF doesn't exist !!!
BUT WHICH ONE ???
Certainly some prefered wavelenghts too (question for biologist ???).

Where :
 Φ - luminous flux affected the lighted surface
t - time, the influence period of luminous flux
K - heath coefficient (amplify factor of EXPOSITION)

What can we do to avoid the grow of LF ?

Prevention - today's the mostly effective method.
1.Minimalize Φ it means, less illuminance (but there is a threshold value for acceptable sight), dynamic of light, more lamps of less power, bigger distance from the objects., suitable positions and aiming of floodlights.

- 2. Minimalize t it means, short controlled parts, no standstill light of paths, (RESTRICT VISITORS QUANTITY !!!!!?)
- 3. Minimalize K it means to use the lamps with less heatproduction, what means high efficiency (lm/W), FL and HPH instead LI/LH today (if possible), LEDs as main light source in the foreseen future.
- 4. To eliminate the "bad" wavelenghts from lamps spectrum.
It's quite speculateve matter, because if we take some wavelenghts from visible spectrum, we get practically the colour light !

The mostly mistakes of CLEs are :
insufient quantity of switched circuits (extremely only 1 for the whole cave),
to long operating time - 3 till 8 hours in a day,
to much luminous flux by CLEs with discharge lamps,
use of HPS lamps,

THERE IS NO EXISTANCE OF ANY "WIZZARD" LAMPS (they give us a lot of harmless light - no LF growing) !!!

2nd RESULTS

Technical datas of cave lighting equipments (CLE)						
	CAVE	Switched circuits	Average daily operation time [h]	[W/m]	[lm/m]	[lm.hours/m/day]
A	Caves with incandescent lamps, planed by COMLUX			45	680	1200
B	Caves with discharge lamps, planed by COMLUX			10	670	1300
A	Other caves with inc. lamps - summ			25	400	1600
B	Other caves with dis. Lamps - summ			15	1100	4800

While other CLEs with LI/LH have mostly less illuminance, they run longer and have more EXPOSITION !

The other CLEs with discharge lamps have to much illuminance and very much EXPOSITION !!!

EXTREMS						
A	Caves with incandescent lamps	1	10	81	1750	8000
B	Caves with discharge lamps	1	8	37	2230	17820

Recomended values for CLEs with incandescent lamps						
A	OK	> 5	< 2	< 60	< 900	< 1800
A	???????	> 1	< 4	< 100	< 1500	< 6000
A	BAD till CRITICAL !!!!!	1	> 4	> 100	> 1500	> 6000

Recomended values for CLEs with discharge lamps						
B	OK	> 5	< 2	< 15	< 900	< 1800
B	???????	> 1	< 4	< 25	< 1500	< 6000
B	BAD till CRITICAL !!!!!	1	> 4	> 25	> 1500	> 6000

The lamps	Ra	for CLE
LI - incandescent lamp, reflector lamp	100%	OK
LH - halogen lamp	100%	OK
FL - linear fluorescent lamp	80%	OK
FLC - compact fl.lamp, compact fl.lamp with reflector	80%	OK
HPH - metal halide lamp (high pressure)	80%	OK
LED - light emmiting diode	80%	OK
HPM - high pressure mercury vapour lamp	60%	???
HPS - high pressure sodium lamp	30%	NO
LPS - low pressure sodium lamp	% !!!	NO

Recomended lamps

LI - incandescent and - less efficient, but small, cheap
LH - halogen - and easy to handle.
FL/FLC - fluorescent (linear/compact) - good but sometimes to big.
HPH - high pressure metal halide - good but specifical start (with electronical ballast) - and reignition behavior.
LED - light emitting diode - seems to be the lamp of the future, (efficiency about 20 lm/W today, 50 till 80 lm/W in the future expected), efficient, small, very long life, easy to handle.

"Forbidden" lamps :

HPM - high pressure mercury vapour - bad Ra, lm/W, start and reignition
HPS - high pressure sodium - bad Ra, (Tc), start and reignition (you don't see LF in this light !!!)
HPL - low pressure sodium - Ra = 0 (no colours visible) !!!

ONE MORE TIME THE SUMMARY - we shoul'd avoid :

the change of colour of the objects caused by :
to much light,
colour light,
light with the bad colour rendering .

the damage of the objects by :
row installation,
IR - light (heat)
UV- light.

Our Tools :

less light ,
luminaires with less power ,
lamps with less heat production,
suitable positions and aiming of luminaires,
sophisticated controll system : smaller controlled circuits,
shorter operating time of CLE.

Fight against the „old“ lampsflora (MEMENTO - some photos will be presented)

Difficult and no tender : mecanical
chemical - several possibilities
optical - UV lamps

Acknowledgements

Many thanks to all known and unknown friends they helped us with our questionnaire.

Bibliographic references :

Ing. Jan Novomesky, COMLUX sro, the slides, papers and posters from the speleologist and lighting designer
meetings in Budapest (H), Skocjan (SLO), Tale (SK), Wien (A), Tatranska Lomnica (SK),
Reykjavik (IS).
Authors own planings of CLE and questionnaire about CLEs in other 55 caves.

O-178

Cave and Karst Centers of Excellence

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Abstract

A Center of Excellence is a concept that brings together state-of-the-art practices, actions, and technologies on a specific topic or subject area. By this definition there are numerous Cave and Karst Centers of Excellence already in existence around the world. Identifying these Centers of Excellence is based on recognizing current activities taking place in that area and their mutual benefit to healthy cave and karst environments, and to the benefit of the people. To achieve this goal, partnerships among governmental agencies as well as academic, non-governmental-organizations, private, and international partners can be brought together. These partnerships will help build an infrastructure to raise awareness and foster an understanding of cave and karst resources within a region and around the country. The goal of a center of excellence should be to enhance resource protection and management through the collaboration and cooperation of the partners and the education of the public. As a Center of Excellence the cooperators focus on objectives that highlight the best management practices of cave and karst resources and their interpretation and environmental education of the public. Major objectives in establishing a Cave

and Karst Center of Excellence are to: (1) Develop working groups and partnerships focused on cave and karst actions and issues ** Cavers, ** Academia, ** Governmental agencies, ** Industry (2) Establish community based tourism opportunities to communicate with and educate the public about cave and karst environments. ** Offer backcountry cave tours, ** Traveling Cave/Karst Exhibits, ** Karst Maps with educational driving tours, ** Cave/Karst Brochures (3) Foster, concentrate, and develop technical expertise for the protection, conservation, and restoration of caves and karst terrains. ** Work with local and regional industries and appropriate interests to develop the best management practices for projects, ** Confer regularly with research groups and encourage cave and karst research projects, ** Highlight best management practices regarding cave and karst resources use. ^ Cave Tourism ^ Logging ^ Grazing ^ Oil & Gas Development ^ Development Projects Cave and Karst Centers of Excellence provide recognized leadership to communities and regions. They support local economy in a sustainable manner by educating the public and protecting cave and karst resources.

O-179

The cadaster of speleological objects in Serbia the support to research, protection and sustainable use of karst

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Abstract

Karst terrains cover 8,150 km² or about 9,3 % of the territory of the Republic of Serbia. The number of known speleology objects (caves and pits) was determined as utterly approximative one to 2-2,500. There is not a unified and technically modern cadaster/register neither for registering those objects nor of the other (geomorphologic, geological and hydrographic) karst phenomena. Data records on these significant heritage objects are kept partially, and they are found in funds of several speleologist organizations, faculties and other institutions or individuals. It is necessary to establish and update this cadaster for many reasons, especially for the reasons of more efficient research and evaluation, more successful protection and appropriate use of caves and karst in general. About 30 speleologist objects, 10 karst sources and some gorges and natural rocky bridges are under the states protection as natural monuments. In

the framework of other protected areas (national parks, parks of nature, protected areas, nature reserves) there is a certain number of significant speleologist objects and karst phenomena. Regardless to long tradition of scientific institutions, supported by concrete achievements (especially in the field of morphology and hydrogeology of karst, speleobiology and speleopaleontology), speleologists' knowledge and skills (including speleodiving and modern techniques of activities in the caves) and research are divided and the results are scattered and hardly accessible so that they do not have quality of general benefit. Six caves have been equipped/arranged for mass tourist visiting, but due to poor management and economy state in the country, a total number of visitors per year does not exceed 100,000.

<P><P>This paper shows the idea/concept of making a Project for creating a cadaster of speleologist objects in Serbia as a Geographic In-

formation System, and organizational, financial and other relevant aspects of that Project feasibility are being considered. A pre-condition for this cadaster formation is a precise legal regulation of research, protection and use of speleologist objects (through the Law on Nature Protection, other laws and sub-law acts) and activity restoration of Speleologist Organization of Serbia. For every speleologist object, as for a key entity, a wide range of hierarchically arranged data have been stipulated through several bases/classes, groups and attributes. Primary databases are: a nominal object identification, location - space identification, geological composition, morphometric characteristics, morphographic characteristics (including cave sediments), hydrological, climate, paleontological, archeological and biological marks, use and protection of the object. Primary map templates are: Generalgeographical Map of FRY 1:1 000 000 (OGK 1000), Descriptivetopographical map 1:300000 (PTK 300), Topographic map 1:25 000 (TK 25).

Main data groups about the object are created in vector format so that interaction/relation between them is enabled, as well as two-way communication between bases and mapping templates. A processing model of the

system, logical and technological architecture of the application are being adapted to basic aims and general contents of the cadaster, as well as to the requirements for efficient data management. A concept of multi-layer application in GIS environment is implied, with the Internet access/use and with the option of making a connection with other (relevant) informational systems. In the final definition of classes and groups and their attributes it is necessary to take into account interantional experience, especially the classification and labelling and code standards which are being applied or proposed in the documents of the UIS (Interantional Speleology Union), including possible changes and improvements that are going to be presented at the 14th World Congress of Speleologists in Athens. A description of other contents will be designed as well: graphic (orthoelevation, longitudinal and cross profile) and textual documentation (scientific and other papers, studies, projects, acts, correspondence etc.), the research history, the review of significant organizations, institutions and individuals, bibliographies of the object papers, photographs, drawings, maps, videos and so on.

O-180

The "Maladie Verte" (Green Disease) of the caves

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As it is known, most of the karst caves a few years after being touristically developed start gradually displaying an anti-aesthetic green patina on the surface of their stalactites and near the areas illuminated by the spotlights. It has been found that this substance is a kind of microflora which, year after year, is spreading on the speleothems of the cave creating irrevocable damage and, consequently, downgrading its tourist value. This phenomenon called "maladie verte" (green disease) became known mainly in the 1960s due to the affliction of the famous rock paintings of the Lascau Cave in France by chlorophyceae. The problem, since then, has been of major concern for the international scientific community without, though, being able to provide an absolutely satisfying solution.

The following were determined from the to-date research in the various Greek caves as regards this problem:

- The green patina of the walls and, mainly of the speleothems of the caves, is of phytogenic origin (microflora and later macroflora) which during the first stage includes lower chlorophyta (mainly chlorophyceae and cyanophyceae) while during the second and third stages it also includes bacteria, fungi and some higher plants.
- The main factor contributing to the development of microflora is the long-term influence of the radiation from the spotlights on the speleothems. As this radiation derives mainly from the visible electromagnetic spectrum, it creates ideal conditions for the photosynthesis, cultivation and development of algae. The green colour is created because of the photosynthetic ability of these monocellular organisms.
- The appearance of the microflora is also favoured by the small but long-term change of the microclimatological conditions of the cave due to the projects of tourist development which irrevocably leads to an increase in temperature, the change in the concentration of carbon dioxide in the air, the creation of micro-currents of air and the transfer of fungi by the visitors. In particular, the high concentration of carbon dioxide in the air (mainly from the visitors' exhalation) in combination with the humidity existing in the caves contributes to the increase of the photosynthetic ability and, consequently, to the faster growth of the flora.

"MALADIE VERTE" IN CAVES

Vegetable microorganism

<u>A' PHASE</u>	<u>B' PHASE</u>	<u>C' PHASE</u>
<u>Chlorophyta</u>	<u>Bacteria</u>	<u>Superior Vegetables</u>
Chlorophyceae	Thiobacteria	
Cyanophyceae	Ferrobacteria	
Diatoms	Nitrobacterium	
	<u>Fungus</u>	
	<u>Lichens (Algae+Fungus)</u>	
	<u>Bryophytes</u>	

On the basis of the data deriving from the to-date studies for the preven-

FACTORS FOR THE DEVELOPMENT OF "MALADIE VERTE" IN CAVES

- Bright radiation
- Temperature augmentation
- Carbon dioxide (CO₂) rise
- Dissemination of fungi and other microorganism
- High percentage of moisture or underground waters
- Rise of movement of underground air

tion of "maladie verte" (green disease) the following are recommended:

- Washing of the recently afflicted areas with the use of water under pressure. It must be noted, though, that the long-term impact of microflora on the crystalline substance of calcium carbonate of speleothems creates permanent deterioration (chemical erosion) and later, incorporation of the biological material; therefore, the above method is not effective in this case.
- Annual spraying of the lighted areas with dense solutions of special

plant protection products based on Cupric Ammoniac or, preferably, with a 1% solution of formalin or 5% solution of Sodium Hypochlorite.

- 3) Installation of appropriate lighting fixtures of "cold light" from special gas-filled tubes mainly emitting in wave lengths from 500-600 nm. (e.g. sodium vapour lamps of low pressure).
- 4) Setting up special electrical installations for partial lighting of the areas that are being toured, both with the use of strong lighting only during show time as well as with the use of weaker lighting during the time the specific area is visited.

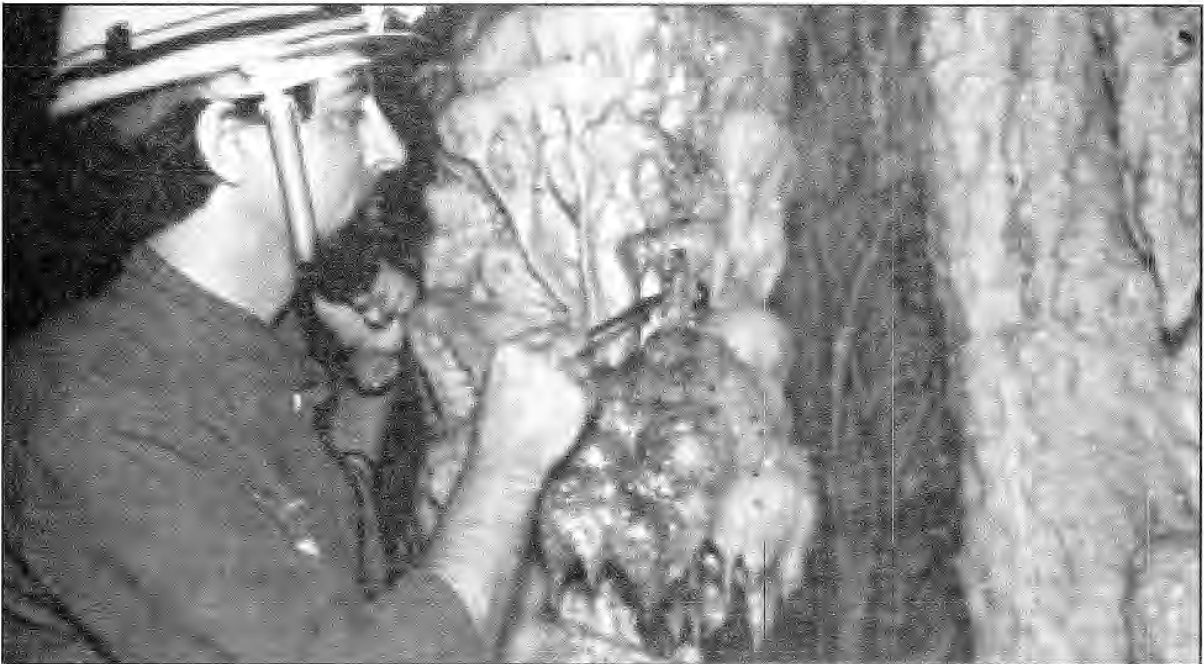
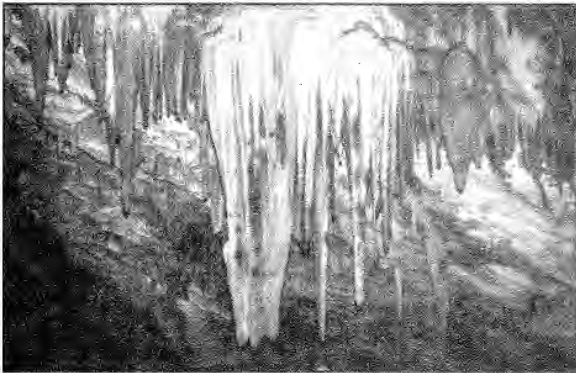
In this way, the time of diurnal duration and lighting intensity will be minimised having as a consequence the significant delay of photosynthetic process for the development of chlorophyta. (Note that to-date, most of the touristically developed caves in Greece are needlessly lighted during visiting hours even if there are no visitors). Apart from everything else, ultra violet lamps (sterilisation) could be used in the lighted areas during the hours that the cave is not open, with the aim of destroying all micro-organisms which

are developed on the speleothems. Although this solution seems to be the best, questions are raised concerning the danger of destroying the Cavernicolous (Cavity dweller) organisms together with the undesirable microflora.

- 5) Careful study for the placement of double doors with the aim of protecting the cave from the undesirable change of its microclimato-logical conditions.
- 6) Temporary closure of the cave's operation during the months which are not considered to fall within the tourist period. Apart from everything else, this will help to the unhindered maintenance and restoration of its damages.

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O-181

Fifty springs on the Niagara Escarpment, Ontario, Canada

D. Ford, S. Worthington

Abstract

The Niagara Escarpment (famed for Niagara Falls) is created by ~50 m of resistant but permeable dolomites resting on weak but impermeable shales. The Escarpment was fully glaciated during the Wisconsinan (Wurm) Ice Age; most earlier karst was destroyed. At Castle Glen, in the middle of the escarpment in Ontario, 50 karst springs of small to intermediate size discharge at the dolomite-shale contact along a 1500 m frontage. There is deep cover of glacial detritus on most of the source dolo-

mite plateau above the springs, but there are several seasonal flood sinks (turloughs) where the cover locally thins. Dye tracing with fluorescein and eosine was combined with frequent water temperature and electrical conductivity measurements at the springs during the annual thaw floods of 2004. This revealed an elegant pattern of flood and diffuse flow waters mixing that changed with time, indicating the presence of a young but well organised conduit aquifer which could be divided into five sub-basins.

O-182

Hydrogeology and speleogenesis in the vadose and phreatic zone of the chain "Peaks of the Musi Mountain" (Western Julian Fore-Alps)

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The chain of the Peaks of the Musi Mountain (1869.4 m), in the western Julian Fore-Alps is east-west oriented and consists of a north dipping uncline, which is made up of carbonate rocks, belonging to Triassic and Jurassic. The karst of the Musi Mt northern slope develops entirely within a Rhaetian - Liassic carbonate succession, while southern slope is characterised by the Norian - Rhaetian Dolomia Principale. The northern slope is of structural type with glacio-karstic landforms. On the plateau the speleological surveys allowed 230 caves to be explored. The largest cave is Abisso "R. Pahor" (altitude 1425 m), 495 m deep, 1091.5 m length; whereas to the west, at the foot of the southern slope of Musi Mt. Grotta dell'Uragano develops (altitude 796 m). It is 743 m length with a positive level of 133 m. In the percolating zone a complex of vadose shafts and canyon-type passages, partially derived from phreatic tubes associated with deep corrosion pits is predominant. The epiphreatic and phreatic karstic zone is scarcely developed. This zone is almost missing in the northern slope. The underground karst waters are typical of mountain aquifers with fast flows, having low contents of Ca²⁺ (28-32.9 mg/L) and Mg²⁺ (5.8-1.8 mg/L). The most important karst springs of the slope are the Group of springs on the left slope of the Voidizza Stream (altitude 653 m), with flows of 10-11 L/s and the Springs of the Torre Stream (altitude 529-532 m), with a discharge of 1.8 m³/s; on the northern slope of the Fontanon del Barmàn spring (altitude 760 m) with estimated floods of 1.5 m³/s. Two tracing tests (Uranine) of the stream on the bottom of the Abisso "R. Pahor" showed, in low waters, traces at the Springs of the Torre Stream and at the Springs of the Voidizza Stream. On the contrary, during a regime due to heavy rainfalls they showed traces at the Fontanon del Barmàn spring, thus suggesting a dynamic underground watershed as a function of the hydrogeological regime. A third tracing test with Tinopal CBS-X, performed in the perennial stream in the Grotta dell'Uragano showed the existing relationships among this stream and the way-outs present in the "canalone di Barmàn" (Barmàn gully) related with the Fontanon di Barmàn spring. Hydrogeological data show that, within the northern slope, water moves within large karst suspended channels (empty only during rain period); in correspondence with Barmàn gully there is a large karstic water circulation, residual in large epiphreatic and phreatic conduits, not related with the base-level of the Barmàn stream. Within the southern slope, the water table is dispersed in a fracture network constituting a real reservoir.

1. Introduction

First information about the karst phenomena in the chain of the Peaks of the Musi Mt were made at the beginning of the 20th century by Friulian geographers and geologists. In 1961 speleologists from Trieste started again researches exclusively focusing on the finding of the Grotta dell'Uragano, principal drain for the karst system. In 1990 new field trips and expeditions by GSSG from Trieste began and they last for 12 years favouring the almost complete speleological surveys of the Musi area. During this period, a lot of specialists and laboratories were involved in geological, geomorphological and hydrogeological studies (three different tracing tests have been performed). These studies allowed obtaining an idea about the underground hydrological circulation and the speleogenesis responsible of the karst network evolution.

2. Geological setting

The chain of the Peaks of Musi Mt (Fig. 1) is located in the western Ju-

lian Fore-Alps and bordered to the N by Rio Ucceca stream (Isonzo River basin), Rio Canizza stream and Rio Barmàn stream (Resia stream basin), to the S by Voidizza and Mea streams (Torre stream basin). The highest peak is Musi Mt (height 1869.4 m).

The chain of the Peaks of Musi Mt is made up by dolomite and calcite rocks, mainly Triassic and Jurassic in age, and by Quaternary deposits (Ceretti, 1965; Carobene et al., 1981; Frascari et al., 1981; Anselmi and Semeraro, 1997; Carulli et al., 1998). Southern slope, is constituted by Dolomia Principale (Norian-Rhaetian). In the northern slope, Dachstein Limestones (Rhaetian) and Lias-Dogger oolitic and cherty limestones outcrop.

The whole area is E-W oriented, N-dipping unclinal. The unclinal is closed to the south by the "M. Brancot-Caporetto-Circhina line": an E-W overthrust passing by the Torre Valley.

The northern slope of Musi Mt, especially towards the peak, is interested by huge karst phenomena. In this area different lithological types outcrop; according to the existing literature, six of them (the most important considering thickness and volumes) were grouped in six lithological Units (Anselmi and Semeraro, 1997).

The six lithological units are represented by: Dolomia Principale (Norian-Rhaetian); Dachstein Limestones (includine Poscala Limestones and Val Venzonassa dolomitic Limestones) (Rhaetian); "transitional grey limestones" (Rhaetian-Lower Lias); "oolitic Limestones" (Lower-Middle Lias); "cherty limestones" (Middle Lias-Dogger). All these facies are generally layered (50 cm - 2 m) sometimes massif (some horizons of dolomitic limestones); thin layering are exclusive of cherty limestones. Ucceca Flysch (supra Cretaceous sedimentary cycle), represented by thin, centimetric layered argillites and silty marls, overlies limestones.

Along the northern slope, Quaternary deposits are represented by talus, while Würm moraines are present in S. Anna di Carnizza and in Lischi-azze (Barmàn stream valley). Along the southern slope, Würm moraines are present in the Voidizza stream valley, and are probably buried below the alluvium in the Mea stream valley.

3. Karst phenomena in the Peaks of Musi Mts

Large karst phenomena are concentrated in the northern slope limestones as the Dachstein Limestones, the transitional grey limestones and the oolitic limestones constituting the so-called "acrocoro del Musi" or "Musi cirque" plateau. It is a structural type plateau, presenting cirques, glaciokarst dells and gullies. In the southern slope, stream trenches in dolomitic rocks are present. In the Musi cirque, with an area of about 5.5 km², 230 caves have been explored. The most of the caves are in the Dachstein Limestones, even if the larger are in the oolitic limestones. Six fundamentals morpho-types (macroforms) are represented within the cirque caves: 1- ancient phreatic conduits: bedding planes or, more frequently, joint planes, usually lenticular; 2- mixed dissolutive/erosive/clastic form galleries: generally larger than canyons, subhorizontal or gentle inclined and presenting several collapses; 3- canyons: erosive galleries, tall and narrow, slightly meander-like, sometimes very large; 4- vadose shafts: vertical erosive conduits, presenting erosion morphology along the wall where water felt or is still falling down; 5- deep corrosion pits: vertical pits bell-shaped; 6- surface corrosion small pits: superficial pits, often inclined, at least 10-20 m deep.

The largest cave of the cirque is the Abisso "Roberto Pahor", (altitude 1425 m a.s.l., 495 m deep, 1091.5 m length). Formed by many passages, it is constituted by pits and canyons; some passages are fossil, other are hy-

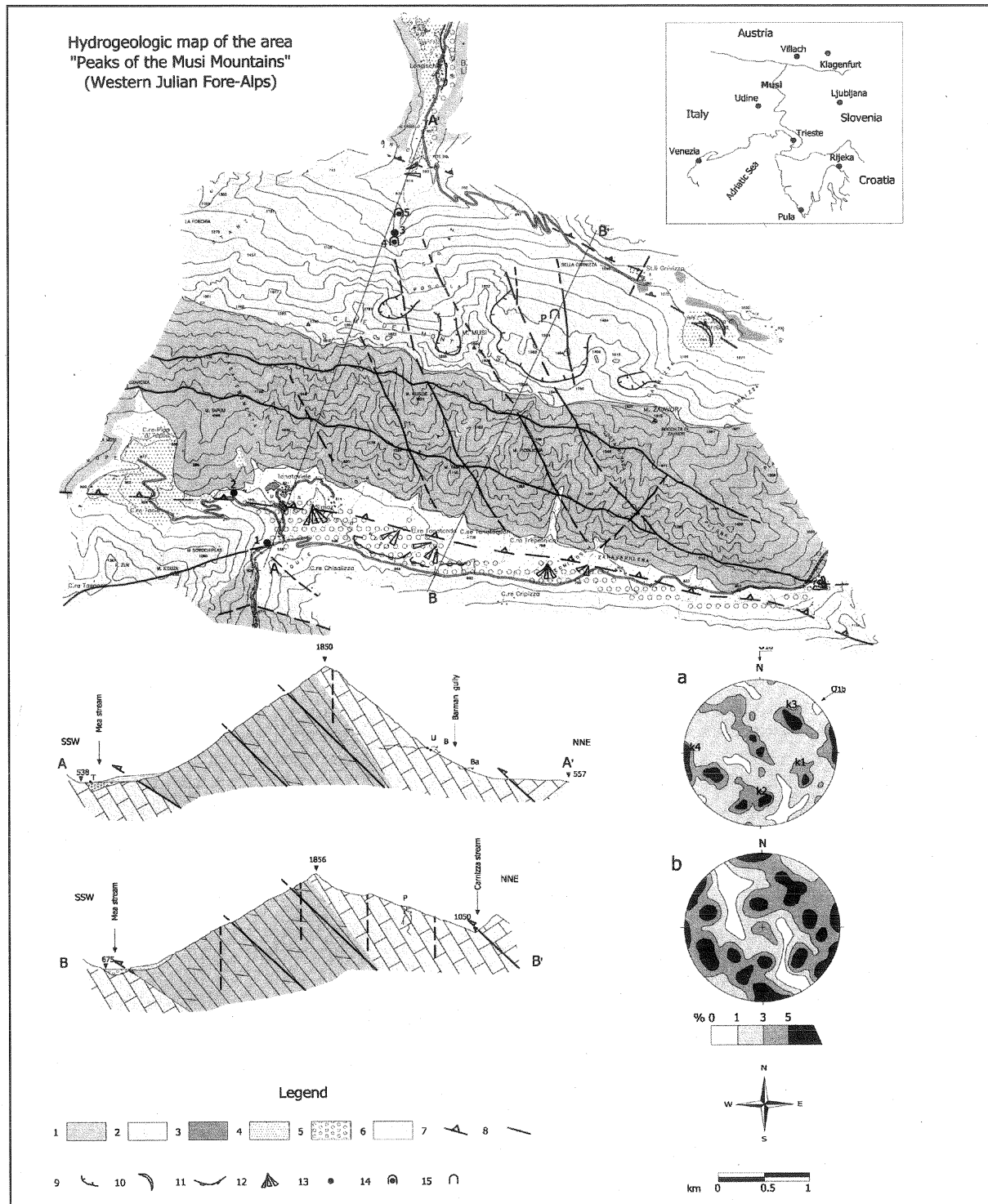


Fig. 1. Hydrogeologic map of the area "Peaks of the Musi Mountains". Legend: 1 = dolomites (prevailing) (Triassic); 2 = limestones and dolomitic limestones (Triassic), limestones, cherty limestones, oolitic limestones, dolomitic limestones (Jurassic); 3 = marly-arenaceous Flysch (Cretaceous); 4 = morain, till, fluvio-glacial deposits (Quaternary); 5 = alluvial deposits (Quaternary); 6 = landslide, talus, colluvial deposits (Quaternary); 7 = reverse fault; 8 = fault; 9 = glacial cirque; 10 = morenic arc; 11 = terrace; 12 = alluvial fan; 13 = main spring: [1] Springs of Torre Stream (T); [2], Springs left of Voidizza Stream, [3] Fontanon di Barman springs (B); 14 = cave-spring: [4] Grotta dell'Urugno (U), [5] Grotta di Barman (Ba); 15 = cave Abisso "R. Pahor" (P); A-A' = cross-section through the Torre springs and Barman gully; B-B' = cross-section through the "Pahor" Abyss; a = lower hemisphere equal-area stereonets showing the 500 joint poles in the calcareous North karstified slope; b = lower hemisphere equal-area stereonets showing the 400 joint poles in the dolomitic South slope.

drologically active; some parts show a 45° inclined feature, related to the geostructural arrangement. To the west of the cirque, at the footwall of the southern Musi slope, in the Barmàn gully, Grotta dell'Uragano develops. In the Grotta dell'Uragano (altitude 796 m a.s.l., 743 m length, +133 m height), paleoflow passages to the top and semi-flooded galleries near the bottom are present. On the bottom a perennial stream flows.

4. Speleogenesis

In the percolation zone a series of vadose shafts and canyons, partially derived from phreatic tubes is predominant. Deep corrosion pits are associated to them. The cavity net is located under the glacial plateau, forming a basin in highly karstified lithofacies. It is actually in an evolutionary stage, especially in deep-seated part of the massif where percolation is kept by drains.

Vadose water trickle formed gorge system connected with shafts. These are phenomena that repeatedly occurred always equal. Small phreatic conduits originated these shafts. The dispersed percolation caused the formation of the deep corrosion pits.

Conduits, shafts and galleries, generally inclined, are linked to N-S fracture system [k4], to E/ESE-W/WNW [k2], to SE/SSE-NW/NNW [k3]. Rarely, some branches are linked to the stratification planes [ss], around E/ESE-W/WNW, dipping north at around 50°. The morpho-structural statistical analysis of the gallery-shaped cavities [G] shows 5 main and subordinate "structures" [P = main, S = secondary, the indication → is the versus], which can be linked to the discontinuity systems: the structures [G1P→N] with the system [k4] and the planes ss, the structures [G2S→NE] with the system [k1], the structures [G3S→SE/SSE] with the system [k3], the structures [G4P→S/SSW] with the system [k4], the structures [G5P→NW] with the systems [k2] and [k3]. As for the pits, the "structures" mainly correlate with the systems [k3] and [k4] and subordinately with the system [k1]; the sequence s of pits that characterise the major abysses predominantly develop on joints and master joints of the system [k3]. Considering only the karstified plateau the predominant joint systems are four, linked to the stresses σ_{1a} and σ_{1b} , respectively north-south, north east-south west, belonging to the phases Mesoalpine (Paleogene) and Neoalpine (Neogene).

5. Karst hydrology

Rocks forming the chain of the Musi are almost totally made up by dolomites, dolomitic limestones and limestones differently karstified, allowing the water to percolate underground.

Both large fractures in "bc" position (shear) along the Musi uniline (Iacuzzi and Vaia, 1975) and large fractures in "hkl/hk0" position with respect to the main B=β (Anselmi and Semeraro, 1997) drain pluvio-nival supplies into depth. It seems that the last fractures, open, are the main drains to the south. Porous aquifer are represented by the Mea stream alluvium and by the Voidizza stream moraines.

The current percolation is important: the isohyets are over 3000 mm/year. On the high altitudes of the Musi, rainfalls over 3500 mm/year are estimated, with a relatively low evapotranspiration (Er) calculated at 14.2%. Since the dripping basin of the plateau of the Musi has an area of ~5.5 km² an average theoretical flow of 0.5 m³/s/day will be obtained, less during winter time and dry summer period.

In the southern slope, according to Iacuzzi and Vaia (1975), Torre springs are supplied by Mea stream groundwater and from water percolating from the Musi chain; according to Mosetti (1989) it is possible a contribution from water percolating in the Sorochiplàs and Postonciccò Mts limestone ridge. In the northern slope, the so-called Fontanon di Barmàn spring (760 m a.s.l.) is supplied by waters percolating from the western area of the slope (Poscala) as well as by Musi cirque.

The Fontanon di Barmàn spring is the outflow of the subterranean stream of the Grotta dell'Uragano. This link, has been established by Brun and Semeraro (2004) by using Tinopal CBS-X tracer test. The hypothesis of deep drains in Musi chain, with a underground watershed migrated towards the north with respect to the hydrographic one has been proposed by Iacuzzi and Vaia (1975). This hypothesis has been confirmed by Anselmi et al. (1997) and Anselmi and Semeraro (2003) using two Uranine tracing tests. The waters normally drain towards the Barmàn gully, whereas during low waters they would flow also towards the maximum point of depression of the aquifer that is the Springs of the Torre stream and the Group of springs on the left slope of the Voidizza stream.

Meteoric and snow melting waters, quickly percolate in depth, especially in the northern calcareous slope. On the contrary, in the southern dolomitic slope, a certain amount of water flood along the stream trenches into the Torre valley alluvium. Percolating water flood into the shallow phreatic zone of the mountain chain. The water table is characterised by an underground watershed, still undefined. In fact, the aquifer drains both to S-SW (maximum topographical low, i.e. springs to the left of Voidizza stream at 653 m a.s.l., discharge Qavg 10-11 L/s and Springs of Torre stream, 529-532 m a.s.l., discharge Qavg 1,8 m³/s) and to NW to the Fontanon di Barmàn (760 m a.s.l., discharge Q ≥ 1,5 m³/s) connected with the perennial stream of the Grotta dell'Uragano (discharge Qavg ≥ 50 L/s). The Grotta dell'Uragano is the terminal part of the N area passages, i.e. large karst conduits representing a principal drainage.

6. Hydrogeological and chemical data of groundwater flows

Torre springs could probably be supplied by stored base-flow, coming from a calcareous and dolomitic reservoir of the karst system, as suggested by low temperature and Mg/Ca ratio ranging between 0.48 and 0.32; another part of waters comes from the outflows of the Musi Valley porous aquifer.

In the spring area, the thickness of the porous aquifer (gravel) is about 70 m, interbedded with lacustrine loam and clays (10-15 m thick) forming an aquiclude, probably separating two different aquifers (one unconfined and one confined). The springs to the left of the Voidizza stream could be probably supplied from the karst water table hosted by the dolomitic rocks as suggested by temperature, 4°C higher than those of the Torre springs and Mg/Ca ratio equal to 0.54.

In the northern slope, waters of the Fontanon di Barmàn spring show Mg/Ca ratio equal to 0.18 evidencing calcareous domain, and the lowest temperature (0.7-1°C less than Torre springs). Chemical features of underground waters of Fontanon di Barmàn spring during summer dry period (Mg/Ca ratio equal to 0.28) are not very different from average values. The result of one analyses of waters sampled on August 10th, 2003 shows: Ca²⁺ 28.9 mg/L, Mg²⁺ 8.33 mg/L, K⁺ 2.82 mg/L, Cl⁻ 2.5 mg/L, Na⁺ 0.55 mg/L, total hardness 7.2 °F, HCO₃⁻ 110 mg/L, conductance 197 μS/cm. It is possible to notice a scarce mineralization showing the paucity of hydrologic resources in that period.

Several chemical analyses on the karst spring waters, including small springs of the southern dolomitic slope, always show low values of Ca²⁺ (28.0-32.9 mg/L) and Mg²⁺ (5.8-18.2 mg/L).

Hydrological and chemical data of spring point out to the existence of an inhomogeneous karst system, divided in two part. The northern part is characterised by large conduits, with a saturated zone extremely reduced (or not present during the seasonal lacking of recharge), with a principal drainage system towards the Grotta dell'Uragano stream (Brun and Semeraro, 2004). The southern area - poorly known - should be probably characterised by phreatic conduits (perhaps a network of lenticular tubes in Dolomia Principale Formation), slowly discharging, as perennial springs are recharge of the saturated zone store, as resulting by hydrograph and recession curve of springs to the left of Voidizza and Torre Streams as well

as by little variations of Ca^{2+} e Mg^{2+} between dry and rainy periods, as described by Iacuzzi and Vaia (1975) and Anselmi and Semeraro (1997).

It seems that Torre springs are a mixing between waters from a basal carbonate aquifer and the porous aquifer of the Mea stream (upper Torre Valley). They are collected by a large well (about 10 meters deep) from which 27 horizontal drains spread out. Repeated chemical analyses show that conductance (K25) is between 186 and 215 $\mu\text{S}/\text{cm}$, and total hardness is between 11 and 13 $^\circ\text{F}$. Rain contribution is very low, chlorides (Cl^-) range between 0.8 and 1.3 mg/L and sulphates (SO_4^{2-}) between 2 and 3 mg/L. Even nitrates (NO_3^-) deriving from soils and anthropic pollution are very low, between 2.8 and 4 mg/L. During three years of analyses total coliforms were absent, apart from some summer period where they were between 15 and 60 UFC/100mL. Only one, 500 UFC/100mL were measured. Faecal coliforms always missed.

Among all the springs of the chain, the temperatures of Torre springs are the most constant being comprised between 4°C and 8.5°C , suggesting a longer standing in the aquifer.

6. Karst outflows in the Barmàn gully

In the northern area, the Barmàn gully is quite interesting. In the gully there are many perennial or temporarily karstic groundwater outflows from buried or impassable cavities. Beneath the Fontanon di Barmàn spring (buried by collapses, 760 m a.s.l.), forming a large waterfall, in the gully there is also the stream of Grotta dell'Uragano (796 m a.s.l.) supplying the Fontanon di Barmàn, and springs at lower quotes are active during low waters. On the left slope there is the Grotta di Barmàn (entrance at 660 m a.s.l.). Giving this, there are about 100 meters of vadose zone. Even the waters of Grotta di Barmàn, normally represented by trickles-flow descending from pits in bedding planes $60\text{-}70^\circ$ inclined, during strong rainfalls outflow from the entrance. In order to better evaluate these phenomena, a lot of measurements on hydrology are available. These data were measured during autumn-winter 2003 and are linked with meteorological data of OSMER. Between 20 and 24/10 about 88 mm rained, then there were three dry days. Following this, underground waters outflow from both Grotta dell'Uragano and Grotta di Barmàn. Rainfalls started again on November 1st, about 4.6 mm. After thirteen dry days, flood persisted in Fontanon di Barmàn (16/11). That day rained 3.4 mm. On December 28th, it rained 84.4 mm and the following day 143.4 mm. The same day after the rain began, inside the Grotta di Barmàn, percolation from the pits started. After 2 hours, the flow increased 4-5 times reaching about 5-6 L/s. Even if the data are scattered, it seems clear that 80 mm rain can be responsible for the outflow of underground water from generally inactive cave entrances.

During the maximum rainfall period, between October and December, the effect of percolations is very fast (hours). Moreover, dry period, in the karstic conduits (Grotta dell'Uragano, bedding planes springs at lower quotes in the gully), the outflows persist for a long time, suggesting the existence of water being stored in depth.

7. Conclusions

In the chain of the Peaks of Musi Mt, the vadose zone is mainly karstic in the northern calcareous slope. In the southern dolomitic poorly karstified slope, the vadose zone is represented by fracture network and lenticular tubes. In limestones, even inclined pits and canyons represented the cavities; but there are ancient phreatic conduits at high altitude cut by glacial erosion or pulling-back of the slope. These conduits testify the long evolution of the karstic aquifer, probably began in the Tertiary, while, the Quaternary glaciations and valley erosion determined downward of drains system and the dismembering and disappearance of the old recharge zones and abandoned cavity.

Percolating area quickly drains water into depth, driving them to the spring levels. The thickness of the saturated zone seems to be minimum, especially in the northern slope where seasonally is almost not existing because water flows in large hanging karst conduits (storing water only in rainy period). In the southern slope the phreatic water is more dispersed in a fracture network constituting a real reservoir. In correspondence with the Barmàn gully, an important hydrological karst residual circulation, exists as large epiphreatic and phreatic conduits, still not linked with the valley base level of Rio Barmàn.

Acknowledgments

The Author kindly acknowledges the "Laboratorio analisi e controllo ACEGAS S.p.A, Trieste" (Fabio Gemiti) and the "Laboratorio di Biologia Marina, Trieste" (Sergio Predonzani) for performing the first chemical and fluorimetric analyses; researchers and technicians at "Geokarst Engineering S.r.l. di AREA Science Park, Trieste" for chemical and fluorimetric analyses (Massimiliano Baldassi, Clarissa Brun), for suggestions in text writing (Davide Lenaz) and CAD design (Andrea Tagliapietra); the "Consorzio Acquedotti Friuli Centrale, Udine" for giving Torre spring chemical analyses; the "Ufficio Idrografico di Udine" and "OSMER, ARPA Friuli Venezia Giulia" for giving pluviometric data of the area. Special thanks to the speleologists of the "GSSG Gruppo Speleologico San Giusto, Trieste", for giving the speleological data obtained from all the explorations began since 1990.

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Karst Hydrogeology of Lookout Mountain, a Synclinal Mountain in the Folded Appalachian Mountains of SouthEast Tennessee AND Northwest Georgia, USA

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The primary objective of this research was to investigate the hydrogeology of Lookout Mountain, located near Chattanooga in southeast Tennessee and northwest Georgia, USA. The National Park Service (NPS) funded this research to better understand the karst groundwater flow under the Chattanooga National Military Park and how urban development in the vicinity of the park might affect the karst and groundwater quality. If a major spill of toxic material occurs on Lookout Mountain as it did in 1996 with a Colonial Pipeline oil spill, the NPS must be able to track the flow of the contaminants.

Lookout Mountain is a synclinal mountain located within the Folded Appalachian Mountains. Its stratigraphy mimics that of the nearby Cumberland Plateau. The caves tend to be oriented along the strike, and there are numerous vertical shafts where cave streams drop off resistant strata.

Dye tracing and cave exploration and mapping were used to investigate the hydrogeology. The Center for Cave and Karst Studies (CCKS) uses fieldwork and fluorimetric analysis for qualitative dye tracing. A karst hydrogeologic inventory was conducted on and around the base of Lookout Mountain, and 43 coconut charcoal dye receptors were placed in all springs, surface streams and several cave streams.

Four different dyes were injected on two separate occasions into spring-sinks in the complicated lithologic structure. The research indicates that surface streams flowing off the sandstone-capped mountain sink into the underlying limestones to create cave streams that then flow along the strike of the synclinal mountain. The cave streams have a stair-step pattern as they breach confining layers and descend through the Pennington, Bangor, and Monteagle Limestones. The deepest of these vertical shafts is Mystery Falls (the deepest vertical shaft known in Tennessee, 85.6 m). It was created by a cave stream dropping through the Hartselle Formation shale confining layer down into the Monteagle Limestone. This hydrogeologic research has identified major flow routes within the karst aquifers under Lookout Mountain.

1. Introduction

Dye tracing is a powerful tool in karst hydrogeology. Dye tracer tests combined with knowledge of the geologic structure and stratigraphy can identify the major flow routes through karst aquifers. They are, therefore, fundamental in explaining the complex nature of groundwater flow in most karst aquifers (Quinlan, 1989). Dye tracing is one of the most effective methods for determining zones of contribution, directions of groundwater flow, and quantifying residence times for water in karst aquifers where conduit flow prevails.

2. Study Area

Lookout Mountain, part of the folded Appalachian Mountain Chain, extends 134 km from the Tennessee River at Chattanooga into northwest Georgia. Lookout Creek flows northeast parallel to the mountain along its western side, and Chattanooga Creek flows northeast along the eastern side of the mountain. Both streams discharge into the Tennessee River at Chattanooga, Tennessee. The mountain lies within the folded Appalachian Mountain physiographic region near the horizontal rocks of the Cumberland Plateau to the west.

Stratigraphy within the mountain is similar to that of the Cumberland Plateau with a Pennsylvanian sandstone and shale caprock above Mississippian carbonates. Lookout Mountain is topped by Pennsylvanian period Whitwell Shale, Sewanee Conglomerate, Signal Point Shale, Warren Point Sandstone, and the Raccoon Mountain Formation (shaley sandstone). A perched aquifer exists within the Warren Point Sandstone, which makes up the majority of the top of the mountain. Groundwater from this perched sandstone aquifer and storm water runoff flow over the steep cliff sides of the Raccoon Mountain Formation confining layer onto the underlying Mississippian stratigraphy. The Mississippian Formations that outcrop along the flanks of the mountain on both sides include: the Pennington Formation (approx 120-150 m, mixed sandstones and limestones), Bangor Limestone (61-122 m), the Hartselle Formation (0-12 m, siliceous sandstones and shales), Monteagle Limestone (61-91 m), St. Louis Limestone (12-30 m), Warsaw Limestone (12-30 m), and the Fort Payne Formation (27-61 m). The Chattanooga Shale (6 m) lies at the base of the mountain below the chert beds of the Fort Payne. The strata form a shallow syncline that plunges gently to the south (Finafayson and others, 1964).

A near vertical joint set strikes N45E towards the interior of the mountain. An opposing joint set strikes N50W. The Cranmore Cove Thrust Fault flanks the west side of Lookout Mountain with the Fort Payne Formation on the hanging wall overlying the Warsaw Limestone. Extending north and south is the Chattanooga Fault, a high angle reverse fault, which extends parallel to the Cranmore Cove Fault to the north. This fault terminates on the northeastern extent of Lookout Mountain (Mies, 2005).

Crawford (1979) describes groundwater flow along the Cumberland Plateau Escarpment (Figure 1). His model proposes cavern development through a drainage system composed of vertical shafts and horizontal conduits acting together in a stair-step pattern. This schematic model indicates that allogenic streams flow off the siliclastic caprock and invade the subsurface as they flow onto the underlying Mississippian Limestones, along the edge of the retreating escarpment. There is a similar pattern noticeable at the northern extent of Lookout Mountain.

3. Dye Tracing

In this ongoing study commissioned by the US National Park Service, dye tracing is being used to delineate the source areas for their undefined watersheds at Chattanooga National Military Park. A comprehensive karst hydrogeologic inventory was conducted over the entire study area to identify all karst features including springs, seeps, sinking and loosing streams, karst windows, major sinkholes, and caves. The two important springs identified during the karst hydrogeologic inventory are Skyuka and Anderson. Skyuka flows directly into Lookout Creek that then flows 8.5 km to the Tennessee River. Anderson Spring is now buried beneath riprap under Interstate Highway 24. Anderson Spring rises through the riprap directly into the Tennessee River (Nickajack Reservoir). Two significant caves also exist on the northern nose of the mountain. The stream in Mystery Falls Cave flows along the Hartselle Formation before dropping 80 m into the Monteagle Limestone. The stream in Ruby Falls Cave also flows along the top of the Hartselle before dropping approximately 24 m into the Monteagle.

Activated coconut charcoal receptors were used to adsorb the following dyes: Sodium Fluorescein, C.I. Acid Yellow 73; Eosine, C.I. Acid

Red 87; Sulphorhodamine B, C.I. Acid Red 53; and Tinopal CBS-X, Fluorescent Brightening Agent 351. Each dye was injected at individual locations on two events, 13 February 2005 and 23 April 2005. Fifteen receptors were placed along the bank of the Tennessee River to catch dye

rising from springs now inundated by Nickajack Reservoir. Three receptors were placed along Chattanooga and Lookout Creeks. Four receptors were placed in cave streams, and twenty-one were placed in springs. All dyes were injected on the west side of Lookout Mountain.

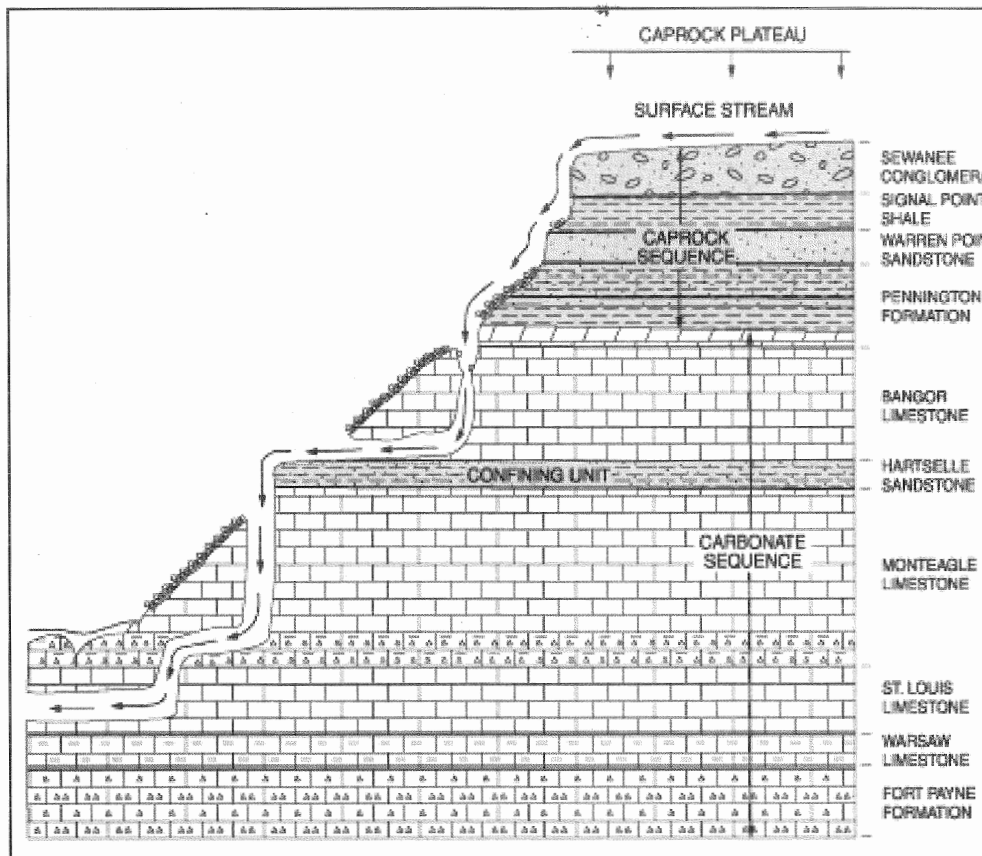


Figure 1. Generalized cross section along the Cumberland Plateau Escarpment in Tennessee (Crawford, 1979)

Receptors were changed on a weekly basis, then analyzed at the Center for Cave and Karst Studies (CCKS) dye tracer laboratory at Western Kentucky University. Smart solution (Smart and Laidlaw, 1977) was used to elute the dye from the charcoal and the elutant samples were analyzed on a Shimadzu Model RF-5301PC Synchronously Scanning Spectrofluorophotometer. Analysis on a scanning spectrofluorophotometer provides the lowest detection limits and most reliable dye analysis. Eight dyes were injected on the west side of Lookout Mountain at seven springs-sinks and at one cave stream location.

4. Dye Tracing Results

The results of the eight dye traces are presented in Figure 2. Lines indicate the suspected flow paths from each of the injection locations to resurgent springs. Injection points are represented by teardrop symbols and dye receptor location sites by round points.

Fluorescein was injected at Craven's House Spring on the Pennington Formation. Receptors picked up dye at Mystery Falls Cave stream and then at the Anderson Spring resurgence in the Tennessee River. The dye did not sink into the Pennington, but instead followed man-made structures (culverts and drainage ditches) until it sank into the Bangor Limestone and flowed along the Hartselle Formation to Mystery Falls.

Sulphorhodamine B was injected into Gum Spring-Sink on the Pennington, and it flowed to Mystery Falls Cave and then to Anderson Spring. Eosine, injected in Apollo Castle Stream Swallet, also followed a similar path after dropping off the Raccoon Mountain Formation, down through the Pennington and Bangor to the Hartselle and then to Mystery Falls Cave and Anderson Spring. Tinopal CBS-X was injected at both Dogwood Spring-Sink in the Bangor and Rock Spring-Sink in the Pennington on separate occasions. Tinopal CBS-X injected at Rock Spring-Sink was first detected at Dogwood Spring-Sink. It then flowed upon the Hartselle Formation confining layer to Ruby Falls in Ruby Falls Cave, and then it was detected at Anderson Spring. Surface water sinking at Warren Point Falls Swallet was traced to Skyuka Spring using Eosine dye. This surface stream drops off the Raccoon Mountain Formation and sinks into the Pennington to then resurge at Skyuka Spring. Similarly, Sulphorhodamine B, injected into Pond Spring-Sink, was traced to Skyuka Spring. Fluorescein injected into a stream in Chambliss Cave flowed along the strike down the plunge of the Lookout Mountain Syncline to resurge at Skyuka Spring.

Water flowing from Rock Spring-Sink may travel along a N50W joint to Dogwood Spring-Sink before continuing to flow along the strike to Ruby Falls and then to a final resurgence at Anderson Spring. Resurgence in Ruby Falls instead of Mystery Falls could be due to a lower flow path in the Bangor Limestone.

SUSPECTED DYE PATHS ON LOOKOUT MOUNTAIN

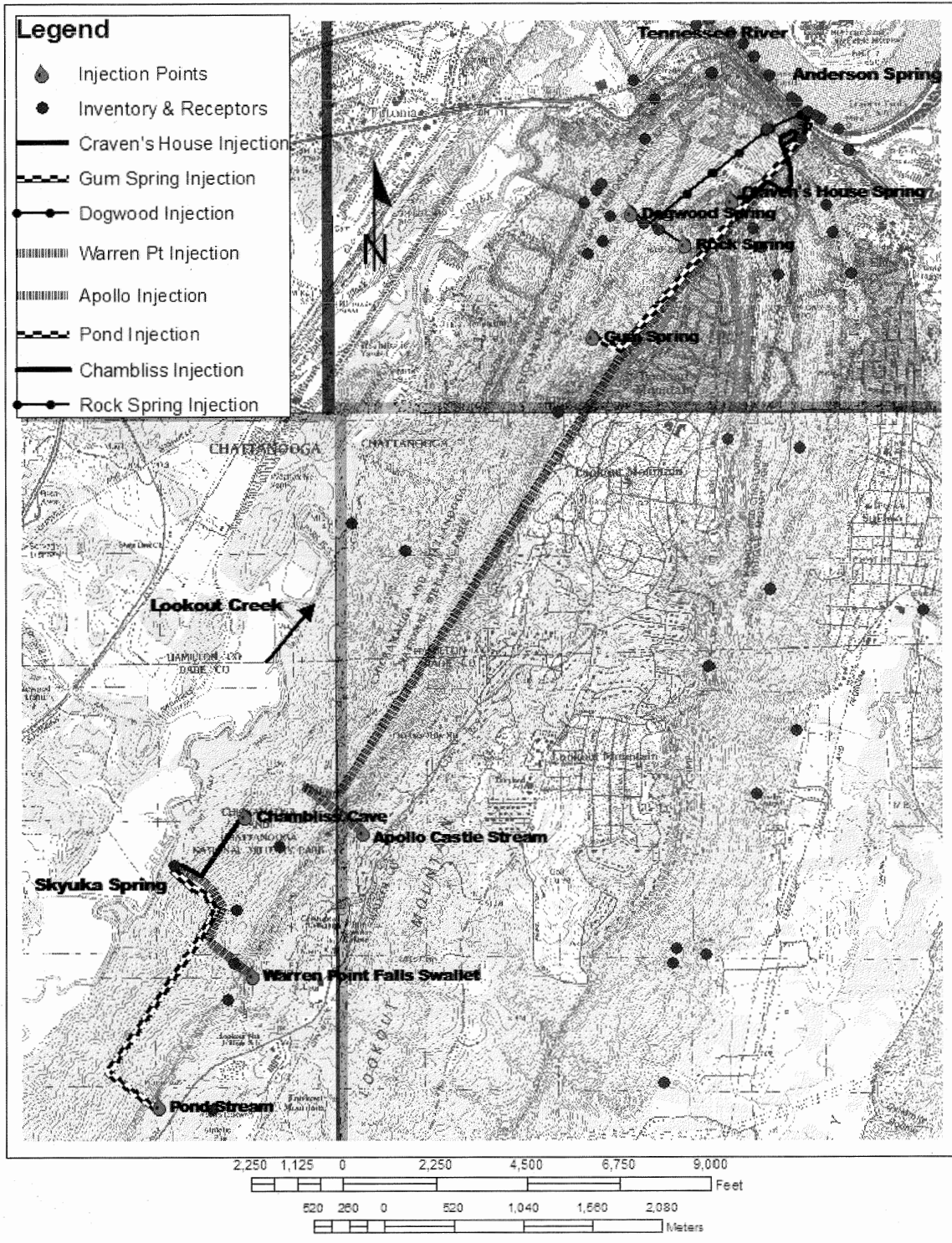


Figure 2. Lookout Mountain in northwest Georgia and southeast Tennessee showing suspected dye paths, dye injection points, major springs, major caves, and dye receptor locations. Source: Chattanooga, Fort Oglethorpe, Hooker, and Wauhatchie Topographic Quadrangles.

Chambliss Cave Stream and the Apollo Castle Stream dye traces show the approximate drainage divide between groundwater that flows north to Anderson Spring and groundwater that flows south to Skyuka Spring. Chambliss Cave Stream flows through the Hartselle Formation instead of being diverted to flow along the strike.

Dyes injected into Chambliss Cave Stream, Warren Point Falls Swallet, and Pond Stream Swallet flowed to Skyuka Spring

and then into Lookout Creek. Dyes injected at Apollo Castle Stream Swallet, Rock Spring-Sink, Dogwood Spring-Sink, Cravens House Spring-Sink, and Gum Spring-Sink flowed north along the strike, perched upon the Hartselle confining layer, to drop off at Ruby Falls or Mystery Falls to a final resurgence at Anderson Spring along the Tennessee River.

5. Discussion

The northern extent of Lookout Mountain receives an average of 138.48 cm of rainfall per year (National Weather Service, 2005). During heavy precipitation events some of this water flows down usually dry streambeds to Chattanooga or Lookout Creeks. However, much of it sinks into perched karst aquifers to then resurge at springs. After flowing off the Raccoon Mountain Formation confining layer, surface streams sink into

limestone beds in the Pennington Formation, Bangor Limestone, or the Monteagle Limestone. During low flow, the entire discharge of a surface stream may sink into limestone beds within the Pennington Formation. At higher flow, it may also sink into the Bangor and Monteagle Limestones. During very heavy precipitation events, some of the stream water may reach Lookout or Chattanooga Creeks without sinking.

As discussed by Crawford (1979), not all cave streams flowing upon the Hartselle confining layer resurge as springs. Some streams breach the Hartselle and sink in back of the escarpment creating vertical shafts and underground waterfalls. These vertical shafts appear to be due to stress-relief fractures caused by the release of confining pressure near the escarpment. It appears that virtually all cave streams flowing upon the Hartselle Formation under Lookout Mountain breach the Hartselle underground creating spectacular vertical shafts and underground waterfalls, such as Mystery Falls and Ruby Falls. This may be due to an increased number of stress-relief fractures and/or faults due to the synclinal folding and thrust faulting of Lookout Mountain.

All of the dye traces indicated that surface runoff flowing down the west side of Lookout Mountain sinks into the limestones and then either flows north to Mystery or Ruby Falls and then to Anderson Spring or flows

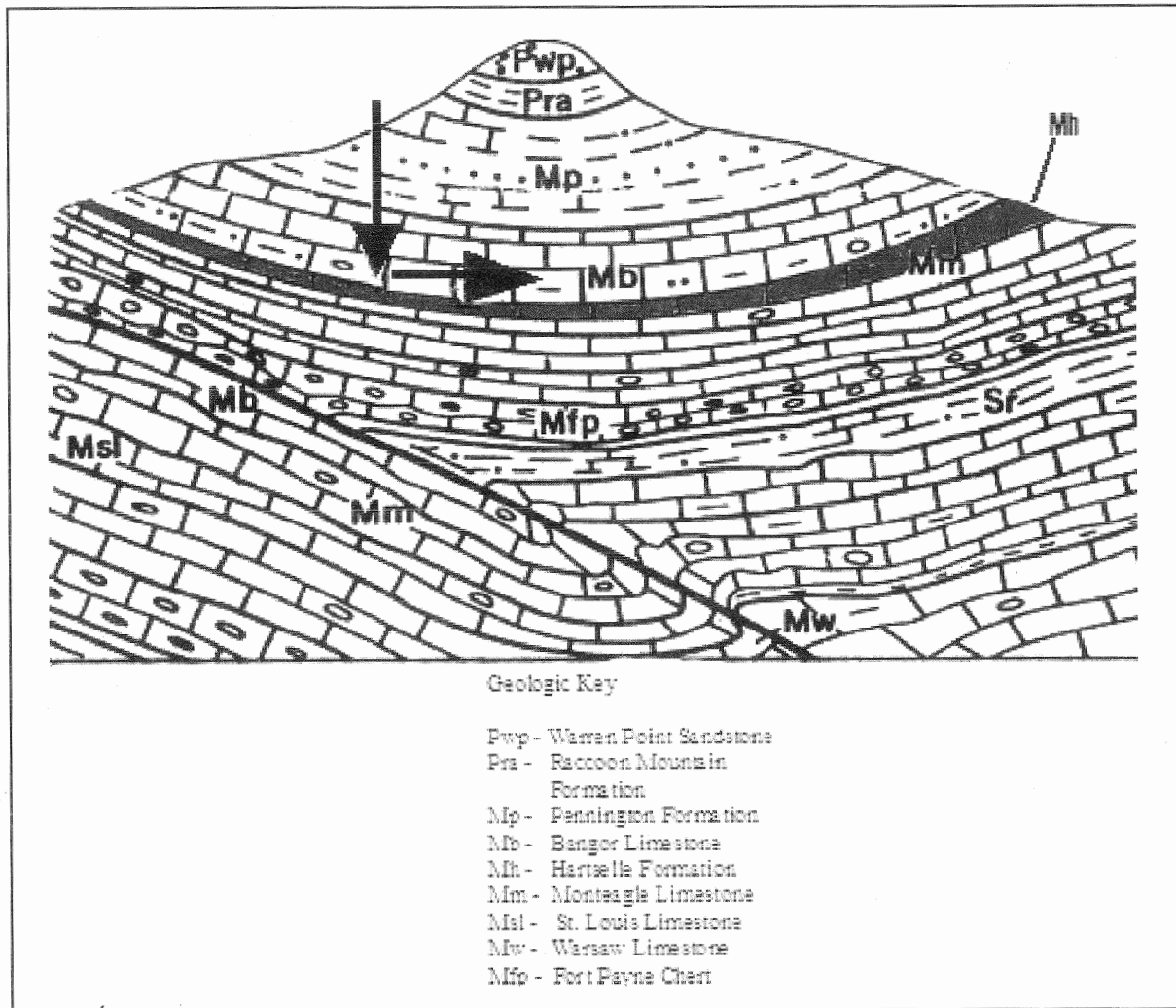


Figure 3. Hartselle Formation directs groundwater downdip toward trough of Lookout Mountain syncline. The perched water table then causes groundwater to flow along the strike until it drops through vertical shafts in the Hartselle, resulting in underground waterfalls, such as, Ruby Falls and Mystery Falls. (Source: modified from Finlayson, 1964). Figure 3. Lookout Mountain in northwest Georgia and Southeast Tennessee showing suspected dye paths, dye injection points, main springs, caves, and dye receptor locations

west to resurge at Skyuka Spring (Figure 2). Dye injected into Apollo Castle Stream Swallet, Gum Spring-Sink, and the Craven's House Spring-Sink sank through the Pennington Formation and Bangor Limestone until they hit the Hartselle Formation confining layer. They then flowed down the dip towards the trough of the syncline (Figure 3); towards the center of the mountain. The dyes then flowed along the strike towards Mystery Falls or Ruby Falls and then to a final resurgence at Anderson Spring. Therefore, this hydrogeologic investigation has revealed that the master conduits have formed parallel to the strike along the western side of Look-out Mountain due to the structure and stratigraphy. The hydrogeologic investigation is continuing along the eastern side of the mountain. Also, the influence of the Cranmore Cove Fault and Chattanooga Fault systems on the hydrogeology is still being investigated.

Acknowledgements

This study was funded by the National Park Service and the Center for Cave and Karst Studies, Western Kentucky University. The authors thank Dr. Jonathan Mies, Buddy Lane, and Dennis Curry for discussions on the area, and Glen Siegest for his lodging throughout the duration of this project.

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Intensive Monitoring of Drip Water in Two Shallow Caves

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Abstract

The role of drip water in cave hydrology is often poorly studied and understood. The duration of observations during most trips into caves is insufficient to adequately characterize drips and delineate their source areas. Two caves in central Texas, USA, were intensively monitored for several months to determine the similarities and differences between their drip waters. The ceiling of Bunny Hole ranges 2-3 m below the surface, and the ceiling of Headquarters Cave ranges from 2-14 m below the surface. Irrigation systems were placed over each cave to artificially induce recharge, and drip water in the caves was measured for temperature, conductivity, volume, and response time.

Both caves showed similar responses to natural and artificial rainfall, with some initiation of dripping as rapid as within the 15-minute sampling interval of the instruments, comparably fast declines in conductivity, and subtle seasonal changes in temperature. Drip water in Headquarters Cave generally exhibited a slightly slower response time, probably due to the cave's greater depth and epikarstic groundwater storage. Tracer testing and artificial rainfall over selected areas demonstrate complex groundwater flow paths into the caves, even where the cave ceiling is as thin as 2 m. The rapid recharge into caves without sinkholes or other large karst features apparent on the surface demonstrates the vulnerability of karst aquifers to groundwater contamination.

Site Descriptions and Methodology

This drip water research is part of a joint project with Texas A&M University and the Edwards Aquifer Authority. The larger goals are to understand and quantify recharge to the Edwards Aquifer through the

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vadose zone, particularly as it may be impacted by vegetation. During the summer of 2004, monitoring equipment was set up at two caves at the Camp Bullis military training facility located just north of San Antonio, Texas, USA. Due to rapidly increasing demands for groundwater in the region, the effects of vegetation on recharge are becoming an increasing concern.

Bunny Hole and Headquarters Cave are caves selected in the vadose zone of the Edwards Aquifer recharge zone at Camp Bullis because of their location, geologic structure, and relative differences. Bunny Hole is a shallow cave developed in the Dolomitic Member of the Kainer Formation. Formed under phreatic conditions, its low-velocity groundwater resulted in a series of braided passages. Bunny Hole reaches a maximum depth of 5 m. Its passages are normally less than 1 m high by 1.5 m wide, with a cumulative length of 198 m, and floors mostly covered by gray-black organic sediment and underlying light-brown silt. Headquarters Cave developed phreatically in the upper member of the Glen Rose Formation, but collapse raised the ceiling so most of its accessible 54 m length is in the Basal Nodular Member of the Kainer Formation. With a vertical extent of 11 m, this cave consists of two moderately large rooms with floors mostly covered by rubble and gray-black sediment. Simulated recharge at the two caves was compared to natural rainfall events to determine recharge rates and volumes, as well as how much precipitation over the cave footprints is recharged through the underlying bedrock.

Significant recharge locations were defined in both caves based on in-cave observations during both natural and simulated rain events. Drip water collectors were built at these locations from PVC pipe and polyurethane sheeting. Collected water drains to tipping-bucket gauges connected to dataloggers, allowing for continual monitoring. Additional cave instrumentation continuously measures electrical conductivity, and

water and air temperatures. At Bunny Hole, each drip collector has its own tipping bucket. At Headquarters Cave, the shallowest four of the drip collectors are grouped into two pairs, and the deepest drip collector has its own tipping bucket.

One air temperature probe monitors Bunny Hole and two of the drip sites are instrumented for water temperature and conductivity. All of the in-cave instrumentation records to the datalogger at 15 minute intervals. This very shallow cave probably has a relatively small catchment area and consequently drips only during and soon after rain events. Because the drips are not always active, months can pass without significant drip water passing through the cave. During these periods, water in the sampling reservoirs becomes stagnant. For this reason, the water temperatures and conductivities at Bunny Hole are only significant during and soon after rainfall events, but the water temperatures provide a good check on the air temperature measurements. Air temperatures were initially measured with relative humidity probes, which began to malfunction in the high-humidity cave environments. The air temperature probe began malfunctioning in mid-December 2004 and was replaced with a solid-state thermistor on 15 February 2005. Despite two months of

missing air temperature data, the close correlation of water temperature to air temperature (about 0.31C during times of no recharge) allows us to assume with confidence what the air temperatures were during this time.

At Headquarters Cave, two drip sites were monitored for water temperature and electrical conductivity. One measures water from a drip site approximately 6 meters below the ground surface in the path of significant air flow. The other measures water from a drip approximately 13 meters below the ground surface with no detectable airflow.

Ultimately, drip data from the caves will be integrated with the following data collected concurrently on the surface above the caves in associated project tasks. Instrumentation included at Bunny Hole consists of stemflow collectors, throughfall collectors, sapflow monitoring devices to evaluate evapotranspiration, and a series of rain gauges to help quantify all aspects of the water budget, as well as runoff measurement instrumentation. A surface weather station records air temperature, precipitation, wind speed, and relative humidity at Bunny Hole. A rainfall simulator at the cave consists of six masts that rise above the tree canopy, each fitted with four sprinklers, capable of producing rainfall rates between 2.54 and 25.4 cm/hr, at 2.54 cm intervals. The rainfall simulator allows comparison of natural and simulated rainfall events. The above-canopy sprinklers provide a more natural re-creation of throughfall and the spatially variable distribution of rainfall, and allow comparison of the other instrumented components of the water budget.

Results: Bunny Hole

The first simulated rainfall experiment at Bunny Hole began on 25 August 2004 at 1205 and ended at 1311. A measured 14,723.1 L of water were intermittently applied to the cave footprint at a rate of 25.4 cm/hr for 39 minutes over a 66-minute period without an in-cave observer. The first recorded recharge into the cave occurred at approximately 45 minutes after the simulation began, and recharge continued to enter for the next 24 hours. The peak of the hydrograph occurred at 1315, four minutes after the simulation ended. Measured recharge into the cave totaled 575 L or 3.91% of the total water applied while throughfall amounted to 10,372 L or 70.44%. Stemflow instrumentation failed to operate properly due to programming errors in the dataloggers. The remainder of rainfall in the water budget was thus lost to canopy interception, storage in the soil, or was transported off site via overland flow or lateral subsurface flow. An important observation made during this simulation was the presence of surface water ponding inside the cave footprint. Approximately 5% of throughfall ponded on the surface, allowing it to later infiltrate the soil

and probably become recharge. No actual surface runoff left the cave footprint, but small amounts of water did move laterally across the surface within the footprint.

Natural rainfall events monitored from late September 2004 through June 2005 show the cave is hydrologically dynamic relative to dripwater. Volumes of water entering the cave on a monthly basis ranged up to 10,281 L in November 2004. During this time, the area received 32.3 cm of precipitation, equivalent to approximately 54,910 L of rain over the cave's footprint. The measured drip response accounts for at least 18.7% of the rainfall. This is a minimum value because not all recharge into the cave is measured, and also because of some tipping bucket equipment failures. Equipment malfunctions in both caves were mostly due to high humidity in the caves. Moisture-vulnerable components were identified and replaced with more suitable equipment during the spring of 2005. The difference in response between simulated and natural recharge events suggests that even a cave as shallow as Bunny Hole has a catchment area significantly larger than its footprint.

Figure 1 illustrates recharge through temperature, conductivity, and precipitation data. On 28-29 May 2005, a shower that lasted 4 hours yielded 2.29 cm of rain. Within 1.25 hours of the rain's onset, low-conductivity recharge had reached the probe. On 1 June 2005, another shower dropped 2.41 cm in 2.75 hours. Within 30 minutes, the recharge reached the probe. Since the surface temperatures are higher than the cave at this time of year, the conductivity dips are matched exactly by increases in water temperature as warm, low-conductivity water entered the cave. These two similar-size rain events illustrate the importance of antecedent conditions to the rate of recharge. After the first shower, only 1 liter of recharge was recorded in the cave. After the second shower, 142.5 liters of recharge were recorded. Additionally, these events may also illustrate the importance of the precipitation rate on the rate of recharge, with the second rain event occurring in a 31% shorter period than the first. Additional data are needed to quantify the effects and limits of precipitation rates on recharge independent of antecedent rainfall.

Results: Headquarters Cave

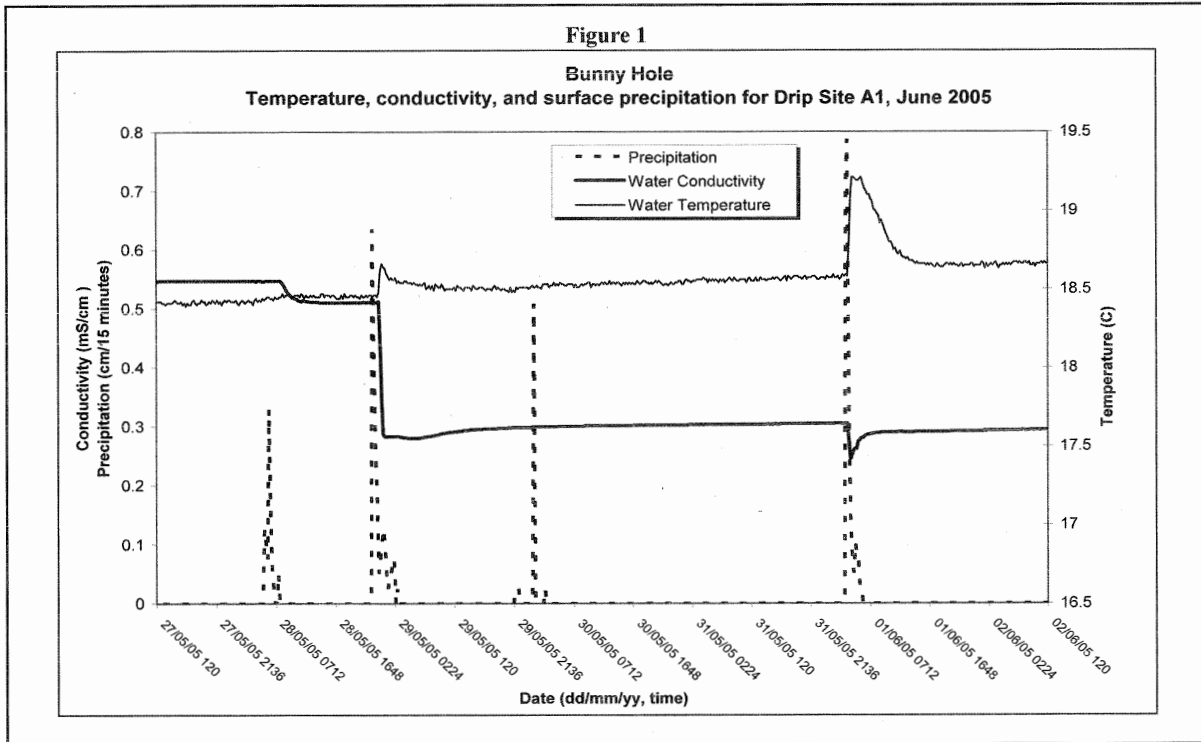
Headquarters Cave was tested for sensitivity to recharge in a simulated irrigation event using perforated garden hoses. On 3 March 2004, approximately 20,800 L of water were applied over the southern two-thirds of the cave's footprint, covering a surface area of 303 m². This irrigation event lasted 109 minutes and maintained an average application rate of 3.91 cm/hour. Personnel inside the cave observed recharge within ninety minutes of initiating irrigation.

Natural rainfall events have been monitored at the cave from November 2004 through June 2005. The cave's response to rain events in November 2004 clearly demonstrates its sensitivity to recharge with 62,480 L of recharge recorded from 32.3 cm of rain, equivalent to approximately 97,869 L of rain falling on the cave's footprint. The measured drip response accounts for at least 63.8% of the rainfall. This is a minimum value, because only one of three tipping buckets was functional. Comparing later responses to rain events, the bucket that was working accounts for 86.9% of the

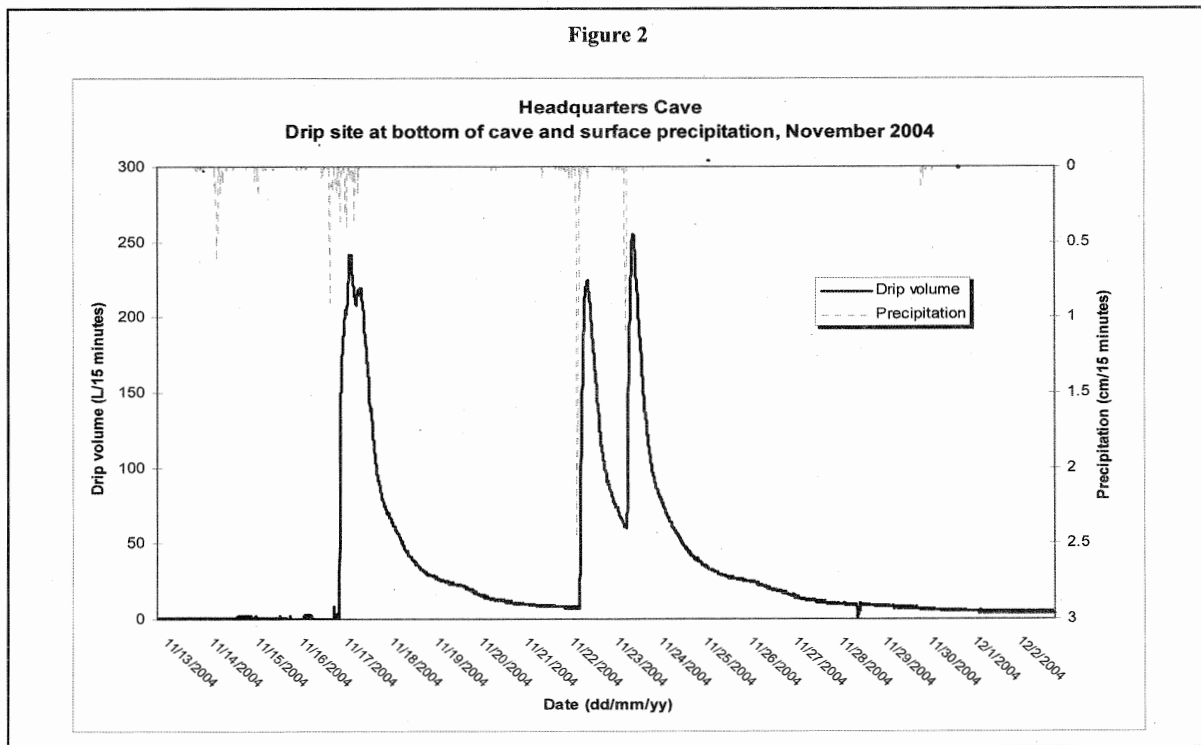
recharge monitored in the cave, so the estimated total volume for the cave's monitoring stations was probably on the order of 73% of the rainfall. This value is still conservative due to all of the drips that were not measured. Figure 2 shows that during this November 2004 rain event, the drips at the bottom of the cave are very responsive to rainfall, even being about 13 m below the ground surface. The time lag between peak rainfall and peak drip rates becomes progressively shorter with each event. The lag time for the first rainfall peak was about 8.5 hours, 6 hours for the second, and 4 hours for the third. Precipitation rates for these events are 0.34, 0.57, and 0.54 cm/hr, respectively.

The November 2004 rainfall event was one of the major precipitation events of the year. However, the cave was also highly responsive to smaller, more typical rainfall volumes. Between 27 January and 7 March 2005, 16.0 cm of rain fell in several pulses. The first event occurred on 27 January, with 4.1 cm of rain (0.18 cm/hr) following several weeks of dry

weather. The response time for the shallower drip area, which ranges from 5.5 to 6.5 m below the surface, was about 15 hours. Soon after, a rain event of 2.4 cm (0.32 cm/hr) on 7 February 2005 had a response time of about 3 hours. A small rain event of 1.6 cm (0.11 cm/hr) on 26 February 2005 had a response time of 10 hours, while one of 3.0 cm (0.7 cm/hr) starting



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on 5 March 2005 had a response time of 12 hours. While the 7 February rain was not the largest in this group, it had the fastest response time by far, but as with Bunny Hole, the relative effects of antecedent precipitation and precipitation rate on recharge volume require additional analysis and data. During the period from 27 January until 7 March, the 48,480 L of rain over the cave's footprint yielded a measured drip response of 7,052 L, or 14.5% of the rainfall.

The fastest response at the shallow drip site in Headquarters Cave was during the initial water application test on 3 March 2004. While the cave was not yet instrumented, human observation in the cave showed that the shallow drip area responded in about 1.5 hours. This response is much quicker than for the natural rainfall events, but water was also applied at a much higher rate: 3.91 cm/hour. By comparison, this rate is about seven times higher than the average rate of the 22 November 2004 rainfall. The difference is almost certainly the result of applying water directly to the ground in March 2004, whereas the natural events allow for interception by vegetation.

Headquarters Cave responded faster to the high rates of the water application test, but the water was only applied over its footprint. During a natural rain event, water falls over a much larger area. While the contributing area is not well known, it is certainly larger than the footprint. Deeper drips should have a larger contributing area than shallow drips. This is evident by comparing the long-term records between the deeper monitoring site and the shallower ones. During the two weeks preceding the rainfall of 27 January 2005, no rainfall was recorded. The shallower drip waters had a constant rate of 0.05 L/hour (18 L total) while the deeper drips had a constant rate of 1.6 L/hour (578 L total). This is not a function of the size of drip area, as the collector for the deeper drips is smaller than any of the collectors in the shallower area. Instead, this difference in volume represents the larger catchment area of the deeper drips.

Drip study conclusions

The drip records from Bunny Hole and Headquarters Cave illustrate their rapid recharge in response to rainfall. Both caves are capable of rapidly transmitting significant amounts of recharge. The rate and volume of recharge into Bunny Hole indicate that water travels primarily along solutionally enlarged fractures and bedding planes. The shallower drips in Headquarters Cave are also probably from such solutionally enlarged features, but the slower response for the deeper drips may indicate less solutional development or simply slower response due to greater depth. Additionally, differences between and within caves may also point to differences in storage capacities in the different lithologies surrounding each cave. Although flow along solutionally enlarged fractures and bedding planes has proven a significant source of recharge into both caves, the contributions of diffuse, fracture, and conduit flow are complex and warrant continued data collection and analysis. Fracture flow and its dynamic nature are easily seen in the quick response of the caves to significant rainfall events. While solutional enlargement of the fractures seems minor, based on visual inspection, their rapid hydrologic response suggests some have enlarged enough to function as conduits.

Some of the potential hydrogeological differences between the caves are illustrated by comparing Figure 1 and Figure 3. Bunny Hole does not have any significant baseflow. The cave responds quickly to rain events, and as shown by Figure 1, at least at drip site A1. When it rains, water flows into the limestone so quickly that it doesn't even have time to change temperature or go through chemical reactions to alter its conductivity. Headquarters Cave has baseflow. The shallower drips may effectively stop during the hottest and driest months, but the lower drips have been continuous for almost a year of monitoring. In Figure 3, instead of decreasing conductivity following precipitation, as at Bunny Hole, the conductivity spikes and then declines, demonstrating the presence of

groundwater with high conductivity, due to limestone dissolution during vadose storage pushed out of storage ahead of the recent recharge.

During natural rain events, both caves recharge a significantly higher proportion of the rain calculated to fall over their footprints than during simulated events limited to their footprints. In both caves, some drips respond to natural recharge events that do not respond to the rainfall simulations. Observations such as these strongly argue even caves as shallow as Bunny Hole can have catchment areas significantly larger than their footprints and indicate the need for tracer studies to delineate those areas.

Tracer studies

On 21 October 2004, a tracer study was initiated at Bunny Hole to begin delineating the cave's catchment area and to better understand flow through the vadose zone. The goal of the first set of tracer tests was to define flow paths close to the part of the cave that has been instrumented for the recharge analysis. Four fluorescent dyes common in groundwater tracer studies were used: uranine, eosin, phloxine B, and rhodamine WT.

Each dye was injected into a separate location in or around the cave footprint: 0.5 g of uranine was injected in a 10-cm long by 3-cm-wide by 2-cm-deep depression at the base of an oak tree just outside and north of the cave footprint, 0.17 g of phloxine B was injected into an open bedrock fracture over the cave's main room, 0.35 g of eosin was injected into a 30-cm-diameter by 40-cm-deep soil-collapse sinkhole just outside of the cave footprint's northeast corner, and 0.14 g of rhodamine WT was injected into a small surface depression south of the cave's main room, within the cave footprint. Since these dyes adsorb strongly to organic material, particularly dry organic material, each injection site was pre-wetted with as much water as possible in three hours. After dye injection, each injection site was flushed with water over the course of the next two and a half days. On the morning of the final flushing, a small storm provided additional flush water.

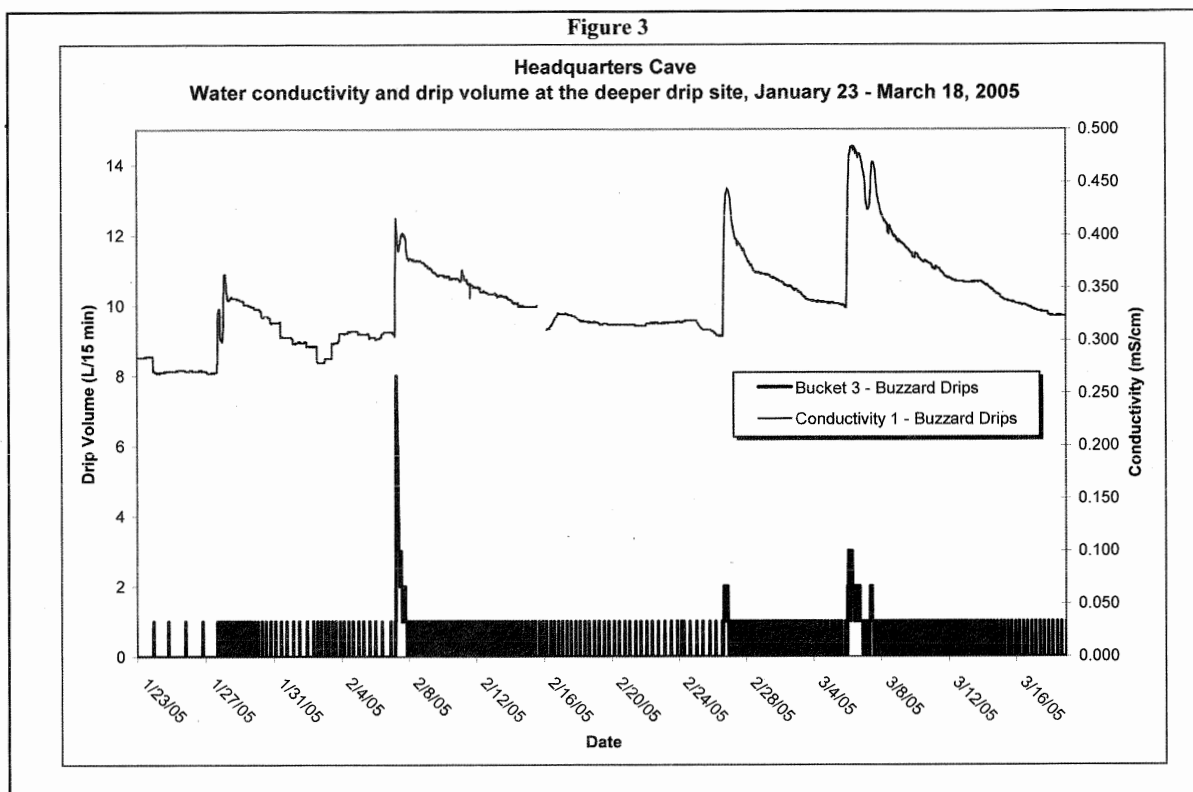
Direct water samples were collected from two drip sites for two and a half weeks, from 21 October through 16 November 2004. Samples began with 15-minute intervals to resolve detail on the leading edge of fast-moving breakthrough curves, then gradually increased to 12 hour intervals by the end of the sampling period. These and nine other drip sites were passively monitored with packets of activated charcoal. Between 21 October 2004 and 25 March 2005, 78 charcoal samples were collected at eleven drip sites, including the sites monitored for direct water samples.

Tracer results and conclusions

The results of this tracer test demonstrate that flow in the vadose zone in karst areas occurs at a variety of velocities that reflect the nature of karst systems. Some components of the epikarst and vadose karst system are very effective at recharge, such as solutionally enlarged conduits and fractures. But in other parts of the system flow velocities can be very low, and all flow paths are hard to predict.

Only one site yielded positive dye results for direct water samples but illustrates how fast groundwater velocities can be in karst, even in the vadose zone. Phloxine B arrived at drips directly under its injection point within 15 minutes of the onset of flushing. This drip site (A1) is located below a prominent enlarged fracture in the ceiling in the middle of the cave's main room; the dye was poured into the same fracture during injection. During the two and a half weeks of direct water sampling, total recovery of phloxine B at that site was calculated at approximately 0.096 grams of dye, or 57% of the total phloxine B injected.

Drip site A1 also illustrates the unpredictability of flow paths in karst. Phloxine B was also detected in charcoal from approximately 1.5 m to the south, from a small set of drips that run down the passage wall onto a flowstone mound (A2). The dye peaks at site A2 were much smaller, prob-



ably indicating these drips are less hydrologically active. Due to

the response from previously observed events, both natural and artificial, phloxine B was expected at drip sites A1 and A3, another focus of drip water issuing from the same solutionally enlarged fracture as A1. Together, A3 and A1 form a large flowstone mound that dominates the main room of the cave; the closest reaches of the two collectors are only centimeters apart. Phloxine B also appeared at A2, but it is not the site that shared hydrologic patterns with A1. Instead, the dye illustrated that the much less prolific drip site A2 must sometimes function as an overflow route for the water that recharges through A1, a relationship supported both by the charcoal packet data and direct observation during water applications.

The only other dye detected in the cave was eosin. During flushing, the in-cave observer noticed sheetflow along the passage floor that trends toward the eosin injection site. A charcoal detector was placed in the passage floor in front of the advancing flow. This site had clear eosin peaks for two months. The relationship of the injection point to the cave is not clear. It may be related to a known sinkhole just outside the cave footprint or be an unrelated soil collapse over a solutionally enlarged fracture like the phloxine B injection site. Additionally, most of the water injected with eosin was not seen in the cave, and it is not known if it was absorbed into the sediment or flowed into a continuation of passages eastward beyond the known sinkhole.

The solutionally enlarged fracture that feeds to A1, where phloxine B was injected, is a relatively young feature vadosely formed to recharge the Edwards Aquifer. Tracer tests demonstrate its very effective conduit recharge. The sinkhole where eosin was injected is also a vadosely-formed recharge feature, and the tracer tests demonstrate it is effective at delivering at least a portion of its recharge to the cave. The other two injection sites, both within or very close to the footprint of the cave, were not karst features. Over a period of five months, they did not deliver dye in detectable quantities to the most significant recharge sites in the accessible

portion of the cave underlying them. Considering the location of these injection sites relative to the footprint of the cave and proximity to the drip sites, it would have been reasonable to detect all of the dyes in the monitored area, albeit at different times due to the differences in mode of travel. There are a variety of reasons that uranine and rhodamine WT were not detected. First, the injected dye volumes were very small, and too much of the dye may have adsorbed to organic material to be detected when the water reached monitored drip sites. Second, the flow velocities may be so low that the dye had not traveled the several meters to the cave in five months. Finally, the dye-laden flush water may have bypassed the accessible portion of the cave and moved downward to recharge the Edwards Aquifer. The multi-stage development history of the cave adds to the possible complexity of recharge paths. At this point, we don't know which reason is most likely, but continued work at the cave may provide answers.

These tracer tests also illustrate the complexity of storage in the vadose zone. While almost 60% of the phloxine B was recovered in two and a half weeks, phloxine was still present above the detection limit in the charcoal sample after five months (25 March 2005). Between the end of direct water sampling and 25 March 2005, at least 5,977 additional liters of flow passed through A1 (the bucket was out of the cave for repairs from 29 November through 16 December 2004, during which time there was 0.97 cm of precipitation), yet some of the unaccounted-for 0.073 g of Phloxine was still passing through the drip site, probably slowly released from epikarstic storage.

Future work

Research at these sites will continue for several years. In the summer of 2005, rainfall simulations will be performed at Bunny Hole and Headquarters Cave. After approximately two years of data collection have been completed, woody vegetation will be removed from the caves' footprints. Natural rainfall collection and simulations will continue for approximately two more years, and those data will be evaluated and compared with

previous data to determine the effects of its removal on the water budget and recharge.

Tracer tests will continue at Bunny Hole and will also be conducted at Headquarters Cave. Tests will focus on different areas to determine what portion of the landscape contributes recharge to the caves. These data will help quantify the results of monitored natural and simulated recharge, as well as improve our understanding of the nature of karst flow through the vadose zone, especially in the Edwards Aquifer recharge zone.

Acknowledgements

We thank Camp Bullis for providing us with access to the caves and the bulk funding for this project, and especially Lucas Cooksey, Jackie Schlatter, and Jerry Thompson for permitting and scheduling support.

We also thank the Edwards Aquifer Authority for providing additional project funding, some instrumentation, and access to their luminescence spectrometer, notably Jon Cradit, Jesse Mireles, and Geary Schindel for their varied assistance. We greatly appreciate their support of the Bexar Metropolitan Water District which supplied us with water for some simulations. Dr. Keith Owens of Texas A&M University has been invaluable with instrumentation. Finally, we thank Bobby Bazan, Lucas Gregory, Dr. Clyde Munster, Gary Nolan, Philip Taucer, Andrew Weichert, and Dr. Bradford Wilcox from Texas A&M University, contractors Jerry Fant, Bruce Johnson, Chris Murray, and Chris Thibodaux from George Veni and Associates and Andy Gluesenkamp, Jean Krejca, and Peter Sprouse from Zara Environmental for their continuing work on this project, and Karen Veni for proofreading this report.

O-185

Groundwater Sensitivity Mapping of the Beaver Dam and Campbellsville 30' x 60' Quadrangles

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Abstract

Groundwater sensitivity is the susceptibility of groundwater resources to contamination as a result of the inherent characteristics of the aquifer and overlying media. In the fall of 2004, groundwater sensitivity mapping for the digital, 30' x 60' quadrangles of Beaver Dam and Campbellsville, Kentucky was completed. Many methods were looked at to produce these maps. In 1985 DRASTIC was created by Aller et al. to make available an objective format to evaluate groundwater sensitivity and provide an index so areas could be contrasted. Due to the inability of DRASTIC to adequately rank some regions in Kentucky, primarily regions with karst geomorphology, Ray and O'dell applied a new technique entitled DIVERSITY in 1993. They created a 1:500,000 scale groundwater sensitivity map that divided the Commonwealth of Kentucky into five hydrogeologic

sensitivity regions. Though DIVERSITY gave a more appropriate ranking for karst regions, the map was at too small a scale to assist in land-use planning. Thus, a rubric focused on lithology and topography was used to create maps at a scale of 1:100,000. The process was done digitally using GIS used the Digitally Vectorized Geologic Quadrangles (DVGQ's) put out by the Kentucky Geological Survey (KGS). We also wanted to consider overland flow of contaminants off low permeability caprock onto high sensitivity areas, a phenomenon that could occur around the Pennyroyal Sinkhole Plain and seems to be unaccounted for using methods such as DRASTIC and DIVERSITY. In the end, we hope to reach the long term goal of developing 1:24,000 scale maps for all of Kentucky that would appropriately articulate the groundwater sensitivity for use in land-use planning.

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A Tale of Looting of Paleontological Cave Resources or International Commerce

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Abstract

The looting of archaeological and paleontological resources has long been a problem in caves. An informal surveillance of Internet sales of archaeological and paleontological items from caves in USA evolved into an eleven-month international survey over the year 2002. This paper summarizes a survey of 430 Internet auctions of 356 paleontological items from the caves of Austria, Canada, "Europe", "Eastern Europe", France, Germany, Italy, Netherlands, Poland, Romania, Russia, and USA. The majority of the fossils were from Romanian (42%) and Russian (31%) caves and overwhelmingly were of *Ursus spelaeus* (98.6 %). The other items were a *Crocota crocuta spelaea* (hyena) jaw, *Crocota crocuta spelaea* (hyena) skull, *Panthera leo spelaea* (lion) sacrum, *Mammuth americanum* (mastodon) patella, and a *Procyon lotor* (raccoon) skull. *Ursus spelaeus* elements included teeth, jaws, articulated paws, skulls, vertebrae, phalanges, claws, articulated skeletons, humeri, ulnae, bacula, a tibia, an ankle element, and

a pelvis fragment. Cave bear remains are common mega-fauna fossils in the caves of Europe. Certainly, some of these items were legally obtained. Contrary to one dealer's claim that "fossil cave bear material is ALWAYS LEGAL!!!" undoubtedly, many of these specimens were taken illegally. The concern is that commercial harvesting of mega-faunal remains probably occurs without the study or documentation of context and associations and archaeological, paleontological, and sedimentological resources are destroyed.

Introduction

Humans have exploited caves throughout history. Significant records of extinct paleo-fauna, paleo- and prehistoric human, and historic human are known from cave sites. Such sites document presence, but more importantly, forensic elements convey information about the nature of an

occurrence and cultural as well as individual patterns of human cave use. Many initial discoveries of spelean faunal records are made by curious and observant cave visitors not formally trained in the disciplines of physical anthropology or paleontology. Private collectors long have competed for a share of the known specimens. The looting of Native American (American Indian) sites in U.S.A. caves historically has eclipsed those examined by scientific methods, but paleontological sites in U.S.A. caves have been more closely balanced between advocational and scientific exploitation. Perhaps the most significant period of commercial exploitation of vertebrate cave fossils worldwide followed the publication of Jean Auel's book *The Clan of the Cave Bear* in 1980. Auel's Cave Bear Clan novel series has spurred an unprecedented interest in the cave bear and an extensive market has developed for cave bear remains. Although cave bear remains are relative common in many eastern- and western European caves, their wholesale acquisition has imperiled fossil cave deposits as well as associated archaeological deposits and the stratigraphic integrity of sediments in which they occur. International markets can be difficult to appraise, but it was thought that Internet sales are one source of information by which the degree of exploitation might be scaled.

This study was initiated after a purported Pleistocene-age raccoon skull, from a Missouri cave, was offered on an Internet auction. It is probable that the taking of this skull was in violation of the Missouri Cave Resources Act.

Methods and Results

Vertebrate remains from cave sites offered on an Internet auction site were recorded for an eleven-month period over 2002. A total of 430 auctions of 356 cave vertebrate items were reported as from Austria, Canada, "Europe," "Eastern Europe," France, Germany, Italy, Netherlands, Poland, Romania, Russia, and U.S.A. (Missouri and Florida). The majority of the fossils were from Romanian (42%) and Russian (31%) caves and overwhelmingly were of *Ursus spelaeus* (98.6%). The other remains were a *Crocota crocuta spelaea* (hyena) jaw, *Crocota crocuta spelaea* (hyena) skull, *Panthera leo spelaea* (lion) sacrum, *Mammut americanum* (mastodon) patella, and a *Procyon lotor* (raccoon) skull. *Ursus spelaeus* elements included teeth (130 lots: 37% of items), jaws (91: 26%), articulated paws (42: 12%), skulls (22: 6%), vertebrae (20: 5%), phalanges (15: 4%), claws (15: 4%), articulated skeletons (6), humeri (3), ulnae (2), bacula (2), tibia, ankle element, and a pelvis fragment. Items sold included a skull for \$3500, paw for \$270, jaw for \$135, canine for \$134, and the only skeleton that sold - for \$2900 in U.S. currency. Of the 356 lots, 274 were successfully sold for a total of \$28,415.70 in U.S. dollars.

Legal and Ethical Issues

Long, long, long ago, humankind as did other animals, utilized many cave sites and took what they could use from caves as well as most other places they visited. Evidence of a prehistoric collection from a cave is preserved in the Grotte de Foissac in France. Off from the commercial trail, in a dry rimstone pool is a site where a prehistoric human shattered the skull of a cave lion to extract the canine teeth. We still are using caves and worldwide have seen to it that our caves and their resources are protected for enjoyment and study.

The legality of removing fossil non-human remains from cave sites is relatively simple and based on the laws in place in the jurisdiction where the cave is located and if the cave owner permission was granted. The caves of Romania and Russia are owned by their governments. Seventy-three percent of the parcels reported in this study were identified as from Romanian and Russian caves. Legislation in Romania, since 2001, specifically protects cave resources and prohibits their removal. The claim of one of the internet cave bear fossil merchant that "fossil cave bear material

is ALWAYS LEGAL!!!" is untrue.

In 2001, American cave historian Dean Snider (personal communication, May 2005) visited some Romanian caves in the Bihor Mountains. In one of the caves he visited, he observed the disturbed remains of *Ursus spelaeus*, which had been excavated (Figure). Examination of this photograph reveals that Dean posed in an excavation, the disturbed fossil bear bones were discarded on the spoil pile adjacent to the excavation. This is not a scientifically excavated site, but evidence of looting, probably for skulls and jaws. Nor are carpals, metacarpals, or phalanges visible, but these small bones - that comprise the paws, could easily be overlooked.

Discussion and Conclusions

It is doubtful that the efforts of the individuals commercially excavating *Ursus spelaeus* remains are using scientific methods and documenting the context and associations of the deposits they are exploiting. One must assume that this glimpse of the international market for non-human vertebrate remains from caves is but a small fraction of the actual market. The enforcement of cave protection acts, where they occur, is difficult and where successful it is usually through the aid of local cavers, who may observe the activities or evidence of looters. The commercial exploitation of spelean fossil deposits is likely to continue. The major concern of this paper is not that there appears to be a large market demand for the relatively abundant remains of the *Ursus spelaeus*, but that the fulfillment of that demand has imperiled fossil cave deposits as well as associated archaeological resources and the stratigraphic integrity of the sedimentary deposits in which they occur.

Acknowledgements

Special thanks to Dean Snider, for his information and permission to use his image of a cave in the Bihor Mountains of Romania. Thanks to Dr. Oana Moldovan, of the Institute of Speleology in Cluj, Romania for information about the caves and cave protection in Romania. Thanks to Fred Grady of the Smithsonian Institution in Washington, D.C., for his suggestions and comments.



Figure. Dean Snider posing in a looters excavation adjacent to the jumble of disturbed cave bear remains in a cave in the Bihor Mountains of Romania.

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Beneficial model development of the Petralona Cave

By the Anthropological Association OF Greece (AAG)

Abstract

The scientific foundation Anthropological Association of Greece for more than 30 years has been conducting the development of the Petralona Cave, in a way to protect both the cave itself as well as the excavating data. There, the life of the humans for hundreds of thousands of years during the Ice ages, made them promote even more the cooperation, which inspires all peaceable people today!

Full Text

Dr Aris Poulianos' (Photo 5: DR ARIS POULIANOS) and AAG's excavations during the last four decades proved that Petralona cave in Chalkidiki (Ellas / Greece) (Photo 6: HALKIDIKI PETRALONA), is a most important prehistoric cave in Europe (Photo 7: PETRALONA CAVE b), since the 0,7 m.y.a skull of Archanthropus was found there in 1960. In its Petralona culture, human cooperation, at least in cave life, and the respect of the wiser elders were of primary importance. The same principles always characterise AAG and its work.

Excavations and studies of palaeoanthropological material proceed in collaboration with an international team of experienced specialists, such as Budil I., Horacek I., Ikeya M., Kretzoi M., Kurten B., Liritzis Y., Murrill R.I. The same Association conducted also the development of the cave, in a way to protect both the cave itself as well as the excavating data. This offered dozens of jobs, while the members of AAG are still working voluntarily, having much contributed economically too, especially Dr Poulianos.

A certain number of measures were taken and are still supported:

1. The tourist corridors were constructed piece by piece with an anti-slip surface cover, and afterwards were put on their bases along the visitors' path inside, in order to permit any displacement needed. The corridors were adapted to the cave path and not the opposite.
2. The tunnel opened in the rock was not covered with cement, so the cost was lower as was the pollution of the environment.
3. Every winter stalactites and stalagmites are cleaned safely from parasitic micro-organisms.
4. Over and around the cave 3.000 pines were planted. Their roots expand horizontally, and prevent the vertical expansion of evergreen oak's roots, thus protecting the cave.

5. Because of the lack of sufficient rain during the last three decades in Chalkidiki, a system of artificial raining has been put externally, over the roof of the cave. Its humidity, which is provided in the cave, revives it and protects the stalagmite decoration.
6. A safety and a fire alarm system are covering the whole area.
7. AAG offered the most in expenses and work for the unique daily open Anthropological Museum in Greece to be built outside the cave from 1977 to 1982.
8. 400 show-cases exhibit more than 2000 findings.
9. A 24 hours guard service with personnel and cameras is provided.

AAG also:

1. Has constructed an open air theatre, where each summer a festival is held.
2. Organized successfully in Petralona an International and a National Congresses of Anthropology, in 1982.
3. Constructed a bilingual website (<http://www.aee.gr>), serving the information of any researcher worldwide.
4. Edited the book "The Cave of the Petralonian Archanthropinae", by Dr Aris Poulianos, in four languages, Greek, English, German and Russian (Photo 8: THE PETRALONA CAVE BOOK).
5. Promotes the scientific development and training on the palaeolithic era in Greece.
6. Is currently erecting three buildings that will shelter labs and research center.

Finally we have to mention that among the numerous eager to learn visitors of the cave from all over the world, who admire it and write about every day, were the presidents of Greece, the late K. Karamanlis, of France, Mr. V. G. d'Estaing, and of Russia, Mr. V. Poutine.

We will be glad to guide you in the famous Petralona Cave, where the life of the humans for hundreds of thousands of years during the Ice ages, made them develop even more the cooperation, which inspires all peaceable people today!

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Photo 1. Dr Aris Poulianos



Photo 2. Halkidiki Petralona



Photo 3. Petralona cave

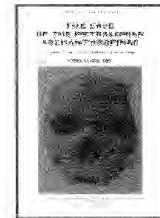


Photo 4. The Petralona cave book

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Protection and utilisation of caves in Slovakia

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Natural values and utilisation of caves, specific features and stability of cave geosystems, negative anthropogenic interferences and state protection of caves in Slovakia are characterized in this paper. Scientific research, environmental monitoring and documentation of caves with practical applications for nature protection (planning and elaboration of cave management programs and cave protection zones), also other practical protection activities (cave guard service, cleaning and dating of caves, expertise inspections and evaluation of human impacts, environmental education, etc.) are realized by the Slovak Caves Administration as a qualified institution of nature protection.

Key words: cave geosystems, anthropogenic impacts, nature protection, Slovakia

Introduction

More than 5,200 caves are known in Slovakia at present. They are formed mostly in carbonate rocks (limestones, dolomitic limestones, dolomites and travertines). Karst areas cover more than 2,700 square km and represent significant landscape units of the Western Carpathians. The most of the caves is located in the Slovak Karst, Low Tatras, Spis-Gemer Karst (Slovak Paradise, Muranska Plateau), Great Fatra, Strazovske Hills, Western, High and Belianske Tatras. Only 179 caves of the whole number are formed in non-carbonate rocks (andesite, basalt and its volcano-clastic rocks, sandstone, granite, quartzite and others), occurring mostly in the Cerova Highland, Kremnické and Stiavnické Hills, Ostrozky, Tatras and Levocské Hills. Every year, new cave spaces are discovered mostly thanks to the volunteer cavers assembled in the Slovak Speleological Society.

Natural values of caves

Several genetic types of syngenetic and epigenetic caves in carbonate and non-carbonate rocks (corrosion, fluviokarst, crevice, crevice-corrosion, crevice-breakdown, crevice-talus and talus caves, caves formed by mechanical weathering, travertine crater caves, caves of constructive travertine waterfalls, volcanic-exhalation caves, fossil abrasion caves and others) are the manifestation of extensive geodiversity of natural values in the territory of Slovakia. The system of the Demanovské Caves (33.8 km long), Stratenská Cave - Psie diery Cave (21.7 km long), Dead Bats Cave (19.2 km long, 320 m deep), as well as some smaller caves are remarkable examples of underground karst phenomena development (some also from the international point of view). Underground exposures, underground river canyons and other rock formations as well as hydrological phenomena that can be observed in caves are illustrations of geological and geomorphic development of the Slovak territory.

Natural values of caves are given by the character of their fills, mainly exceptional calcite and aragonite sinter forms. From the scientific point of view important are also profiles of clastic or chemogenous sediments, which are representative from the viewpoint of cave genesis reconstruction. There are 40 permanently glaciated caves in Slovakia (Dobsinská Ice Cave, Demanovská Ice Cave, Big Ice Abyss in Ohniste and others). They mostly occur in the regions with mountain cool, cold and very cold climate (almost 85%). A remarkable phenomenon, from the viewpoint of conditions for permanent preservation of ice, is the Silická ladnica Ice Cave situated at only 503 m's elevation (probably the lowest elevation for permanently glaciated cave in the northern temperate climatic zone). Cave

climate (speleo-aerosol) has curative effects on human organism. Several endemites and protected animal species are the part of cave fauna (water and terrestrial invertebrates, bats). Some caves are rich in osteological findings, mainly of cave bear bones (Bear Cave and Dogs Holes Cave in the Slovak Paradise and others).

The caves of the Slovak and Aggtelek Karst (including Ochtinská Aragonite Cave in the Revúcka Highland) are inscribed on the World Heritage List since December 1995 on the basis of bilateral Slovak-Hungarian project. The extension of this project in 2000 appended the Dobsinská Ice Cave (including Stratenská Cave) to the existing world heritage site. As invaluable and irreplaceable values of universal importance they require special protection, care and presentation. The Domica Cave has been included among the internationally important wetlands according to the Ramsar Convention since 2001.

The use of caves

Caves have been drawing attention of man by their mysteriousness since the ancient times. Some of them were settled or used as sacrificial places, shelters and refuges. Several caves are significant archaeological finding places (Domica Cave, Ardovska Cave, Silická ladnica Ice Cave, Kostrova Cave, Prepostska Cave, Derava skala Cave and others). Historical inscriptions on the walls were preserved in some caves (Jasovská Cave, Demanovská Ice Cave and others). Many caves served as refuges during the World War II.

At present, the caves are mostly used as educational localities within the framework of tourism. The twelve show caves (Belianska Cave, Bystrianska Cave, Demanovská Cave of Liberty, Demanovská Ice Cave, Dobsinská Ice Cave, Domica Cave, Driny Cave, Gombasecká Cave, Harmanecká Cave, Jasovská Cave, Ochtinská Aragonite Cave, Vazecká Cave) are attended by 650 to 720 thousands of visitors a year. The Bojnice Castle Cave is visited as a part of the castle tour. The Dead Bats Cave, Krasnohorská Cave and Zla diera Cave are opened for visitors in a half natural way, however with higher demands on visitors' movement and safety underground (overall, boots, helmet, individual light). Influence of visitors on natural environment is studied and regulation is aimed at adequate and optimal use.

Speleotherapy is provided in selected caves (Bystrianska Cave), healing speleoclimatic stays (Jasovská Cave, Belianska Cave) and spa treatment (Parenica Cave in Skleň Teplice) in some others. Several karst water springs as well as water flows in caves are used as resources of drinking water (Vyvieranie Cave in the Demanovská Valley, Bobacka in the Muranska Plateau, Riečna Cave in the Borinský Karst in Little Carpathians). Benedikt's Cave and Svorad's Cave serve for religious purposes. Some caves were used for storage of food and especially dairy products (Vyvieranie Cave).

Caves as specific natural geosystems

Cave geosystems present underground spaces, entirely or mostly bordered by rock environment or cave georelief. They are characterized by specific physiognomic features of geographical sphere components, spatial organization and natural processes. Pedogenetic processes and photosynthesis are absent in caves. Specific features of biocomponent, speleoclimate and water as a part of hydrosphere and lithosphere with cave georelief in the zone of hypergenesis are characteristic. Under-

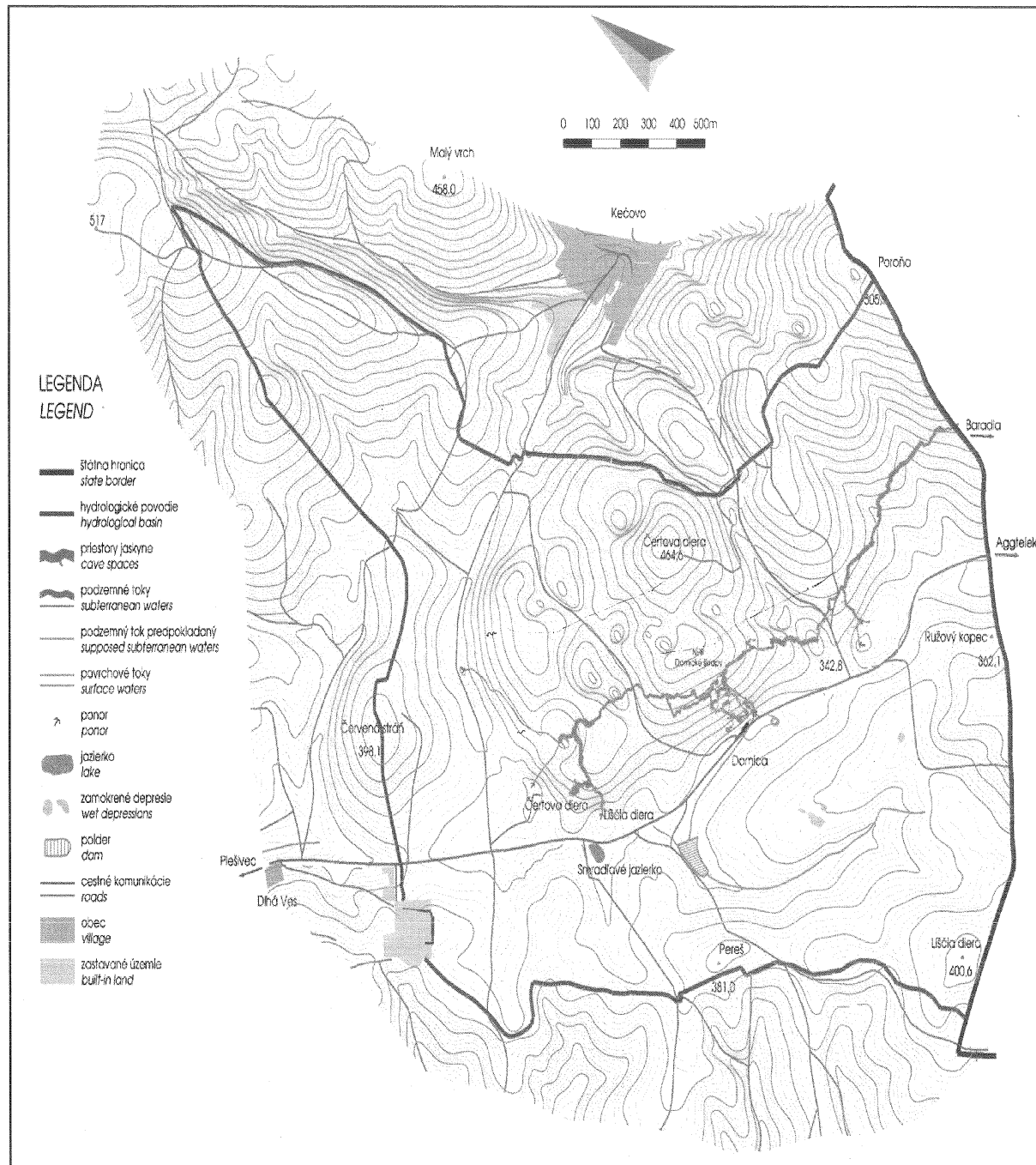


Fig. 1. The protection zone and Ramsar boundary of Domicia Cave. Compiled by P. Gazik

ground water flows, seepage of atmospheric waters as well as lakes occur in caves. Steady annual course of climatic parameters is typical for the caves. Genuine cave animals (troglobites) are adapted to conditions in underground cavities (darkness, constant lower temperature, high air humidity) by reduction up to ceasing of sight organs, depigmentation, by body size and shape, as well as by life functions.

The cave geosystems are characteristic by spatial (vertical and horizontal) structure (speleotopes, speleochores, set of speleochores) and time-spatial changes (seasonal regime, dynamics conditioned by the

change of geoeological invariant, evolution development in geological periods). The knowledge on spatial structure and time-spatial changes of cave geosystems are important in dealing with various analytical and synthetic tasks, including environmental problems in karst landscape (Bella 2002).

Cave geosystems in karst territories have stronger connections with surface landscape systems than it is in non-karst territories. From the vertical point of view it is mainly seepage of atmospheric waters, from the horizontal one it is ponor autochthonous or allochthonous water flows.

Cave geosystems are influenced by adjacent non-karst territories, which drain into karst by ponor allochthonous water flows.

Negative anthropogenic interventions and stability of cave geosystems

Many anthropogenic activities influence the natural processes (accelerated seepage and drainage of waters, accelerated corrosion, changes in air movements, washing off soil sediments, etc.) by which the stability of cave geosystems structure is disturbed. The most frequent negative anthropogenic interventions caused by improper human activity is pollution of underground waters with damages and destroying of water fauna by sinking allochthonous water polluted from manure dump and agricultural chemicals or industrial fertilizers, deterioration of hydrological regime of seepage atmospheric waters into cave spaces due to removal of vegetation cover, washing off soil sediments into cave spaces after deforestation or improper tillage above the cave and in its basin, chemical destruction of sinter fill by aggressive waters due to anthropogenic influences, breaking of sinter fill, rubbish disposal and throwing of dead animals into abysses, illegal collection of cave fauna, osteological and archaeological findings (Jakal 1979, Bella 1992, Gaal 1997 and others). Cases are known of destroying caves by excavation in quarries or during construction of communications. Regeneration capability of karst landscape including cave geosystems is low, and in some cases impossible (Jakal 2002). Non-karst cave geosystems are substantially more resistant to anthropogenic interventions.

Self-regulation of cave geosystems and threshold values of their resistance is important from the viewpoint of cave protection. An example of self-regulation of cave geosystems is balancing of speleoclimatic changes (increase of temperature and decrease of relative air humidity) due to visitors' movement in show caves. On the basis of monitoring these changes the number of visitors is regulated and limited in show caves. On the contrary, the self-regulating linkages are absent when the static speleoclimatic conditions in glaciated cave spaces are disturbed due to tunneling to the surface or through siphons filled with sediments to passages without ice (improper way of speleological research or development of caves for tourists). Regulative anthropogenic interventions are necessary for prevention of ice fill decrease (filling up or walling up the openings, etc.). Since the karst permeability in soluble rocks is connected with low filtration capability, the self-cleaning capability of polluted underground waters in karst is low and in advanced stage of karstification almost none.

On the basis of character of hydrological processes, degree of karst permeability and character of further components of cave environment we can distinguish very instable speleotopes with fractional value of car-

rying capacity, instable speleotopes with low value of carrying capacity, moderately stabile speleotopes with increased value of carrying capacity and relatively stabile speleotopes with high value of carrying capacity (Bella 2002). The character of speleotopes with the rate of their representation can serve for categorization of speleochores stability. In case the cave is composed of the set of speleochores, the stability is considered in combination of stability of individual speleochores. The problems of cave geosystems stability categorization needs to be worked out in more detail, mainly for practical use.

Caves and state nature conservation

All the caves are the ownership of state according to the constitution of the Slovak Republic. They are also protected by law of the National Council of the Slovak Republic no. 543/2002 on Nature and Landscape Protection. The most significant are designated national nature monuments (44 caves and abysses). The stimulus for their protection are geomorphic values, occurrence of unique sinter or ice fills, palaeontological and archaeological findings as well as historical monuments. The most of caves is situated in protected areas (national parks, protected landscape areas, natural reserves).

Protection and practical care for caves in Slovakia, operation of 12 show caves, as well as administration of caves as the ownership of the state is secured by the Slovak Caves Administration seated in Liptovský Mikuláš - the qualified organization of nature protection under the Ministry of Environment of the Slovak Republic. Since a complex approach to cave protection deserves scientific information and vocational foundation, the Administration conducts and coordinates research, monitoring and documentation of caves. The Administration also cooperates in work on national cave database, which is operated by the Slovak Museum of Nature Protection and Caving in Liptovský Mikuláš.

Research, monitoring and documentation of caves

Geological, geomorphic, hydrological, hydrochemical, speleoclimatic and biospeleological research of caves is, according to the capacity, primarily aimed at caves designated national nature monuments. The newly discovered caves and caves with no previous detailed research undergo a preliminary research to find out basic natural values of caves and determine main tasks of the cave protection. In case the preliminary study brings important data on cave values, a detailed inventory research is necessary. Hydrological monitoring is conducted mainly in caves threatened and polluted with ponor allochthonous waters due to agricultural activities (Domica Cave, Gombasecka Cave, Ponický Karst, Váževský Karst).

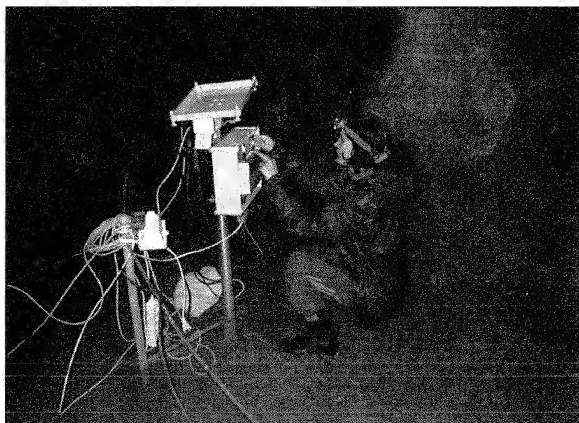


Fig. 2. Hydrological and climatic monitoring, Domica Cave. Photo: P. Bella



Fig. 3. Biospeleological research, Dobsina Ice Cave. Photo: P. Luptacik



Fig. 4. Cleaning the doline from waste, Vazecky Karst. Photo: P. Holubek



Fig. 5. Securing the Veterlin Abyss entrance. Photo: P. Stani



Fig. 6. Gating the upper entrance of Belianska Cave. Photo: L. Plucinsky



Fig. 7. Marking the protection zone of Liskovska Cave. Photo: I. Matocha

Speleoclimatic monitoring in show caves records the influence of visitors on cave environment (Ochtinska Aragonite Cave, Driny Cave, Vazecka Cave, Dobsinska Ice Cave and others).

The results of research and monitoring are used when processing expert opinions in cases of anthropogenic impact assessment on cave geosystems and their surrounding, when working out proposals of protection zones of threatened or potentially threatened caves, when working out cave care programs, visitors' rules for show caves etc. Geographical information system is set up also in connection with the national cave database. GIS applications are used also in dealing with research, documentation and practical protection tasks. The scientific conferences "Research, Utilization and Protection of Caves" are organized biannually.

Practical care for caves

Speleological guard service (cave rangers) and gating of important caves is organized in cooperation with the Slovak Speleological Society. Several caves were cleaned from waste materials, which is important also for protection of underground waters. Legal expertise of aragonite and sinter forms societal value is conducted in cases of damaging the sinter fill in caves. The Slovak Caves Administration issues expert opinions for decision support of state authorities in nature protection, proposes revisions of natural monuments - caves, supervises allowed activities in caves and coordinates speleological surveys conducted by volunteer cavers. Environmental education is aimed at presentation of cave values, necessity of their protection and prevention against negative anthropogenic impacts (expositions and permanent exhibitions in entrance buildings of show

caves, educational paths, information boards, educational printed materials and films, seminars, etc.).

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O-189

Protection of caves and their findings

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Abstract

Protection of caves and their findings is a special duty of peaceable civilised societies, as cultural heritage, especially of our pre-war prehistory, promoting understanding between peoples and the dissemination of culture for the well being of humanity.

Full Text

Caves are monuments of nature. They bear data of Earth's history, including mankind's evolution during prehistory - which was peaceful for its greatest part (Photo 1: THE PEACEABLE PREWAR HUMANS), before dangerous overpopulation occurred 10.000 years ago (Photo 2: WARLESS SOCIETIES) - and modern times. As such, caves deserve to be protected by any spelaeological body, either state or not. The main tools to achieve this purpose are education, through discussion, research (including guided simulation by a beneficent team of experienced inspiring individuals), application of laws and actions.

Although methods concerning exploration and exploitation of caves are widely developed, the same can not be stated as regards their protection. Cultural objects (palaeontological, archaeological, zoological, botanical etc) found inside or outside caves, are frequently irreparably damaged by illicit excavations and export from their country of origin.

Since the beginning of wars until our ages, the hate-addicted manio-attacking groups beyond the "legitimate right to kill", promote the violent "right to plunder and destroy" (Afghanistan and Iraq being the latest known examples).

Greece has also suffered since middle-eastern kings' and Romans' attacks, from such inhuman mentality, untill recent times, when the famous Parthenon Marbles of Athenian Parthenon removed by lord Elgin, English monarchy ambassador to the falling Ottoman empire. Several cases of such practice have followed ever since worldwide.

As Greek caves are concerned, not much has been done for their protection. Clandestine activity has been taking place inside and outside Greek caves. Non tourist caves are often looted and/or prehistoric material is illegally removed (e.g Ayia Triada cave - Boeotia). In tourist caves, all the possible ways to protect stalagmite decoration are not applied. To this purpose a program is applied to the Petralona cave (Photo 3: HALKIDIKI - PETRALONA), where every winter stalagmites are cleaned safely from parasitic micro-organisms (Photo 4: PETRALONA CAVE a).

As for cave findings, there have been several instances of their being stolen and illegally exported abroad. Such an example concerns the thousands of fossils exported in 1968 to Hannover. AAG denounced this action but the Ministry of Culture still has not promoted any investigation on the case. During the violent removal and absence of aag from the place

(1983-97) other fossils were stolen from the museum; an illegal excavation during night took place too...

Our Association asks the help of the present 14th International Congress of Speleology to assist findings' - human remains included - returned to the Petralona museum where they belong.

On our own initiative, the Minoan microcephalic skull from Zakro palace in Crete, was repatriated; it is our expectation that the same thing will happen for every similar cases.

So a record by the Ministry of Culture of all caves' findings in Greece, as well as in every country, will help the efforts for their restitution, preservation and study. UNESCO (United Nations Educational, Scientific and Cultural Organization), is working with its Intergovernmental Committee for Promoting the Return of Cultural Property to its Countries of Origin or its Restitution in Case of Illicit Appropriation. In its Thirteenth Session, 7-10 February 2005, in Paris it announced generic examples of return and restitution of cultural property.

As the protection of cultural heritage promotes the understanding between peoples and the dissemination of culture for the well being of humanity, the objective of improving the protection of cultural and natural heritage is a matter of priority. The practical preservation of caves and monuments in general and the restitution of cultural objects is in the interest of all.

Scientists and governments must further support such actions, proving their interest for common welfare, because the closer to their original place the cultural objects are studied, the better knowledge is served, helping the international efforts for peaceable co-existence and prosperity.

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Photo 1. The peaceable prewar humans' in and around caves



Photo 2. Warless societies



Photo 3. Halkidiki where the famous Petralona cave



Photo 4. From the Petralona cave of the Archanthropinae

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THE CLIMATE OF KARTCHNER CAVERNS (Arizona, USA)

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Abstract

Kartchner Caverns is a recently developed show cave in the southwestern United States. One tour opened to the public in November 1999 and another opened in 2003. These openings followed over 11 years of work carried out by the Arizona State Parks. Monitoring of the cave began prior to development and has extended to the present. In this monitoring, some changes in temperature and humidity have been detected. Comparison of the changes at Kartchner Caverns with some undeveloped caves in the vicinity suggests that much of the change seen at Kartchner can be attributed to regional changes in climate; however, development and tourism is also a factor.

Introduction

The climate of Kartchner Caverns was already the subject of a paper (Cigna, 2001) where the propagation of the seasonal heat wave from outside was evaluated for different sections of the cave. The delay grouped mainly around two-three months and extended in one case to about 8 months. In addition, predevelopment data on the cave microclimate has been reported (Buecher, 1999).

Because development and exhibition of caves may cause significant changes in the microclimate, the cave temperature and humidity has been monitored from before development through the present. The long-term monitoring has occurred at approximately 11 environmental monitoring stations throughout the cave (Figure 1). The series of temperature and relative humidity measurements, which extends for some stations from mid-1988, shows either a positive and negative trend, depending on the station. The most extreme example of the climatic changes at Kartchner was noted in the Lower Throne station (Figure 2). This could suggest an effect due to the development of the show cave in spite of the great care paid to avoid, as much as possible, any disturbance. Therefore more detailed studies were carried on to investigate the cause of such climatic changes (Toomey, 2002; 2003).

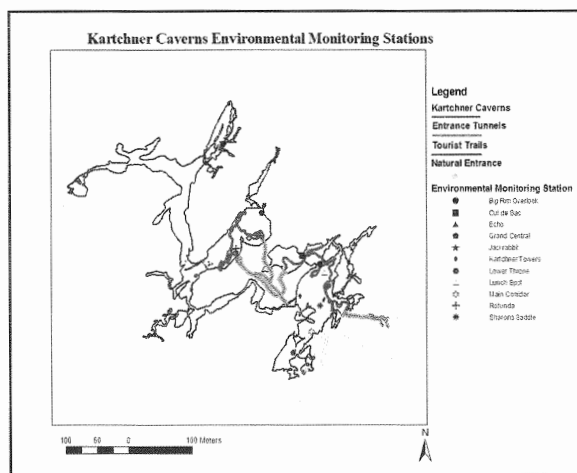


Fig. 1 - Map of Kartchner Caverns showing the natural entrance, the excavated tour tunnels, tour trails, and the location of the environmental monitoring stations discussed in this paper.

Relationship between outside and inside climate

A first indication of a possible influence of a natural change was detected by a comparison between the Palmer Drought Severity Index for the southeastern area of Arizona. This index is a climatological parameter that uses rainfall, temperature, and soil moisture to express the moisture state of an area. When this index was compared to the most extreme changes noted in the cave, notable similarities were observed in the records. These similarities suggested an influence of the outside climatic variation on the cave environment (Toomey, 2002).

To further examine the possibility that changes observed at Kartchner relate to regionally observed changes, the quarterly to semi-annual measurements of temperatures and relative humidity in four caves in the Coronado National Forest near Kartchner Caverns were considered. The four caves are Whetstone Cake Cave #1, Whetstone Cake Cave #2, SP Cave, and Cave Mine Cave. They are all located in Cochise County relatively near Kartchner Caverns (Figure 3). Whetstone Cake Cave #1 and #2 are small caves (100-150 m long) with relatively large entrances in the Whetstone Mountains above Kartchner Caverns State Park. They are not very good analogues to Kartchner Caverns, because their small size and large entrances result in large seasonal differences in temperature. However, they do provide data from undeveloped caves that are near the park. Cave Mine Cave and especially SP Cave are much better analogues for Kartchner Caverns. They are each relatively extensive caves with somewhat restricted entrances. They are each located in the Huachuca Mountains near Sierra Vista. The characteristics of these caves are here summarized:

Whetstone Cake Cave #1

Elevation ~1800 meters

Length ~100 meters

Depth ~10 meters

Large entrance

The measurements are taken in the variable temperature zone near to the entrance

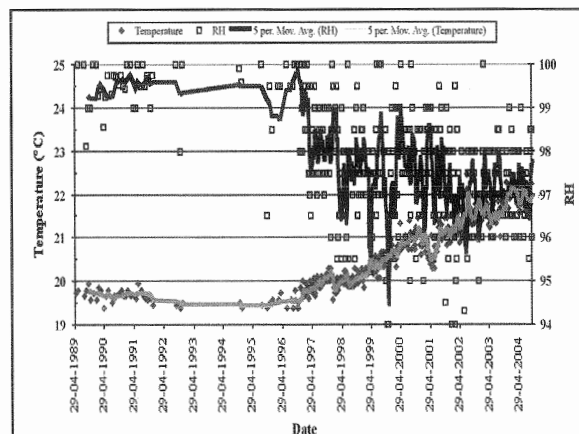


Fig. 2 - Temperature and relative humidity measurements and trends from the Lower Throne environmental monitoring station. The point symbols show individual measurements. The black (relative humidity) and gray (temperature) lines show five measurement moving averages of the individual readings to show the general trends more clearly and to reduce data noise. This station shows the most extreme change of the stations at Kartchner caverns.

Whetstone Cake Cave #2

Elevation ~1800 meters
 Length <50 meters
 Depth <10 meters
 Large entrance
 The measurements are taken in the variable temperature zone near to the entrance

SP Cave

Cave Mine Cave
 Elevation ~1900 meters
 Length ~300 meters
 Depth ~20 meters
 The measurements are taken in the large room just off the fairly large mine entrance

Cave Mine Cave

Elevation ~1850 meters
 Length ~600 meters
 Depth ~25 meters
 Entrance small (less than 1 square meter)
 The measurements are taken tens of meters back from entrance in the stable temperature zone.

An initial comparison between the values of temperature and relative humidity obtained in these caves and the corresponding ones in the Kartchner Caverns (Toomey, 2003) showed some similarities which indicated that certain climatic changes in Kartchner Caverns might be attributed to regional changes in surface climate. In order to investigate more accurately the role played by natural and human factors, a quantitative evaluation

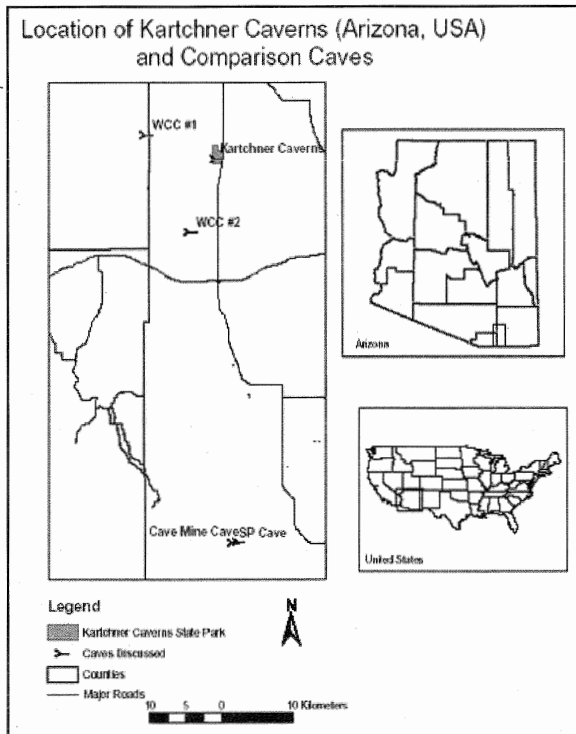


Fig. 3 - Simple map of the region around Kartchner Caverns including other caves discussed in this paper.

of the data obtained in the wild caves was performed. In particular the linear best fit of the results available for these caves was calculated. In Table 1 and 2 the coefficient "a" of the best fit linear equation for temperature and relative humidity values are reported. Such a coefficient is a measure of the variation of temperature or relative humidity through time.

A systematic trend is quite evident, with an increase of the air temperature and a corresponding decrease of the relative humidity. Average values of "a" were also calculated. Similar evaluations were carried on for some stations in Kartchner Caverns by taking into account the values obtained roughly in the same time interval (Tables 3 and 4). The trends of the climatic variations from a surface station, in the wild caves and in Kartchner Caverns is also similar from a quantitative point of view, confirming that the general trend observed in Kartchner Caverns is mainly due to a natural cause.

Table 1 - Best fit of the air temperature values obtained outside and in the wild caves.

Station	Period	T=ax+c "a"
Outside	January 1991 - July 2004	0.0007
SP Cave	November 1991 - September 2004	0.0003
Cave Mine Cave	July 1991 - September 2004	0.0002
Whetstone Cave 1	July 1991 - February 2002	0.0005
Whetstone Cave 2	July 1991 - February 2002	0.0007
Average±1 sigma		0.00048±0.00020

Table 2 - Best fit of the relative humidity values obtained in the wild caves.

Cave	Period	RH=ax+c "a"
SP Cave	November 1991 - September 2004	- 0.0005
Cave Mine Cave	July 1991 - September 2004	- 0.0009
Average±1 sigma		- 0.0007±0.0002

In order to evaluate the delay of the propagation of the seasonal heat wave from outside into the wild caves a sinusoidal best fit equation was calculated. Unfortunately on account of the very few values for each season, only indicative values were obtained, these suggest a delay ranging between 0 to 2 months with respect to outside. Such values compare favorably with most of those obtained in Kartchner Caverns (Cigna, 2001) and reported in Table 5.

Table 3 - Best fit of the air temperature values obtained in Kartchner

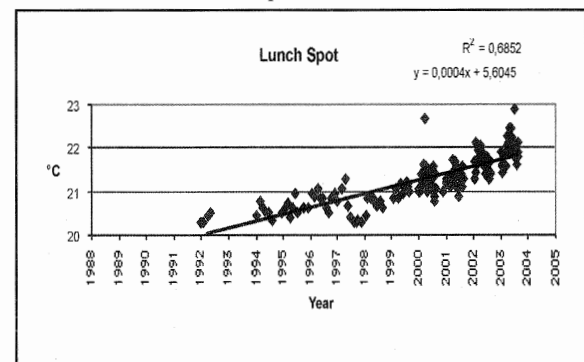


Fig. 4 - Lunch Spot: linear best fit of temperature measurements

Caverns.

Station	Period	T=ax+c "a"
Big Room	January 17, 1991 - April 9, 2004	0.0003
Cul de Sac	January 17, 1991 - January 13, 2003	0.0003
Echo Passage	January 17, 1991 - January 13, 2003	0.0001
Grand Central	January 17, 1991 - July 5, 2004	0.0002
Jack Rabbit	June 6, 1994 - August 9, 2004	0.0005
Kartchner Towers	January 17, 1991 - April 4, 2004	0.0003
Lower Throne	January 15, 1991 - August 6, 2004	0.0007
Lunch Spot	September 8, 1992 - May 3, 2004	0.0004
Main Corridor	January 17, 1991 - July 5, 2004	0.0003
Rotunda	January 15, 1991 - August 9, 2004	0.0009
Sharon Saddle	January 17, 1991 - July 19, 2004	0.0003
Average±1 sigma		0.00039±0.00022

Table 4 - Best fit of the relative humidity values obtained in Kartchner Caverns.

Station	Period	RH=ax+c "a"
Big Room	January 17, 1991 - April 9, 2004	- 0.0003
Cul de Sac	January 17, 1991 - January 13, 2003	- 0.0002
Echo Passage	January 17, 1991 - January 13, 2003	- 0.0001
Grand Central	January 17, 1991 - July 5, 2004	- 0.0008
Jack Rabbit	June 6, 1994 - August 9, 2004	- 0.0007
Kartchner Towers	January 17, 1991 - April 4, 2004	- 0.00005
Lower Throne	January 15, 1991 - August 6, 2004	- 0.0005
Lunch Spot	September 8, 1992 - May 3, 2004	- 0.0004
Main Corridor	January 17, 1991 - July 5, 2004	- 0.0002
Rotunda	January 15, 1991 - August 9, 2004	- 0.0004
Sharon Saddle	January 17, 1991 - July 19, 2004	- 0.0003
Average±1 sigma		0.00036±0.00024

The result of the investigations reported above indicates that the devel-

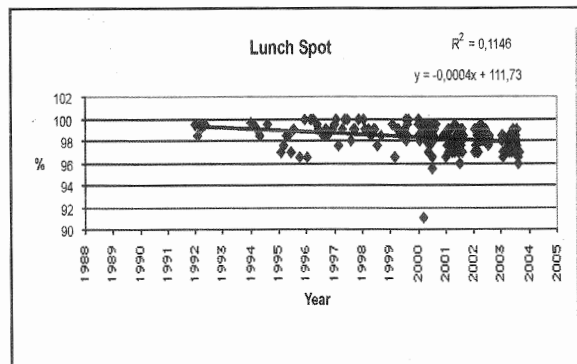


Fig. 5 - Lunch Spot: linear best fit of relative humidity measurements

opment work performed within the Kartchner Caverns, as well their opening to visitors, played a very minor role in the variation of the climatic parameters inside the cave. However in some stations of the Kartchner Caverns, e.g. Lower Throne and Rotunda, a polynomial best fit of the 3rd order is preferable to a linear one, with a correlation ratio R² around 0.9 instead of a R² around 0.7 obtained with the linear best fit.

This result, combined with characteristics of these stations, may be local effect due to heat released by visitors and by the electric plant. Because the Rotunda station results also exhibit the minimum delay (1 month) in the propagation of the heat wave from outside, they could infer the existence of some possible connection with outside through unknown passages.

Because development and tourist activities contribute some component of the warming, there may be steps that can be taken to mitigate this portion of the climate change. Using more efficient lamps and reducing time that such lamps are switched on may contribute to a decrease of the human impact. These steps are being taken incrementally at Kartchner and the results are being examined to see if they improve the situation.

Table 5 - Delay of the propagation of the seasonal heat wave from outside in some stations of the Kartchner Caverns (Cigna, 2001).

Station	Date of max	Delay (days)
Outside	1-Aug	0
Rotunda	5-Sep	35
Cul-de-Sac	30-Sep	60
Main Corridor	30-Sep	60
Grand Central	30-Sep	60
Lower Throne	30-Sep	60
Big Room Overlook	30-Sep	60
Kartchner Towers	16-Oct	76
Jack Rabbit	22-Oct	82
Sharon's Saddle	15-Nov	105
Echo Pass. (Start)	28-Mar	238

Acknowledgements

The authors are grateful to Jerry Trout, USDA-Forest Service, who kindly provided temperature and humidity data on caves from the Coronado National Forest. We would also like to thank the Cave Unit staff at Kartchner Caverns who made most of the measurements at the environmental monitoring stations.

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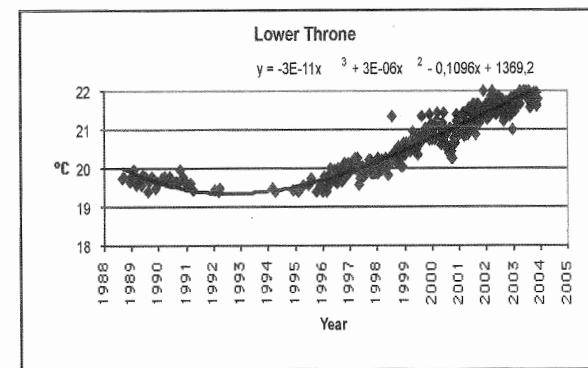


Fig. 6 - Lower Throne: polynomial best fit of the 3rd order

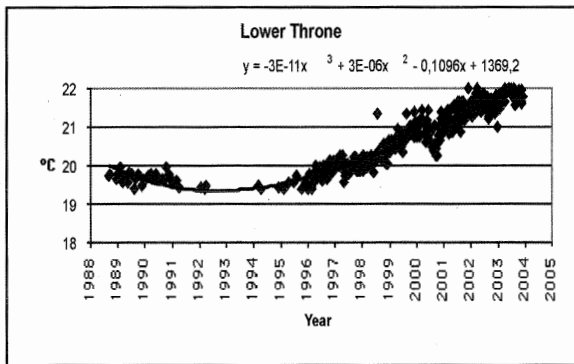


Fig. 7 - Rotunda: polynomial best fit of the 3rd order

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Ground water flux distribution between matrix, fractures, and conduits: constraints on modeling

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Introduction

Attempts to describe, analyze, or model ground water flow in karstic carbonate aquifers usually begin with some aspect of the triple permeability model (White, 1999; Worthington et al., 2000; White, 2002). The three components are matrix permeability, fracture permeability, and conduit permeability. Each contributes to the flow field but frequently only one or at most two of these components are included in the calculations. The choice of components and decisions concerning what can be neglected are often based on little more than guesswork.

The object of the present paper is to show the relative contribution of each of these permeability components to the overall flux of moving ground water. The calculations are based on a cross-section spanning the full width and thickness of the aquifer. By varying the contributions of each of the permeability components a measure of their relative importance to the overall flow system is obtained. The intent is not to provide

an aquifer model, but rather, by using actual numerical values, provide some insight into when and under what circumstances, one or more of the components of aquifer permeability can be neglected. Such calculations provide some constraints on the various equivalent porous media models such as the one developed for the Edwards aquifer in Texas (Scanlon et al., 2003).

The Triple Permeability Concept

Table 1 gives the essential characteristics of the three components of the triple permeability model for karst aquifers. The matrix, fracture, and conduit permeability are, essentially, independent components. Any specific real aquifer will have a mix of these contributions. There also exist real aquifers in which one of the components is completely dominant.

Table 1. Characteristics of the three components of the triple permeability model.

PERMEABILITY	APERTURE	TRAVEL TIME	FLOW MECHANISM	GUIDING EQUATION	DISTRIBUTION
Matrix	μ m to mm	Long	Darcian flow field. Laminar	$h_f = \frac{h \nu L}{r g (N^2)}$	Continuous medium
Fracture	10 μ m to 10 mm	Intermediate	Cube law. Mostly laminar; may be non-linear components	$\frac{Q}{h} = \frac{C}{f} b^3$	Localized but statistically distributed.
Conduit	10 mm to 10 m	Short	Darcy-Weisbach. Open channel and pipe flow. Turbulent	$h_f = \frac{f L v^2}{4 g r}$	Localized

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Calculations

The framework used for the calculations is shown in Fig. 1. A fixed cross-section of aquifer is assumed. The aquifer is taken as rectangular, 100 meters thick and one kilometer wide, giving a cross-sectional area of 10^5 m^2 . The aquifer cross-section is an adjustable boundary and can be set to any value, providing that the area is large compared to solution features that are embedded in it. The head is assumed to be constant and uniform across the aquifer area. This is an extreme assumption but one that eliminates concern for the water table and also the variable heads that would be characteristic of most aquifers containing conduits. The rock matrix is characterized by an adjustable hydraulic conductivity. Varying

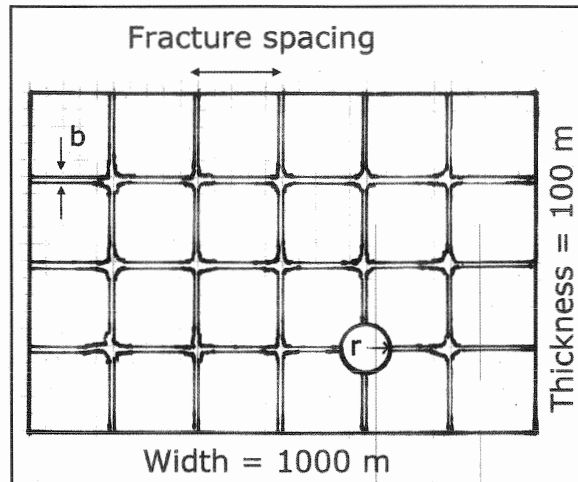


Fig. 1. Sketch showing the aquifer cross-section used for calculations.

proportions of fractures and conduits of adjustable fracture apertures and conduit diameters are the calculational parameters. A further assumption is that there is sufficient recharge behind the aquifer cross-section to provide whatever flow is called for by the calculations.

The guiding equations for the permeability (Table 1) show that the flow rate, Q , varies linearly with the head in laminar flow but with the square root of the head in turbulent flow. The head becomes a scaling variable. The head, or hydraulic gradient, dh/dL , is here set equal to 0.01, a nominal value for small karstic drainage basins. The guiding equations contain the density and viscosity of water, both of which are functions of temperature. A temperature of 10°C was selected as typical of karst ground waters but the variation in the parameters over the range of temperatures expected in karst aquifers is relatively small.

The Matrix Component

Ground water flow through the limestone or dolomite bedrock is not intrinsically different from ground water flow in any other aquifer. The guiding equation is Darcy's law. However, calculations must use hydraulic conductivities for the rock. Such data are sparse. Most hydraulic conductivities are based on pump tests on wells and those data are dominated by the fracture flow component. Intrinsic hydraulic conductivities of the bulk rock must be measured on core samples in the laboratory. Some representative data are shown in Table 2.

The flux through the matrix is a fixed quantity for chosen values of hydraulic conductivity. Lines of constant flow rate were calculated for Kentucky Mississippian limestone ($K = 2 \times 10^{-11} \text{ m/sec}$) which should be typical of many Paleozoic limestones and dolomites. Other lines of constant flow were calculated for the Edwards Limestone ($K = 1 \times 10^{-8}$) and for the mean value of the Floridan aquifer ($K = 3.65 \times 10^{-6}$). The latter is a carbonate aquifer in which matrix flow is a dominant component.

Table 2. Hydraulic conductivities for some carbonate rock aquifers.

Rock Unit	K (m/sec)	Reference
Floridan Aquifer		Budd and Vacher (2002)
Wackestone	1.97×10^{-7}	
Packstone	9.61×10^{-7}	
Grainstone	3.82×10^{-6}	
Sucrosic dolostone	9.61×10^{-6}	
Mammoth Cave, Mississippian limestone	2×10^{-11}	Worthington (1999)
Silurian dolomite, Ontario	1×10^{-10}	Worthington (1999)
English chalk	1×10^{-8}	Worthington (1999)
Pliocene limestone, Yucatan, Mexico	7×10^{-5}	Worthington (1999)
Edwards Aquifer, Texas, Cretaceous	1×10^{-8}	Worthington et al. (2002)
Swabian Alb, Germany, Jurassic	8×10^{-9}	Worthington et al. (2002)

The Fracture Component

The idealized model for fracture flow assumes a fracture with plane parallel walls and a uniform aperture. For the ideal case, the cubic law can be derived theoretically from the Navier-Stokes equations.

$$Q = \frac{w r g b^3 \Delta h}{\eta h \Delta L} \quad [1]$$

Here, Q = flow rate in m^3/sec , w = fracture width in m , ρ = density of water = 999.7 kg/m^3 , g = gravitational acceleration = 9.8 m/sec^2 , b = full aperture of the fracture in m , and η = viscosity of water = $1.307 \times 10^{-3} \text{ Pa sec}$.

It has been long recognized that real fractures do not have uniform apertures and that the walls are not parallel. Witherspoon et al. (1980) resolved this problem by compacting the constants of equation [1] into a single constant and then adding an empirical friction factor, f , to give the form of the equation shown in Table 1. More recent work (e.g. Brush and Thomson, 2003; Konzuk and Kueper, 2004) has proposed more quantitative descriptions of rough-walled fractures but in general the results change by no more than a factor of 2. For the rough calculations in this paper, the plane-walled fracture (equation [1]) should suffice.

The fracture width, w is the total extent of fractures measured perpendicular to the flow direction. There may be multiple fracture sets at different angles with respect to each other. In the model assumed in Fig. 1, there are both vertical fractures and horizontal bedding plane partings in an assumed horizontal bedding. The total width of vertical fractures is the aquifer width/mean fracture spacing. The total width of horizontal fractures is the aquifer thickness/mean spacing of bedding plane partings. With the aquifer dimensions given in Fig. 1 and a typical 10 meter spacing for both vertical fractures and bedding plane partings, the model would contain 18,900 meters of fracture assuming that the boundary planes are not fractures. A second curve was calculated using only vertical fractures with a 50 m spacing.

Fracture flow calculations were cut off when the aperture reached 0.01 m as this is the dimension at which turbulent flow is expected to develop. The cubic equation applies only to laminar flow. If all fractures were to develop to the largest aperture, fracture flow would completely dominate

the flow system. Something like this occurs in aquifers with maze cave development. In most aquifers, rearrangements of the flow path would have occurred before all of the fractures reached this very large aperture.

The Conduit Component

A single conduit is assumed as sketched in Fig. 1. The conduit radius, r , is taken as the dependent variable. Conduit flow in the laminar regime is described by the Hagen-Poiseuille equation [2].

$$Q = \frac{\rho r g r^4 h}{8 \eta h} \quad [2]$$

Turbulent flow in a conduit is described by the Darcy-Weisbach equation. Written as volume flow and taking the cross-section as a circular conduit gives

$$Q = 2\rho \left(\frac{g}{f}\right)^{\frac{1}{2}} r^{\frac{5}{2}} \left(\frac{h}{L}\right)^{\frac{1}{2}} \quad [3]$$

Application of equation [3] requires numerical values for the Darcy-Weisbach friction factor, f , which must be determined empirically. The friction factor relates to the wall roughness and, in the case of a conduit that behaves as a uniform pipe, estimates of f have been made from irregularities, usually scallops, on the conduit wall. Most conduits, however, are not uniform pipes. Breakdown, sediment chokes, and varying passage shapes also contribute to the effective roughness. An alternative approach is to measure all other parameters in equation [3] and then back calculate f . The two approaches give dramatically different results as shown in Table 3. Because the friction factor enters the Darcy-Weisbach equation as a square root, the effect of the different numerical values is somewhat muted. Calculations were made with the smallest value (0.039) and one of the largest values (130).

Table 3. Estimates of the Darcy-Weisbach friction factor.

Location	From Discharge	From Roughness	Reference
Mendips (UK)	24 - 340	---	Atkinson (1977)
Castleguard (Canada)	0.87 - 2.31	0.33 - 0.90	Atkinson et al. (1983)
Morecombe Bay (UK)	---	0.077	Gale (1984)
Glomdalsvatn (Norway)	0.116	0.039	Lauritzen et al. (1985)
Turnhole (KY)	27	---	Worthington (1991)
Friars Hole (WV)	46 - 74	---	Worthington (1991)
Holloch (Switzerland) ---	0.322	Jeannin (2001)	
Maligne Basin (Canada)	130	---	Smart (1988)

Discussion and Conclusions

The results of all calculations are plotted in Figure 2. The x-axis gives the aperture, either fracture aperture or conduit radius. The y-axis shows the flow volume that would be expected under the specified conditions of aquifer cross-section and hydraulic head. Changing the aquifer cross-section and the hydraulic head would shift the numerical positions of the curves but not their relative pattern.

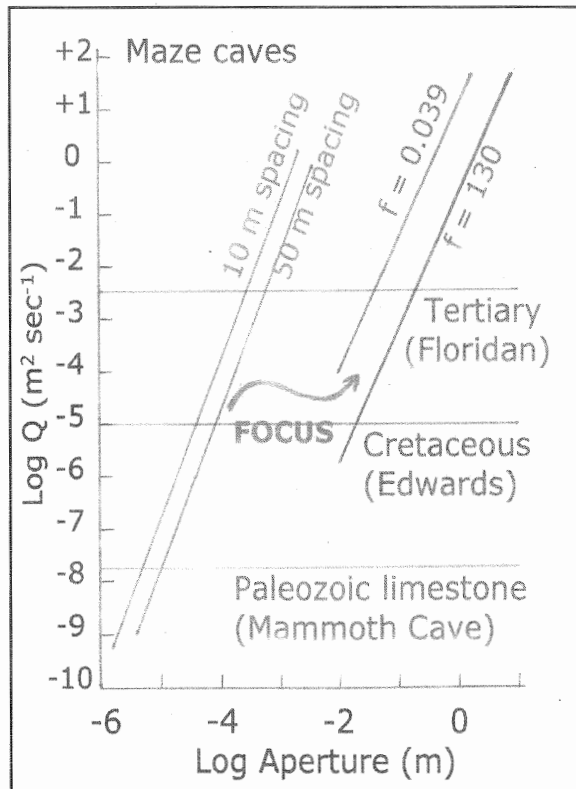


Figure 2. Discharge through the components of the triple permeability system as a function of aperture. The horizontal lines are the matrix contribution. The lines labeled 10 m and 50 m spacing are the fracture contributions at the specified fracture spacing. The lines for the conduit contribution are labeled with the chosen values for the Darcy-Weisbach friction factors, $f = 0.039$ and $f = 130$.

For matrix flow the "aperture" is the total cross-section of the aquifer so the matrix components plot as horizontal straight lines whose vertical position depends only on the assumed hydraulic conductivity. As expected, in the dense, low permeability Paleozoic limestones, the matrix flow is negligible. It becomes more important in more permeable limestones and yields a significant contribution to the flow field when K exceeds values of 10^{-6} m/sec.

A surprise in the calculations is the dominance of fracture flow. Most observed fractures in carbonate aquifers have apertures in the range of hundreds of micrometers. If these fractures were enlarged by dissolution to the millimeter to centimeter range, fracture flow would completely dominate the system. What happens in most aquifers is the focus of the flow into a few localized pathways early in the development of the system. Because of the acceleration of dissolution kinetics at the critical aperture in the one-centimeter size range, a single conduit or small set of conduits grow at the expense of near by fractures. Lowering hydraulic heads in the conduits cause the conduits to act as drains and the simplified model used for the present calculations is not applicable. In those aquifers where geologic factors prevent the focus of flow into single conduits, fracture enlargement does continue with the product of maze caves. These results are

consistent with the conclusions of Worthington et al. (2000) that although the main portion of the flow in karstic aquifers is through the conduits, the main portion of the storage is in the fractures. The results are also consistent with the high well yields obtained from fractured dolomite aquifers.

Conduit systems do indeed dominate the flow system in many carbonate aquifers. However, in order for them to develop there must be a focusing mechanism to drain off water from the fractures before they develop wide apertures.

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THE HYDROGEOLOGICAL REBUS OF THE COASTAL KARST OF OROSEI (EAST SARDINIA, ITALY)

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Hydrogeological research of karst areas in Sardinia is often hindered by the discontinuity of superficial runoff and as a consequence the difficulty in performing dye tests. Recent combined speleological and hydrogeological surveys have brought to important scientific results in the carbonatic massif of Supramonte (Central-East Sardinia) where hydrological input and output points are well known and easily monitored. Not the same can be said for the adjacent Gulf of Orosei coastal karst area where inputs and outputs are relatively well known but difficult to monitor.

From a geological point of view the Gulf of Orosei is characterised by a Mesozoic sedimentary sequence covering a crystalline Palaeozoic basement composed of granites and metamorphic rocks. The Mesozoic sequence starts with transitional alluvial-lacustrine conglomerates, sandstones and marls of the Genna Selole Formation (Bajocian-Bathonian) immediately followed by greyish dolostones, fossiliferous limestones and oolitic limestones, deposited in more or less shallow water characterised by coral reefs, back- and fore-reef and inner continental shelf environments (Bathonian-Berriasian).

The whole Mesozoic sedimentary sequence has been folded and faulted during tertiary according to main N-S, NW-SE and NE-SW directions. The overall monocline eastwards tilted structure of the Gulf of Orosei greatly influences the hydrogeological asset, showing a general tendency for underground water to flow from West to East. Water flows in through various sinkholes in the western part of the area and flows out of the system through several submarine resurgences, the most famous of which are Bue Marino, Cala Luna, Bel Torrente and Ispignadorgiu springs. In the Southern part, where the granite basement crops out close to the sea, two other outflows are known, s'Erriu Mortu and Olcoé caves.

Besides direct infiltration in the carbonate aquifer, some of the water is allogenic, coming from the Palaeozoic basement to the West. The best example is given by the Codula Ilune drainage basin, introducing water in to the Codula Ilune karst system through several sinkholes.

Some dye tests have enabled to reveal at least partially the hydrogeological asset of the coastal aquifer, but especially the central-southern area remains a rebus.

Recent cave surveys, carried out along the coast by German and Italian cave divers and in the contact area at almost 1000 m altitude by French and Sardinian cavers, have enabled to discover several active and very long submarine karst springs and contact-sinkholes that have induced to organise new dye tests.

This paper resumes the hydrogeology of this important aquifer based on past researches and on the new data derived both from cave surveys and from dye tests.

Introduction

The Gulf of Orosei is a coastal karst area located in the central-eastern part of Sardinia (Italy) and is constituted of an almost 40 km long limestone coast with cliffs reaching heights up to 700 meters. Recent cave research combined with geomorphologic investigation has enabled to enhance the understanding of the hydrogeological asset of this coastal karst area, even though many questions remain unanswered. In the future dye tests should be carried out in this difficult area where surface runoff is very scarce and extremely limited in time and main outlets are almost all located in submarine karst springs, hindering the monitoring operations.

Geological outline

The Gulf of Orosei coastal karst area is characterized by a thick Mesozoic sedimentary sequence of dolomites and limestones covering a Palaeozoic granite or biotitic schist basement (De Waele & Pisano 1997) (Fig. 1). The Mesozoic transgression occurred after a long-during continental period (Permian-Lower Jurassic), and slowly flooded an undulating Variscan peneplain during Bajocian-Bathonian. The Middle Jurassic-Lower Cretaceous sea remained relatively shallow and the different carbonate facies evidence several shallow depositional environments, going from lagoons to coral reefs. This sedimentary sequence is composed of dolostones containing limestone lenses, oolitic limestones and massive fossil-rich outer-shelf, reef, interreef and backreef limestones (Dieni & Massari 1985).

The Jurassic transgression is introduced by clastic sediments of the Genna Selole Formation, represented by quartz conglomerates and sandstones with plant fossils typical of a fluvial or delta environment influenced by tidal movements (Amadesi et al. 1960; Fazzini et al. 1974; Dieni et al. 1983). This facies becomes marly towards the top, typical of a littoral depositional environment and the alternation of marl and dolostone beds precludes the Dorgali Formation dolostones (Amadesi et al. 1961; Calvino et al. 1972; Dieni & Massari 1985; 1987). These dolostones range from sandy in the basal levels to pure brownish dolostones in the upper beds and locally contain fossils of Bathonian-Callovian age (Middle Jurassic) (Dieni & Massari 1985).

Upon these dolostones two heterotopic limestone Formations are reported: the Monte Tului and Monte Bardia Formations (Dieni & Massari 1985).

The first is characterized by microcrystalline and oolitic sandy limestones for a varying thickness of 0-120 m deposited in an outer-shelf environment, according to the fossil fauna of Callovian-Upper Kimmeridgian age (Middle-Upper Jurassic). The Monte Bardia Formation instead is composed of typical reef and bioclastic limestones, with frequent fossil corals (sometimes in life position) and their debris. The age of these limestones is Kimmeridgian-Berriasian (Upper Jurassic-Lower Cretaceous).

The first sediments locally recognizable upon the Mesozoic rocks in the Gulf of Orosei are alluvial conglomerates and quartz sands related to an intense erosion-deposition cycle caused by an uplifting phase of Middle Pliocene age (Massari & Dieni 1973). These sediments precede and are contemporary to the effusion of Pliocene basalts that have given K-Ar ages comprised between 2.0-3.5 million years (Savelli & Pasini 1973). Upon these basalts alluvial sands and conglomerates are found (Cala Gonone, San Pietro valley, Biddunie, Cala Luna) probably deposited during Early Pleistocene (Dieni & Massari 1966). During Pleistocene several periglacial sediments were deposited, the most interesting are the stratified slope-waste deposits (éboulis ordonnées), composed of limestone fragments in a reddish clay matrix forming coastal cliffs of more than 40 meters height and developing up to 600 m a.s.l., and aeolian sands visible in karst pockets, along the limestone cliffs up to several meters a.s.l. and also on the near shore continental shelf up to 40 meters b.s.l.

From a structural point of view the Jurassic carbonate cover is tilted towards the East (center of the Gulf) with an almost constant dip of 20-30°. This monocline structure is disturbed by two transcurrent arcuate fault systems directed NNW-SSE and NNE-SSW (Pasci 1997). Among the first the Serra Oseli fault can be mentioned with an inverse and sinistral cinematic with almost 500 meters vertical uplifting of the eastern limb. The second fault system is well represented in the Southern part of the Gulf, with the Piano d'Otzio and the San Pietro-Onamarra dextral faults with

up to 400 meters uplifting of the Eastern limb. These faults are related to the continental collision between the Apulian and the South-European plates. The eastwards lowering of the Jurassic carbonates is thus compensated by this tectonic style, and the sediments outcrop continuously up to a bathymetric depth of almost 100 meters on the continental shelf (Orrù & Ulzega 1987).

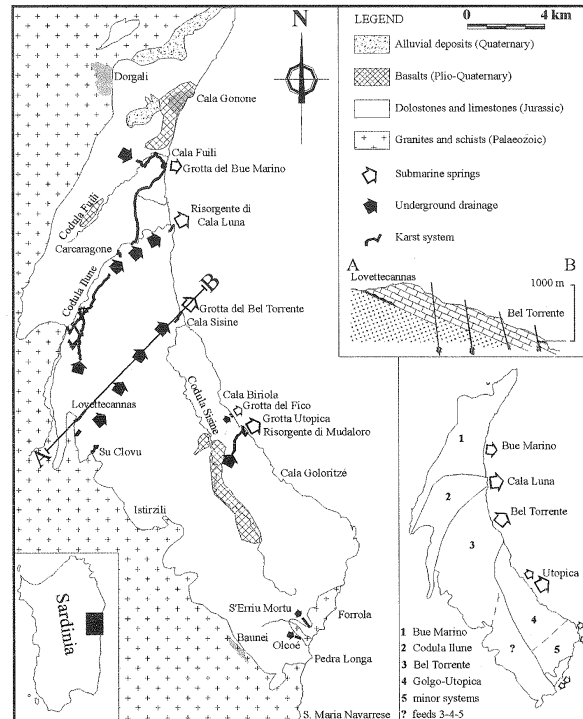


Fig.1 - Hydrogeological scheme of the Gulf of Orosei.

Surface and underground drainage

The Gulf of Orosei karst area, occupying a surface of more than 210 square km, is a spectacular coast of high carbonate cliffs cut by some major streams, from North to South Codula Fuili, Codula Ilune and Codula Sisine, forming canyons that end in the Sea. This surface drainage network is most probably a relic of the ancient hydrography related to wetter (thus warmer) periods and continues also on the shelf for several kilometers up to a depth of at least 120 meters (Orrù & Ulzega 1987), corresponding to the maximum lowstand of the Mediterranean Sea during the Last Glacial Maximum, around 22,000 years ago.

At present surface drainage is activated only after heavy rain periods and almost exclusively interests the major rivers, meaning Codula Ilune and Sisine, and only exceptionally other tributaries (Codula Fuili, Codula Goloritzé, Bacu Maore, Bacu Mudaloro etc.). This also because Codula Ilune has more than 60 % of its drainage basin extended upon granites and Sisine drains part of the basaltic San Pietro plain. Almost all other rivers are completely comprised in the carbonate structure, characterized by well developed underground drainage.

The fluviokarstic landscape is enriched by typical karst landforms such as dolines, well developed on the dolomites close to the contact with the Palaeozoic granites in locality Marghine. Here a N-S directed series of more or less big dolines and semi-closed depressions makes up one of the most important absorbing areas of the Gulf where many cave systems have been explored in the past few years (Brozzi et al. 1989; De Waele, 2001; De Waele et al. 2002).

Morphology in the coastal areas is caused by a combination of karst and littoral processes, and erosion is locally enhanced by corrosion that becomes prevalent where mixing between fresh and salt water occurs leading to hyperkarst phenomena (De Waele et al. 2001). Many erosion sea caves, formed by the wave action on joints and structurally weaker areas, are located along the coast. Where fresh water outlets occur, instead, mixing phenomena have led to the development of important coastal karst caves reaching development of several kilometers (De Waele & Forti 2002).

Cave exploration has revealed much new information on underground karst development in the Gulf of Orosei in the past few years, and many Authors have reassessed this speleological information (Fercia & Pappacoda 1991; De Waele et al. 1995; Fancello et al. 1997; De Waele et al. 2002; Schafheutle et al. 2002; De Waele, 2004).

The most interesting areas are the Codula Fuili and Codula Ilune canyons, the Marghine plain and the entire coastline.

Codula Fuili is the northernmost fluviokarstic canyon of the Gulf and flows in a SW-NE direction following an important strike-slip fault and ending in the Tyrrhenian Sea forming the Cala Fuili beach. Many caves have been documented along its course (Fancello et al. 1997), mostly representing remnants of well developed karst systems. The underground drainage is characterized by the important Bue Marino cave, the present outflow of the system located on the coast 500 meters South of Cala Fuili, with a development of more than 15 km part of which are open to public.

The northern branch of this cave, in fact, follows the Fuili canyon and almost reaches the Barisone doline, and is constituted of a long succession of more than 40 sumps and many dry parts for a total development of 7 km (Fancello et al. 1994). Maximum water depth corresponds to 33 m b.s.l. and the underwater conduits, decorated with speleothems, have average water flow of 50 l/s reaching some cubic meters/s during important floods.

The Southern branch, instead, initially flows in a Southwest direction for about 3 km where the passage becomes submerged. This 630 meters long sump reaches 32 meters of water depth and gives access to further 2.5 km of cave with some other smaller sumps, eventually passing under the Codula Ilune canyon (Fancello et al. 1994). The huge pre-sump passage is characterized by important sediments prevalently composed of granites, dolomites, and limestones and has cut phreatic conduits which are completely filled with basalt (Mahler 1979), related to the Pliocene volcanic period and contemporary to the basalts outcropping in the upper parts of Cala Luna, Cala Fuili and on the San Pietro plain dated 2-3.5 M.y. (Savelli & Pasini 1973). This branch is characterized by water flow only during floods of Codula Ilune (after heavy rain periods) and in these circumstances discharges some cubic meters/s (Fig.2).

The Codula Ilune canyon contains the biggest cave system of Sardinia, explored since the early 80's and totaling a development of more than 42 km. The Codula Ilune cave system, discovered in the upstream part of the canyon and partially developed on the contact granite-dolomites, is characterized by two underground rivers that meet in a subterranean lake forming a unique collector. The system has at least four different cave levels easily recognizable by the presence of abandoned phreatic cave tubes and main stream passages developed at different altitudes and likely corresponding to different climatic phases (De Waele 1997; Forti & Rossi 1991). The present outlet of this cave system is located 100 meters South of the Cala Luna beach, and is characterized by a narrow and rectilinear passage explored for 630 meters and with a maximum depth of 37 m b.s.l. but developing essentially at 10 m b.s.l. (Hovorka 1993). Inside this submarine karst spring remnants of aeolian cemented sediments have been found related to an arid and cold period (Antonoli & Ferranti, 1992). Discharge in average is about 100 l/s, reaching peaks of several m³/s during floods.

Recent explorations have discovered several interesting caves at Mar-

ghine, South of the upper Codula Ilune river at an altitude of approximately 1,000 m a.s.l., probably representing branches of a unique absorbing cave system that has its outlet in the Bel Torrente cave, located 500 meters North of Cala Sisine. The sinkholes of Lovettecannas, Su Canale superiore and Su Clovu develop for several kilometers along the contact between granites and dolostones (Brozzi et al. 1989; De Waele et al. 2002) and show only scarcely formed phreatic passages, typical of an allogenic karst system (Palmer, 2001), also suggesting their relatively recent formation. The Bel Torrente submarine spring, instead, is a large underwater passage that develops at an average depth of 5 m b.s.l. and has been explored for more than 1 kilometer. The cave divides in a huge dry phreatic passage and a submerged active branch at 700 meters from the entrance, both branches are decorated with speleothems. This submarine spring has been defined the most important of the Gulf, thus having discharges greater than Cala Luna spring and Bue Marino cave (Morlock & Mahler 1995; Fancello et al. 2000).

Several other important caves are reported along the coast such as the Fico cave and the Utopia-Ispuligidenie karst system. The Fico cave is located about 4 km South of Cala Sisine, at an altitude of 15 m a.s.l., and develops for more than 1 km (Jantschke 1998). This cave has a rather complex development with ascending branches up to almost 60 m a.s.l., characterized by abundant concretions (e.g. aragonite helictites), a main corridor parallel to the coastline and submerged passages up to a depth of 20 m b.s.l. A modest fresh water spring inside the cave is probably co-responsible of the widening of the joints by hyperkarst processes due to mixing.

The Utopia-Ispuligidenie cave system is located one more km to the South, in correspondence with the outlet of the Bacu Mudaloro canyon. This system is composed of two main branches that meet close to the coastline; the active submarine karst spring of Ispuligidenie to the South and the submerged Utopia passage to the North. This impressive submarine cave system, with extremely well developed and wide cave tunnels, showing both phreatic and surface evolution, reaches a total length of more than 4 km representing one of the biggest underwater caves of the Mediterranean. The mean depth of the main karst tunnel is around 30 m b.s.l., the maximum depth is 80 m b.s.l. and only rarely the passage develops above sea level. Submerged speleothems have been observed to depths of 30 m b.s.l., representing the deepest ones found in the Eastern Sardinian coasts (Bohnert et al., 2003). Water flow is difficult to estimate, but should range between 20 l/s and several m³/s during intense floods.



Fig.2 - The famous Cala Luna beach during the December 2004 flood. The river eroded temporary the eroded the beach. The Cala Luna spring is located right behind the big limestone blocks in the sea (Photo Mario Pappacoda).

Hydrogeological asset

From a hydrogeological point of view the underground drainage is controlled by the structure of the carbonate sequence and the downward

confinement by the impervious Palaeozoic basement complex. The overall structure of the Gulf is characterised by the monoclinical dipping towards the centre of the Gulf, thus underground water flow is directed towards the East. Coastal surveys (Colantoni, 1967; Bianco, 1995; Morlock & Mahler, 1995; Jantschke, 1998; Schafheutle et al., 2001; De Waele & Melis, 2003) have allowed to discover the most important outlets of the karst aquifer, from North to South Bue Marino cave, Cala Lune resurgence, Bel Torrente cave and Utopica cave. Some minor outlets such as Fico cave, S'Erriu Mortu and Olcoé are related to smaller hydrogeological systems. Dye tests (Mucedda, 1985; Pappacoda & Fercia, 1991) have allowed to define the hydrogeological system of Codula Ilune-Resurgence of Cala Luna and its relationships with the adjacent systems of Bue Marino and Su Clovu in a satisfactory manner. This latter cave system, together with the recently discovered underground rivers of Lovettecannas and Su Canale Superiore are probably part of the Bel Torrente hydrogeological system, even though dye tests carried out in the summer of 2003 did not have a positive result after two months of monitoring, probably due to the small quantities of water. The Bel Torrente system probably also drains part of the Southern Gulf (sinkholes of Istirzili etc.) based on the structural model, but here also dye tests should be carried out, hindered by the fact that no underground rivers are yet known. Future dye tests will be repeated in the near future to help and solve this rebus.

The Utopica system, instead, surely drains the basaltic Golgo plain (since it develops underneath) and is probably limited to the West by the important SSE-NNW San Pietro-Onamarra fault.

Conclusions

From this short review it is clear that the hydrogeological setting of the Gulf of Orosei coastal karst area is not yet well defined because of the difficulty in performing dye tests. Hydrogeological studies are hindered by the lack of surface flow, the present absence of cave systems with underground water flows that would allow tracing experiments and the difficulty of monitoring the submarine karst resurgences accessible only by boats and cave diving. The structural model allows to define, in a rather rough manner, the different hydrogeological systems (Fig. 1). The situation is quite well understood in the North (systems of Bue Marino and Codula Ilune), moderately in the center (Lovettecannas-Su Clovu-Bel Torrente and Golgo-Utopica systems) and almost completely ignored in the southwestern part. This is related to the knowledge on caves and underground streams, much better known in the areas of Bue Marino and Codula Ilune. Future cave explorations should be carried out in the absorbing areas on the western border of the Gulf (Istirzili) with the hope of finding a cave system with underground water flow that would allow to carry out some dye tests.

The monitoring of the submarine springs (at least Cala Luna, Bel Torrente and Utopica) is not easy outside the summer season because of the weather (often causing surf), the logistic difficulty of finding transport by sea and the fact that monitoring must rely on cave divers. A serious dye test program should be settled in the near future to put light into this hydrogeological rebus.

Acknowledgements

This paper resumes the hydrogeological data collected by many speleologists and cave divers that have greatly enhanced the knowledge of the Gulf of Orosei coastal karst area. Without their contribution the hydrogeological asset would have been defined in a much poorer way.

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Application of dye tracer techniques in the preparation of a conceptual hydrogeologic model for a contaminated karst aquifer: saad superfund site, Nashville, Tennessee, USA

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The SAAD Oil Company, a U.S. Environmental Protection Agency (USEPA) Superfund site, is located in Nashville, Tennessee, USA. SAAD Oil Company extracted impurities from used motor oil to enable recycling, and the USEPA suspected it was the source of over 20 years of contamination flowing from Croft Spring which is located approximately 762 m (2,500 ft) southeast of the SAAD site and the headwaters of a stream that flows through the Nashville Zoo. After SAAD Oil declared bankruptcy, over 200 of its clients who had sent used oil to them for recycling were named as the primary responsible parties (PRPs) for the contamination, and according to U.S. law, for its clean-up. Attorneys for the PRPs believed the source of contamination to be from two other sites, 1) the General Electric factory to the east that had lost polychlorinated biphenyls (PCBs), and 2) the CSX Railroad Radnor Switching Yard (CSX Radnor Yard) located adjacent to the SAAD site to the west that had a groundwater contamination problem due to loss of diesel fuel. Therefore, the USEPA funded a hydrogeologic investigation by Crawford to determine which facility or facilities were responsible for the contamination. The results of a karst hydrogeologic inventory which included over 100 dye receptor locations, a water table surface elevation investigation, a stage height investigation at Croft Spring, six dye tracer tests, and a matrix interference analysis revealed that both the SAAD Oil Company and the CSX Radnor Yard were responsible for the contamination at Croft Spring. Results are presented in a map showing the karst hydrogeologic features, water table contours, and the approximate dye trace flow routes and groundwater basin boundaries. Also included is a hydrogeologic profile across the site showing the geologic stratigraphy, the water table surface and a general model of the interrelationship between groundwater flow and geology.

Karst Hydrogeologic Inventory

A hydrogeologic inventory was performed to locate all springs, water wells, monitoring wells, caves, karst windows, sinkholes and other karst features within an area that covered approximately 103.6 km (40 sq mi). This required several weeks of field work by karst scientists trained to locate these features. Activated coconut charcoal dye receptors were placed in over 100 springs, wells (primarily monitoring wells), and surface streams, and automatic water samplers were placed at Croft Spring and at the Radnor Yard Outfall (this storm sewer outfall is actually a spring that discharges both groundwater and storm water runoff from the CSX Radnor Yard).

Water Table Investigation

The water table surface for the uppermost karst aquifer was contoured by measuring the water levels in the numerous monitoring wells at various factory sites that were screened into the water table aquifer. In addition, spring and surface stream elevations were determined by leveling from nearby benchmarks. This data permitted the water table surface to be contoured during both a dry period in October and a wet one in March. The water table elevation fluctuated only a small amount between these two periods. The water table data provided very important information concerning groundwater flow direction. It indicated a water table ridge that extended northeast-southwest in the vicinity of the SAAD Oil and CSX Radnor Yard sites, and it revealed troughs in the water table that extended

from the water table ridge downgradient to the east toward Croft Spring and to the northwest toward the Radnor Yard Outfall Spring.

Dye Tracer Investigation of Groundwater Flow

Groundwater flow direction could not be established from the water table data since all three sites were in the vicinity of the water table high. Therefore, six dye tracer tests were performed to better define groundwater flow direction. Previous to dye injection, fluorescent dye background levels were established at all monitored locations to determine dye selection and to observe the fluctuation in background levels for the various dyes being considered. Both one-week and two-week background levels were established, with background monitored during at least one significant storm event.

Matrix Interference Analysis

There were three concerns relating to the groundwater contaminants' possible effect upon the dyes being considered for injection. Some of the contaminants might: 1) diminish the dye's fluorescence, 2) diminish the ability for the dyes to be adsorbed onto the charcoal dye receptors, and/or 3) impact the ability of the Smart Solution (Smart and Laidlaw, 1977) to elute the dyes adsorbed onto the charcoal. Therefore, a three-part laboratory matrix interference analysis was performed on four-liter (1.06 gal) grab water samples from the following locations in order to quantify these variables for the dyes being considered for use: 1) Croft Spring, 2) Radnor Yard Outfall Spring, and 3) contaminated groundwater from wells in the vicinity where the dyes were to be injected.

The matrix interference analysis did not indicate a significant impact on the fluorescence ability of the dyes investigated, nor upon the adsorption capacity of the activated charcoal, nor upon the eluent's (Smart Solution) ability to elute the dyes from the charcoal.

Hydrogeologic Investigation

U.S. Geological Survey, 7.5 minute, geologic quadrangle maps were investigated for the SAAD site vicinity. In addition, numerous well logs from monitoring wells at several industrial sites in the area were studied. Although regolith is typically very thin above bedrock throughout much of the vicinity, this data indicated that the regolith (residuum) in the vicinity was over 15.4 m (50 ft) thick in some areas. In addition, data revealed that, in order to prepare a level surface for the CSX Radnor Yard, approximately 9.1 to 15.2 m (30 to 50 ft) of fill material had been placed over a large area above the regolith. The geologic data indicated that the regolith was underlain by the Ordovician Bigby-Cannon Limestone which was typically 6.1 to 12.2 m (20 to 40 ft) thick. Below the Bigby-Cannon was the Ordovician Hermitage Formation, an argillaceous and shaley limestone which tends to be a confining layer. Croft Spring and the Radnor Outfall Spring are located directly upon or slightly above the Hermitage Formation. Therefore, the karst aquifer was located within the Bigby-Cannon Limestone. At most places, the water table was located in the regolith, well above the top of the Bigby-Cannon Limestone. This fact indicated laminar groundwater flow through the regolith until it reached a conduit in the underlying Bigby-Cannon Limestone. It also indicated that

the dye traces would be difficult, and that dye would move slowly through the regolith until finally getting into an open conduit in the underlying Bigby-Cannon Limestone.

Stage Height Investigation at Croft Spring

Croft Spring, an obvious karst spring, was reported to rapidly rise and fall over 1.22 m (4 ft) after heavy rains. This information tended to indicate a turbulent flow karst aquifer with rapid recharge through sinkholes and sinking streams. However, the landscape in the area does not have noticeable sinkholes or sinking streams and the hydrogeologic investigation indicated that the water table was in the regolith well above bedrock, indicating more diffuse flow with slow recharge rather than rapid conduit flow. Precipitation and stage were monitored at Croft Spring with a pressure transducer/data logger during the dye tracer tests for a period of approximately 10 months. Even though several large rain events occurred during this period, the spring stage only fluctuated .06 m (0.2 ft), indicating that recharge was primarily from slow percolation through the thick regolith down into the solutionally-enlarged conduits in the Bigby-Cannon Limestone. This data provided very useful information concerning the nature of the karst aquifer and the relatively slow dye flow rates.

Dye Traces

Previous consultants had drilled and installed monitoring wells over 45.7 m (150 ft) deep in the vicinity of the General Electric factory. An investigation of the well logs indicated that monitoring wells had been drilled completely through the Hermitage confining layer and screened into a confined aquifer in the underlying Carters Limestone. Further examination of the logs revealed that one of the wells had encountered a 2.1 m (7 ft) void only 7.3 m (24 ft) underground in the Bigby-Cannon Limestone directly above the Hermitage. The drillers did not encounter sufficient water at this depth, so this void was cased off, and drilling continued through the Hermitage down into Carters Limestone confined aquifer.

For this investigation, a new well was drilled approximately 0.9 m (3 ft) from the well that intersected the 2.1 m (7 ft) air-filled void, and Sodium Fluorescein (Color Index: Acid Yellow 73) dye was injected and flushed with 7,570 l (2000 gal) of potable water. The dye did not resurge at Croft Spring but instead resurged 45 days after injection at McNally Drive Spring located about 609.6 m (2,000 ft) east of the site. This data agreed with the flow direction indicated by a downgradient trough in the water table. Therefore, the dye tracer results indicated that the General Electric facility was not responsible for the contaminants resurging from Croft Spring.

Five additional dyes were injected into monitoring wells and open excavated pits in the vicinity of the SAAD Oil facility and CSX Radnor Yard. Eosine (Color Index: Acid Red 87) dye injected into a pit at the SAAD Oil site was detected 103 days later at Croft Spring, and interestingly, also detected 103 days after injection at the CSX Radnor Yard Outfall Spring. Rhodamine WT (Color Index: Acid Red 388) dye injected into a monitoring well at the CSX Radnor Yard site was detected at the Radnor Yard Outfall Spring 102 days later and at Croft Spring 174 days after injection. Three other dyes injected in the vicinity of the SAAD Oil site and at CSX Radnor Yard were also detected at both springs with dye flow rates that varied from 5.25 to 9.43 m (17.24 to 30.93 ft) per day. Interestingly, slug tests performed on several monitoring wells in the vicinity by previous consultants indicated an approximate flow rate of 40.2 m (132 ft) per year. Slug and pumping tests do not provide valid data in most karst aquifers as has been demonstrated on numerous occasions by dye tracer tests.

The dye tracer investigation revealed that groundwater flow from the

General Electric factory flows directly to McNally Drive Spring and does not flow to any other location. The results of the dye tracer investigation indicated that groundwater from the SAAD Oil and the CSX Radnor Yard sites, both located along a ridge in the water table, flowed to both Croft Spring to the east and to the Radnor Yard Outfall Spring to the west.

Site Conceptual Hydrogeologic Model

Figure 1 is a site conceptual hydrogeologic model showing the water table contours, the results of the six dye traces and the approximate location of the groundwater divide boundaries between the Croft Spring Groundwater Basin, the Radnor Yard Outfall Spring Groundwater Basin and the McNally Drive Spring Groundwater Basin. The diagram clearly shows that five of the dyes injected along the top of the groundwater ridge flowed downgradient to both Croft Spring to the east and Radnor Yard Outfall Spring to the west.

Figure 2 is a hydrogeologic profile from Radnor Yard Outfall Spring across the drainage divide to Croft Spring, and it clearly reveals how groundwater flows to both springs. The placement of 9.1 to 15.2 m (30 to 50 ft) of fill material along the headwaters of Brown Creek by the CSX Railroad had a damming effect upon groundwater flow. Not filling the area near the headwaters of Brown Creek created a large depression approximately 457 m (1,500 ft) in diameter. CSX Railroad installed a storm sewer to drain this large depression which extended under CSX Radnor Yard to discharge at the Radnor Yard Outfall. The fill material increased infiltration and reduced storm water runoff causing the water table to rise above the storm sewer, even during base flow conditions as indicated in Figure 2. Therefore, groundwater has been flowing out the Radnor Yard Outfall since its construction in the 1950s. It also appears that this large area of fill material displaced the water table divide to the west, and the divide is now located directly under the Radnor Yard surface depression (Figure 2). Since the dyes injected in the vicinity of the SAAD Oil and the CSX Radnor Yard sites were injected into the regolith (residuum) along this divide, some of the dye traveled to Croft Spring, but some also flowed into the storm sewer to discharge in the opposite direction at the Radnor Yard Outfall Spring. Therefore, the site conceptual hydrogeologic model indicates that SAAD Oil and CSX Railroad are both responsible for the groundwater contamination of Croft Spring and Radnor Yard Outfall Spring. This investigation provides a good example of the application of dye tracer techniques in the preparation of a conceptual hydrogeologic model for a contaminated karst aquifer. It provided definitive evidence of contaminant flow through this karst aquifer, and the results have withstood serious scrutiny by not only government regulatory agencies but also numerous attorneys representing all three companies.

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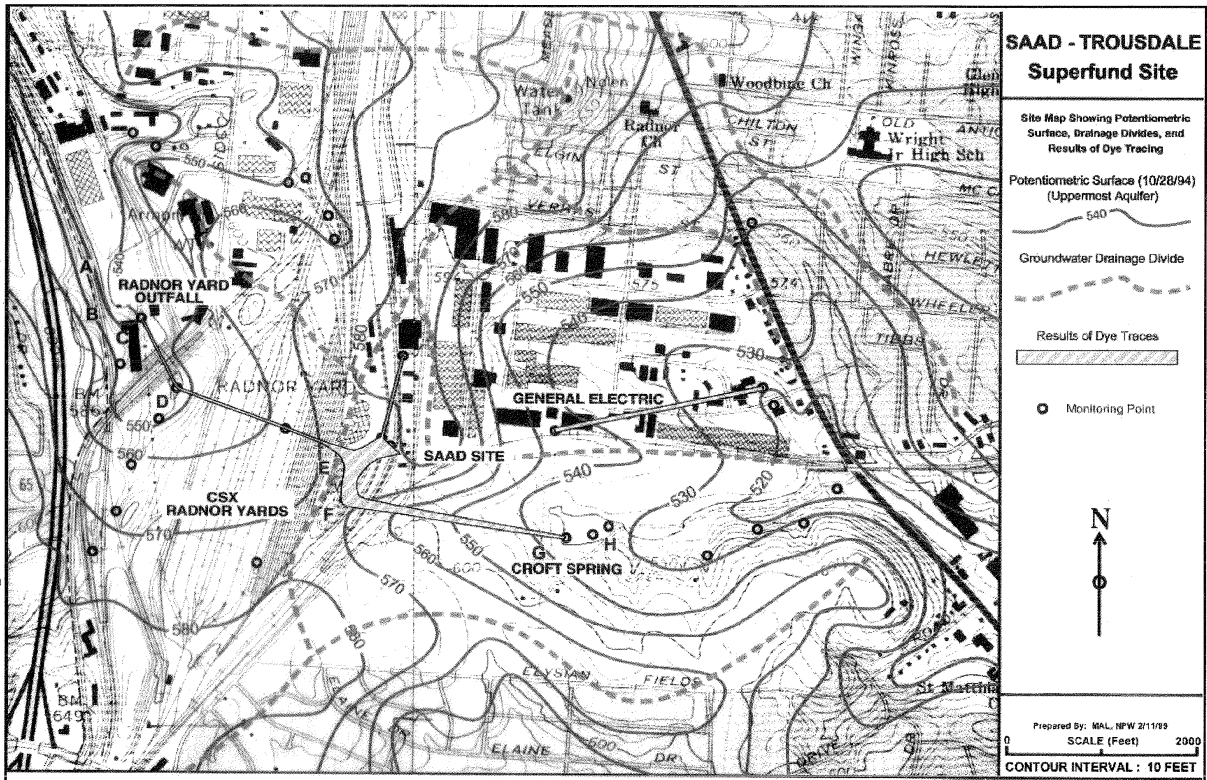


Figure 1. Site conceptual hydrogeologic model showing water table contours, groundwater basin drainage boundaries and dye traces.

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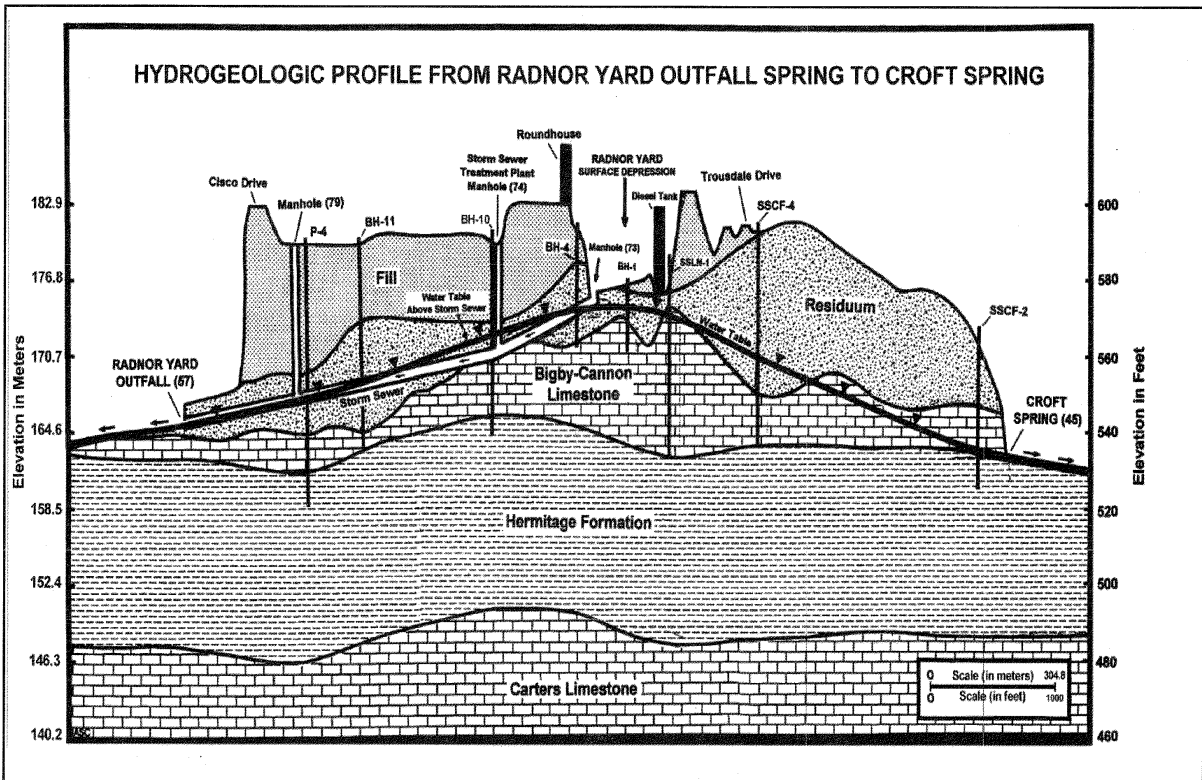


Figure 2. Hydrogeologic profile from Radnor Yard Outfall Spring to Croft Spring.

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Development of innovative karst hydrogeologic research techniques for solving karst environmental problems

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Since its inception in 1978, The Center for Cave and Karst Studies has played a major role in the development of innovative techniques to facilitate the work of geologists, hydrologists and engineers in karst terrains. These techniques include: cave exploration and mapping, dye tracer tests to determine groundwater flow through karst aquifers, and microgravity and electrical resistivity to investigate karst subsurface conditions. The techniques provide accurate karst hydrogeologic information to engineers and planners who can then make informed decisions on how to best protect the public and karst environment. Karst hydrogeologic investigations have dealt with proposed routes for highways, dam locations, foundations for proposed buildings, storm water runoff, and various groundwater contamination, sinkhole collapse and sinkhole flooding problems. The Center has received numerous grants and contracts from various federal, state and local government agencies as well as numerous engineering and environmental consulting firms from throughout the U.S.A. as well as several foreign countries. Several applications are provided within this paper.

The applied research within the Center provides a major learning experience for Western Kentucky University undergraduate and graduate students. They have the opportunity to work on "real world" problems in cooperation with Center faculty and professional staff. These research experiences facilitate their employment after graduation. Several graduate and undergraduate students are listed as coauthors of this paper.

Introduction

The Center for Cave and Karst Studies, established in 1978 at Western Kentucky University, was the first center established primarily to deal with karst problems in the U.S. The Center's offices and labs are located within the Department of Geography and Geology in the Environmental Sciences and Technology Building at Western Kentucky University. The Center's personnel consist of a director, chemist/laboratory manager, research hydrologist, education coordinator, office coordinator and graduate and undergraduate assistants.

The objectives of the Center are as follows:

- (1) To be a research center dealing with all aspects of cave and karst studies, with an emphasis on solving environmental problems associated with karst;
- (2) To provide educational programs concerning cave and karst studies: a) undergraduate and graduate instruction, b) cooperative education program with Mammoth Cave National Park International Center for Science and Learning, c) workshops, seminars, and scientific meetings;
- (3) To provide public service by assisting individuals, private firms, and government agencies with karst environmental problems.

Over the past twenty-seven years, the Center has attracted outstanding undergraduate and graduate students from various parts of the United States. Graduate and undergraduate research assistants are actively involved in the research efforts of the Center. Several graduate students, and even a few undergraduate students, have a substantial number of publications and presentations to their credit. Students get "hands-on" experience in dealing with karst groundwater problems through the Center's research

for government agencies, as well as for private business. Our graduates have been very successful in obtaining positions with both government and private consulting firms.

Subsurface investigations**Microgravity**

Gravity surveys are used to detect variation in the density of subsurface materials. Variations in the earth's gravitational field higher than normal indicate underlying material of higher density while areas of low gravity indicate areas of lower density. In most karst areas, the following average density values are assumed:

Air = 0 g/cm³ Water = 1.0 g/cm³ Sandstone = 2.35 g/cm³
 Regolith or cave sediments = 1.5 g/cm³ Limestone = 2.5 g/cm³

Therefore, density contrasts of 1.0 to 2.5 g/cm³ are anticipated for any subsurface cavity, depending on whether the cavity is filled with air, water or sediment. This makes the microgravity method a good technique to investigate subsurface conditions in the vicinity of sinkhole collapses. Microgravity provides useful information concerning a) depth to bedrock, b) extent and shape of a void below the surface, c) location of a crevice, or crevices, through which regolith and water are sinking and d) additional regolith voids in the vicinity of a sinkhole collapse (Crawford 1999 and 2000). In order to detect voids or cavities, very high precision is required. A SCINTREX CG-3M Autograv Microgravity Meter that has a 0.5-microGal sensitivity is used by the Center.

After all corrections have been calculated, the reduced data consists of a Simple Bouguer Gravity value for each measured point. Increasingly negative values for Bouguer gravity indicate greater deficits in mass below each measurement point. Graphic plotting of data produces a trend line that illustrates the relative fluctuations in gravity along each traverse.

Electrical resistivity

Electrical resistivity surveys provide an image of the subsurface resistivity distribution. Features that are not good conductors of electricity, such as air-filled voids in the regolith or a cave in the bedrock, result in high resistivity anomalies. This makes the resistivity method a good exploratory technique for investigating karst subsurface features, or where depth to bedrock is needed.

Several different electrode configurations can be used to collect resistivity data. These include the Schlumberger, Wenner, Pole-Pole, Pole-Dipole, Square arrays, and Dipole-Dipole. The Dipole-Dipole array generally provides the highest precision, permits reasonable depth investigation and has the greatest sensitivity to vertical resolution and data coverage (Loke, 1998).

The resistance measurements gathered by the field survey are reduced to apparent resistivity values. This conversion is performed by the AGI Administrator Version 1.1.0.4 program. The RES2DINV program is then used to convert the apparent resistivity values into a resistivity profile model that permits interpretation of the subsurface. The modeled results along a traverse are calibrated by comparing observed anomalies with physical data, such as, topographic maps, geologic quadrangles, rock outcrops, and drilling/boring data.

Cave mapping

Many jobs require caves within or near investigated sites to be explored and mapped in order to determine if the underlying cave is within the proposed project area. Surveying is done with a nylon tape, Suunto compass and clinometer. Backsights are taken within one degree. The cave passages are surveyed and sketched and profile sections of the cave dimensions are provided on the cave maps. Dimensions such as shot length and bearing can be inputted into a program known as COMPASS which produces a line plot of the survey data. However to gain more information on the size, shape and orientation of the rooms so that more can be learned of the geology, hydrology and origin, more information such as left, right, up and down measurements must be added so that a 3-D model can be created.

Cave radio

In order to better coordinate the subsurface position and depth of a cave with that of surface features, an instrument referred to as cave radio is used. This technique uses a receiver antenna to locate the position of a transmitter beacon, called a cave radio, placed inside the cave, which emits a very low frequency signal, generated by an amplifier attached to the transmitter antenna, resulting in a magnetic field (Figure 1). Therefore, the technique works through magnetic induction rather than audible radio waves. When the receiver antenna is in such a position that it no longer detects the magnetic field, the exact position of the underlying transmitter beacon can be determined (Gibson 2002).

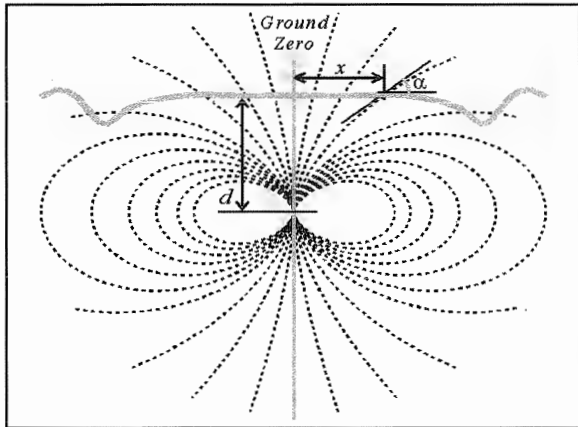


Figure 1: Magnetic field lines from an underground transmitter. Image courtesy of www.caves.org.uk/radio/radioloc_for_cave.html

Dye tracer investigations

Research Procedures

Karst hydrogeologic inventory

The field survey for the Karst Hydrogeologic Inventory is conducted under conditions ranging from moderate to high flow during a wet period when all resurgence points are active. The survey is conducted by walking or floating all streams and associated impoundments (lakes, ponds) in the study area to visually identify karst features including but not limited to: Springs, seeps, sinkholes, swallets, karst windows, sinking streams and caves.

The features are located on a 7.5-minute series topographic map. Each feature is given a name and a unique inventory number. General information and physical characteristics of the feature are recorded on the Karst Feature Inventory Form. The physical characteristics of inventoried springs, streams, and wells include a measurement or estimate of the discharge and measurement of the temperature, specific conductance, and

pH. The feature is photographed to complete the inventory record. The results aid in the dye receptor location placement.

Lineament analysis

A lineament analysis is performed for the area within and surrounding the study area using topographic and geologic maps, the county soil atlas and aerial photographs. A field investigation is necessary to confirm the accuracy of the geologic map and to identify important geologic features not on the map, such as joint sets, prominent bedding plane partings, chert or shale beds that might constitute confining layers, etc. This information combined with field measurements of joints, strike and dip, etc. provide indicators of possible groundwater flow routes. It also provide important information for locating monitoring wells if needed.

Potentiometric surface mapping

All accessible water wells and monitoring wells in the area are measured during a dry period and the depth to water subtracted from the ground surface elevation. In addition to wells, the elevations of springs, karst windows and selected points along streams and lakes are measured by leveling. These elevations and terrain features, such as, topography, sinkhole distribution, sinking streams, cave locations, etc. are used to construct a map of the water table (Figure 2) for the uppermost aquifer. If sufficient wells are available, it may be possible to delimit groundwater basin divides.



Figure 2: Potentiometric Surface map of investigated site.

Background monitoring and matrix interference

The Background Fluorescence Monitoring task involves the monitoring of springs, wells and streams in the study area for background concentrations of dye from previous dye traces, pollution, and natural interference. The results of the background monitoring is used to evaluate the appropriate dyes and dye concentrations to be used for the dye tracer investigation. In addition, a matrix interference investigation may be needed previous to selection of the dye or dyes to be used. This involves a laboratory investigation to measure the potential impact of chemicals in the groundwater on the dye concentration, the adsorption of the dye by the charcoal or the release of dye from the charcoal during elution.

Analysis Procedures

Charcoal and water analysis

Analysis on a scanning spectrofluorophotometer provides the lowest detection limits and most reliable dye analysis. For a typical analysis for

Tinopal CBS-X, Direct Yellow 96, Fluorescein, Rhodamine WT, Eosine, FD&C Red 3, D&C Red 28 or Sulphorhodamine B, a synchronous scan is performed where the excitation and emission monochromators are kept at a fixed wavelength separation during the scan. If the scan indicates positive results for fluorescent dye, a second printout is made utilizing spectrum integration and calibration curves stored in the computer to determine the concentration of the dye or dyes. If the sample is a water sample, the scanning parameters are adjusted to compensate for shifts in the excitation and emission maximum wavelengths as well as differences in the Stoke's shift caused by the differences in pH and polarity of water as compared to eluent.

Quantitative dye tracing

Quantitative dye tracing involves installing ISCO automatic water samplers at the hypothesized spring or springs. The collected samples are then analyzed according to water sample analysis procedures. This provides a graph of the complete dye breakthrough curve at the spring or springs (Figure 4). A quantitative trace is often performed simultaneously with the qualitative dye receptor trace. It provides more definitive proof of dye flow to a spring since the dye concentration in the water is measured during the entire passage of the dye cloud as it flows from the spring.

Case studies

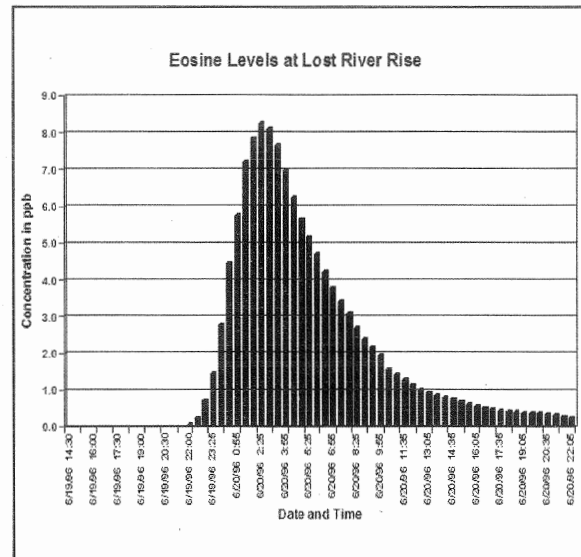


Figure 4: Histogram showing breakthrough curve during quantitative trace.

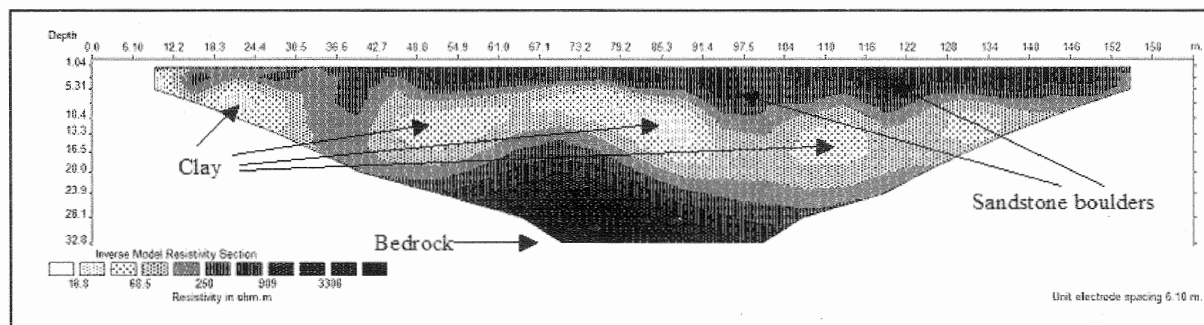


Figure 5: Electrical resistivity profile showing deep depths to bedrock and the presence of conductive clays below resistive sandstone boulders

Proposed highways

Microgravity and electrical resistivity were used to locate possible voids in the regolith and/or bedrock under the proposed roadway for the new Highway 27 route in east Kentucky. In addition, the area contained three caves whose entrances were near the investigated site. The research approach was to conduct microgravity and electrical resistivity traverses down the center of the northbound and southbound lanes and along each shoulder and to explore and map each cave. The microgravity stations and the resistivity electrodes were placed in the same locations so that the data could be compared. The cave passages were surveyed and mapped so that the caves could be placed on a site map for comparison with the locations of the roadways. This research confirmed that the engineers would not have to adjust their plans due to the caves, but that changes had to be made to deal with large amounts of deep, unexpected clays during construction of the road and to plan for deeper depths to bedrock that were discovered during the investigation (Figure 5).

Sinkhole Collapse

Microgravity was used to locate a possible sinkhole collapse underneath a preexisting distribution warehouse. The area, prior to construction, had been pockmarked with sinkhole collapses that were repaired before the building was completed. However, a sinkhole collapse occurred at the

east end of the building years later. The business was concerned of the possibility of other collapses occurring in less accessible locations beneath the building. Areas of low gravity that could be considered hazardous and subject to surveillance were located. The previous collapse was visible on the microgravity data (anomalies E and F, Figure 6) due to a remediation failure, along with other lesser anomalies (anomalies A-D, Figure 6). A profile extending from areas of higher gravity to areas of lower gravity can be seen in Figure 7.

Ground water contamination

An oil leak from a pipeline company line was discovered in Central Tennessee. As part of the emergency response a dye trace study was conducted. The study intended to determine probable resurgence points of the oil at springs or surface streams. Dye tracing, Potentiometric mapping and geologic mapping were used to determine site hydrology (Figure 9).

The dyes injected at the pipeline spill site resurged at Four Spring on the opposite side of the Stones River. The research revealed that a cave stream from the site flowed under the perennial Stones River, which is flowing upon the Lower Ridley Limestone confining layer at this location. The flow through the karst aquifer was down dip toward a structural low located on the opposite side of the Stones River.

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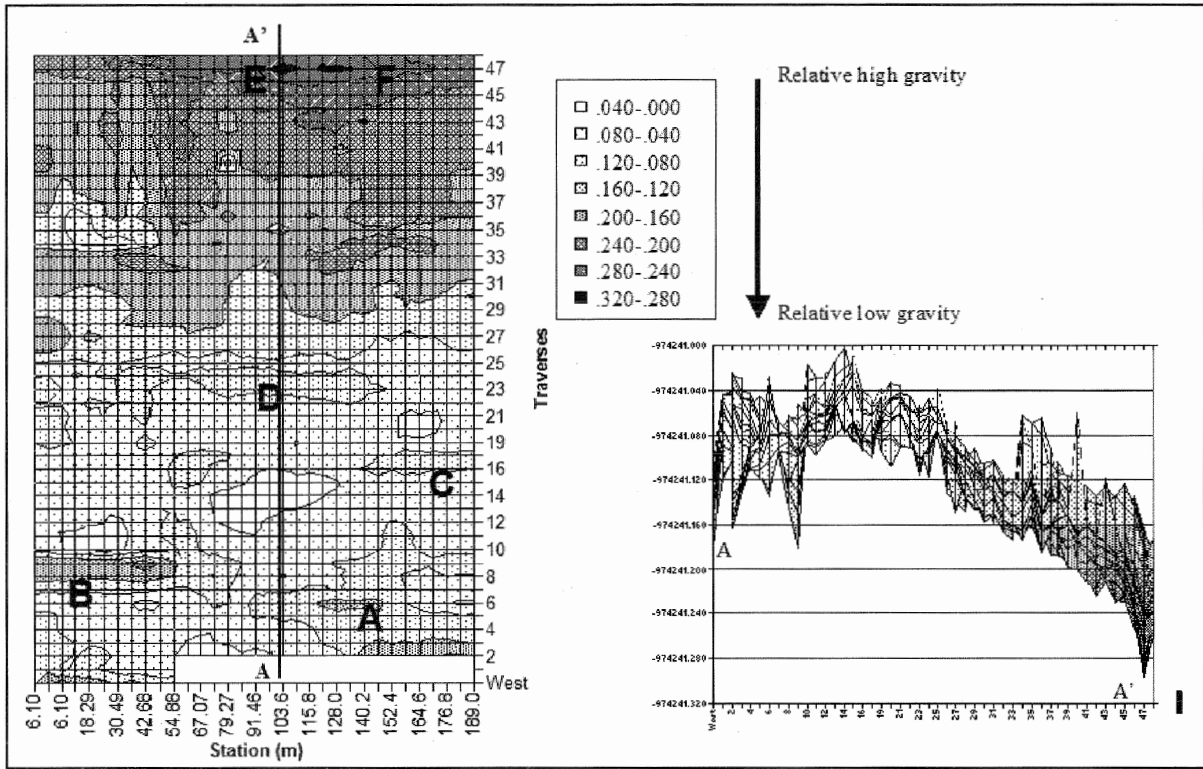


Figure 6: Contoured microgravity

Figure 7: Microgravity profile along Line A-A'

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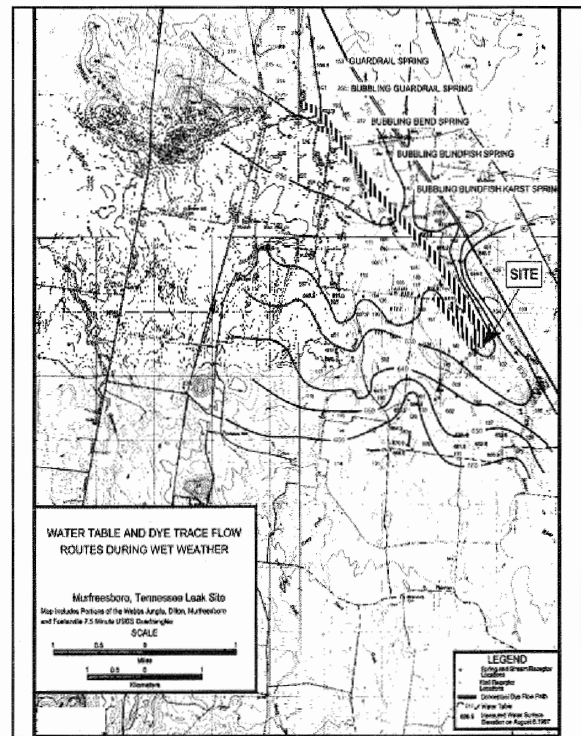


Figure 9: Portion of the map showing water table and dye trace flow routes.

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Drip-water monitoring in a superficial Alpine cave (Cogola di Giazzera, Trentino, NE Italy)Renza Miorandi¹, Andrea Borsato¹, Silvia Frisia¹ & Flavio Corradini²⁽¹⁾ Museo Tridentino di Scienze Naturali, Trento, Italy - miorandi@mts.n.tn.it;⁽²⁾ Istituto Agrario di S. Michele all'Adige, Trento, Italy**Abstract**

The two-year-long drip-water monitoring of ten stalactites at Cogola di Giazzera cave located on the Pasubio mountain (Trento Province, NE of Italy) reveals the predominant seasonal discharge of all the studied stalactites. The discharge, electrical conductivity and saturation state of the stalactite drips are directly controlled by the infiltration events and, as a whole, the longer is the time elapse from the infiltration event the lower is the drip-rate, and electrical conductivity of the water. This latter phenomenon is clearly related to prior calcite precipitation along the flow-path, both in the rock above the cave and within the cave itself along the feeding stalactites. In fact, the chemical analyses of two stalactite drips (G1 and G10) reveal a linear relationship between Ca content and calcite saturation state ($R^2 = 0.74$ for G1 and 0.67 for G10), an exponential correlation between drip rate and Ca content ($R^2 = 0.59$ for G1 and 0.85 for G10) and an exponential correlation between drip rate and calcite saturation state ($R^2 = 0.41$ for G1 and 0.47 for G10).

Riassunto

Il monitoraggio di due anni del drip-water di dieci stalattiti alla Cogola di Giazzera, situata sul Massiccio del Monte Pasubio (Provincia di Trento, Italia nord-orientale), rivela un dominante flusso stagionale per tutte le stalattiti studiate. Il flusso, la conducibilità elettrica e lo stato di saturazione dei drip di queste dieci stalattiti sono direttamente controllati dagli eventi di infiltrazione e, nel complesso, più è lungo il tempo di mancata infiltrazione, più è lento il drip-rate e più è bassa la conducibilità elettrica dell'acqua di stillicidio. Quest'ultimo aspetto è chiaramente collegato con la precipitazione di calcite lungo le fessure di scorrimento dell'acqua, sia attraverso la roccia soprastante la grotta sia all'interno della cavità stessa lungo i punti di alimentazione delle stalattiti. Infatti, le analisi chimiche dell'acqua di stillicidio di due stalattiti (G1 e G2) rivelano una relazione lineare tra il drip-rate e il contenuto di Ca ($R^2 = 0.59$ per la G1 e 0.85 per la G10) e una relazione esponenziale tra il drip-rate e lo stato di saturazione della calcite ($R^2 = 0.41$ per la G1 e 0.47 per la G10).

1. Introduction

Dripwater monitoring is more and more utilised for testing the present-day cave environment condition in order to calibrate the paleoclimate proxy-data extracted from speleothems (Borsato, 1995; Baker et al., 1995). In the frame of the AQUAPAST project - which aim was to reconstruct past climate in Trentino region studying speleothems from different caves - was monitored chemical and physical parameters for five caves in Trentino. One of this monitored caves was Cogola di Giazzera that we are going to illustrate.

2. Cave site and environmental setting

Cogola di Giazzera is located on the Pasubio mountain in the Trento Province, NE of Italy (Longitude $11^{\circ}05'50''$; Latitude $45^{\circ}51'11''$ N) at the elevation of 1025 m a.s.l. The cave is cut in fissured Lower Jurassic well-bedded limestones (Calcarei Grigi formation), with a maximum rock overburden of 30 m (Fig.1). The cave opens on a slope with a south-west orientation covered by deciduous forest with brown-calcareous soil cover.

The cave entrance is a big chamber at the end of which starts a gallery

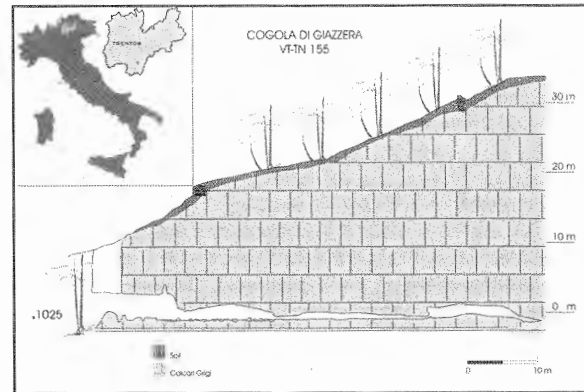


Fig.1. Location map and cross-section of Cogola di Giazzera cave.

consisting in a single 20 m long chamber connected by a flat, narrow passage with the entrance chamber. A second very narrow passage lets to the last chamber of the cave where the monitoring program and the following palaeoclimatic study were carried out. The central area of the terminal chamber is decorated with hundreds of stalactites, stalactites and columns (Fig. 2), with several active morphologies and small pools.

The precipitation in the area (Terragnolo meteorological station, 800

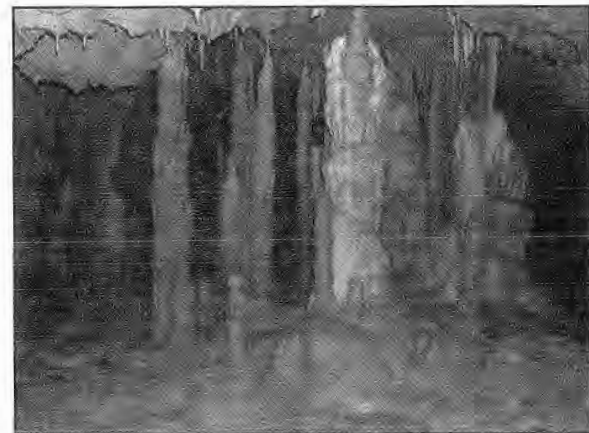


Fig. 2. Several stalagmites and columns in the terminal chamber.

m a.s.l.), is 1162 mm/year (average period 1923 to 1990) and show a bimodal distribution with a maximum between April and June and a second maximum in October- November. The mean annual air temperature at the cave site is about 8.8°C , while the mean monthly temperature is near zero from December to February, period during which the area is cover by snow. The theoretical infiltration, calculated using the Thornthwaite formula, show summer dryness from June to August and occasionally in September, whereas the highest values are recorded in November (110 mm), October (90 mm) and December (75 mm). The result is a strong seasonal signal that is recorded in the fabric of the active growing stalagmites that are mostly composed by dendritic texture.

3. Material and methods

The monitoring program started in 2002 and lasted for two years including a hydrogeological and microclimatic study of the cave. To realise that some instruments were installed in the terminal chamber and the cave was visited each month. We utilise a Logotronic temperature and electrical conductivity (EC) datalogger for the G1 stalactite drip (EC range: 1-2000 $\mu\text{S}/\text{cm}$, accuracy of $\pm 1 \mu\text{S}/\text{cm}$, resolution 0.1 $\mu\text{S}/\text{cm}$; temperature range: -5 to 100 $^{\circ}\text{C}$, accuracy: $\pm 0.2^{\circ}\text{C}$, resolution 0.01 $^{\circ}\text{C}$) and two Hanna Instruments datalogger for the air temperature (range: -10 to +40 $^{\circ}\text{C}$, resolution: $\pm 0.1^{\circ}\text{C}$). Electrical conductivity, pH and temperature were checked monthly by a portable WTW Multivarn instrument that has similar technical characteristics of the Logotronic datalogger. All the EC measurements are corrected to the reference temperature of 20 $^{\circ}\text{C}$.

Inside the terminal chamber 10 stalactites (G1 to G10) with different drip-rates and response time were chosen for the monthly measure of the drip rate in order to investigate the hydrological behaviour and the lag-time of the aquifer with respect to the infiltration events. Two of the most regular drip points (G1 and G10) were chosen to collect water for chemical and isotopical analyses. Being that the water flux for each stalactite was quite slow (mean annual flow < 0.1 ml/min) we utilise 500 cc plastic bottles below each drip site to collect enough water for chemical analyses that were carried out at San Michele all'Adige laboratory. The chemical analyses include the ionic composition, pH, EC and alkalinity that allow to calculate the calcite saturation state. Moreover, below four other drips, were installed glass templates used to investigate the present-day calcite precipitation.

4. Results and discussion

4.1. Drip-water discharge

The two-years period records a different annual precipitation amount with 1793.8 mm during the 2002 and 730.6 mm during the 2003 (Ter-

ragnolo meteorological station). However, the strongest annual difference was the snow precipitation that, in the quarter from January to March varied from 176.2 mm in 2002 to 36.6 mm in 2003 (fig. 3 A).

The measured stalactite drips show a mean annual discharge between 0.6 and 0.006 ml/min (i.e. $\sim 10\text{-}5$ to $10\text{-}8 \text{ L s}^{-1}$), with a marked variability from one to the other and less pronounced intra-annual variability. Figure 2 B show the trend of five stalactites that represents the whole spectrum of the 10 monitored ones. The general feature of the two years monitoring is a clear seasonal trend, with drip-rate increase in late autumn following the November recharge and a progressively decrease, punctuated by episodic short-living increases, in spring and summer. The major difference from 3/4 2002 and 2003 is the strong recharge in late February 2002 due to the snow melting that is not present in 2003 due to the near-absence of snow precipitation in the winter. Discharge of stalactites G1 and G2 are more constant during the year while G7, G9 and G10 display a greater variability and during some period (Jan to Feb 2002 and autumn 2003) they reduced strongly the discharge and some of them stopped. Nevertheless, as a whole the coefficient of variability of all the drips vary between 50 to 150%, with few intraannual variability, and match the field of "seasonal drip" follow Smart and Friedrich, 1987 and Baker et al., 1999 definitions.

4.2. Electrical conductivity and temperature

The general trend of electrical conductivity measured on G1 drip-water (Fig. 3 C) is characterized by some abrupt increase in EC up to 70-90 $\mu\text{S}/\text{cm}$ followed by gradual decreases. The more pronounced of these latter occurred in winter-spring 2003 when was reached the lowest value of 234 $\mu\text{S}/\text{cm}$. The strongest EC increases are due to precipitation events exceeding 20 mm (19.11.02, 19.05.03, 17.11.03, 29.11.03) or, only for 2002, to snow melting event (22.02.02). The lag-time between the EC rising and the mid-point of the rainfall events vary from 12 to 48 hours. These episodes triggered the drip-rate increase in all the monitored stalactites and the strongest drip-rate increases are recorded in the faster discharge stalactites G7 and G10 (cf. Fig. 3 B and C). The general trend, therefore, is exactly the opposite of fast dripping stalactites monitored at Grotta di Ernesto, that open about 45 km NE from Cogola di Giazzera, were the strongest rainfalls were followed by abrupt EC drops of -20 to -50 $\mu\text{S}/\text{cm}$ due to the fast infiltration of the lowmineralized water associated to the rainfall events (Borsato, 1997).

Figure 2 C visualize the water temperature: although the terminal chamber is near to the cave entrance, and the rock overburden is less than 25 m, the temperature is constant throughout the year with a mean value of 8.08 $^{\circ}\text{C}$. In the graphic are visible some minor peaks that are connected with the monthly visits to the cave that usually last 2 hours.

The cave needs one or two days to re-equilibrate its temperature.

4.3. Calcium content and saturation state

Figure 4 visualize the relationship between drip-rate, Ca content and calcite saturation (SIcc) of drip G1 and G10. For both stalactites there is a clear positive correlation between the three variables. In particular, we observe a linear relationship between Ca content and SIcc ($R^2 = 0.74$ for G1 and 0.67 for G10), and an exponential correlation between drip rate and Ca content ($R^2 = 0.59$ for G1 and 0.85 for G10). The exponential correlation between drip rate and SIcc ($R^2 = 0.41$ for G1 and 0.47 for G10) is weaker, due to some dispersion at low-SI values, but still striking. These situation reflects the calcite precipitation inside the aquifer and along the flow-path in the cave (mostly along the feeding stalactite), that lower the Ca content and the SIcc during low-discharge periods.

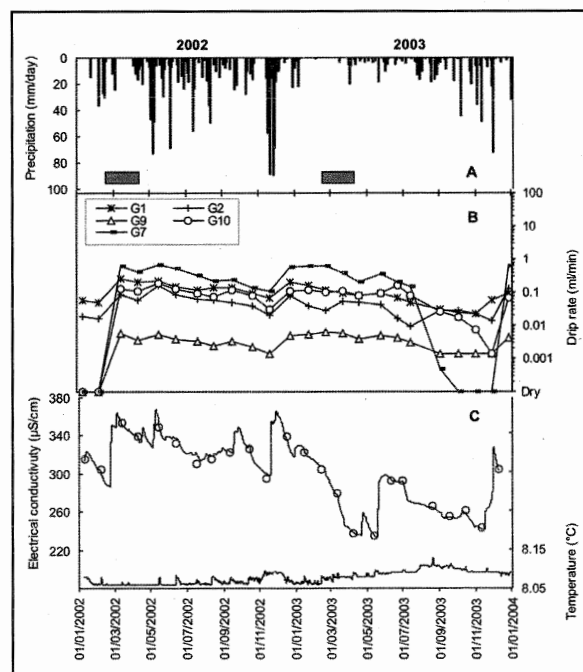


Fig. 3. Two-year long drip rates of five selected stalactites in Cogola di Giazzera main chamber (B) compared with the rainfall record at Terragnolo (A) and the electrical conductivity and temperature continuous monitoring of stalactite G1. The grey bars in (A) represent the snow-melt periods; the circles in (C) the periodic electrical conductivity measurements.

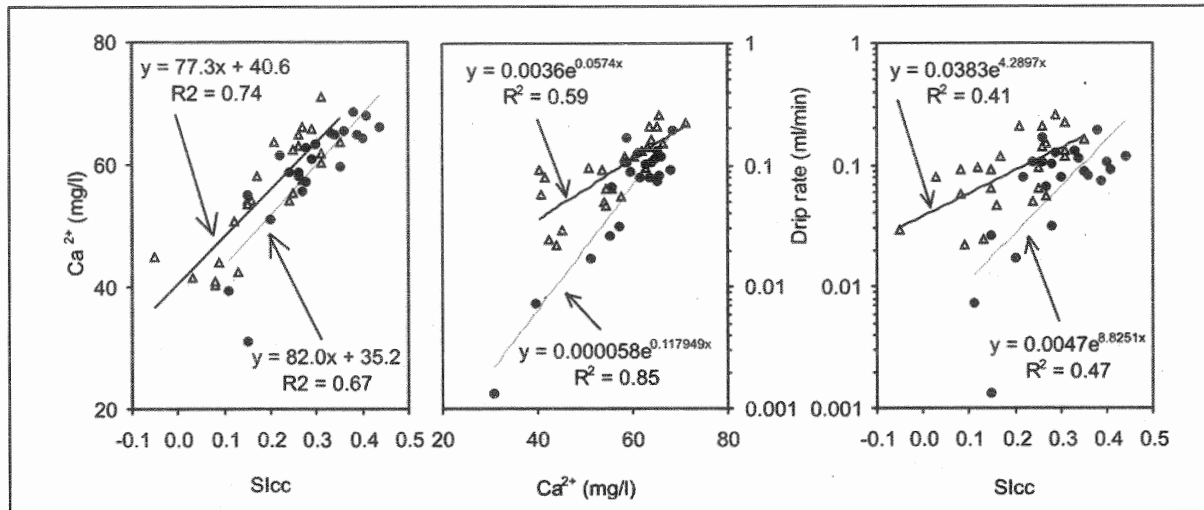


Fig. 4. Correlation between Ca content saturation state and drip-rate of stalactites G1 (triangles) and G10 (black circles) for 24 monthly measurements.

5. Conclusion

The two-year-long stalactite drip-water monitoring at Cogola di Giazza reveals the predominant seasonal discharge of all the studied stalactites. The discharge, electrical conductivity and saturation state of the stalactite drips are directly controlled by the infiltration events and, as a whole, the longer is the time elapse from the infiltration event the lower is the drip-rate, Ca content, electrical conductivity and calcite saturation state of the water. This feature is clearly related to prior calcite precipitation along the flow-path, both in the rock above the cave and within the cave itself on the stalactite. This study testify the peculiarity of shallow caves in fissured aquifer with respect to karst hydrology, and the implication for palaeoclimatic reconstruction from speleothems. The cave show an enhance sensitivity that can record even sub-annual and monthly-long episodes, but is prone to possible discontinuous growth during drier periods.

Acknowledgements

The study is part of the AQUAPAST project funded by the Autonomous Province of Trento.

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The geothermal flux shielding by deep drainage conduits

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Abstract

The geothermal flux role is analysed for mountain with underground water or air drainage in conduits. The problem of interaction between caves and the geothermal flux is converted to classical thermo-engineering problems in terms of shape factors. It is then possible to show that the fluid flow perturbs the whole rock temperature field until the geothermal flux of a large area is focalised onto the conduits. The introduction of the "geothermal cross section" of an underground drainage structure allows to improve the classical formula of minimum provenance depth of a geothermal water, always underestimated, and the geothermal heating of caves.

The geothermal energy flux

It is widely known that the rocks below us have a temperature that increases with depth due to a thermal energy flux coming from the Earth bulk.

The geothermal flux is widely variable but the world average (VERHOOGEN, 1956) is

$$F_{gt} = 0.06 \text{ W m}^{-2}$$

That is some 60 kW per square kilometre.

The geothermal flux will heat the rock until the temperature gradient in it becomes able to evacuate the geothermal power on the surface. This equilibrium condition is then obtained when the gradient is

$$F_{gt} = K_R \frac{\partial T}{\partial z}$$

In this case we can assume a rock thermal conductivity $K_R = 2.5 \text{ W m}^{-1} \text{ K}^{-1}$, typical for granite, whilst the limestone conductivity is some 10% less. The temperature gradient at the equilibrium is 24 °C per kilometre.

At first, this appear not true in the case of caves' atmospheres, that are really quite cold (essentially at the external average yearly temperature (BADINO, 2004) -from hereafter T_{ave} -) whilst the mines' atmospheres can be very hot.

It is then useful to compare two Underground Neutrino Observatories, in Mont Blanc (between France and Italy) and in Gran Sasso (in central Italy), which are assembled in halls in motorway tunnels. The depth of first, dismissed in 2001, was some 1800 m below the surface, at an altitude of 1300 m asl, whilst the depth of second is around 1050 m at an altitude of 1000 m asl. Their temperatures are nevertheless completely different, in the first it is around 32 °C, in the second at 6 °C, the two unsuitable for working.

The reason of the two different temperatures is the different rock permeability.

The Mont Blanc rock is mainly granite and the waters met by tunnel were essentially fossil waters, the meteoric water circulation being quite epidermal (up to depth of 100-200 m below the surface), with some exception localized along large major rock discontinuities.

The Gran Sasso rocks is limestone. The infiltration waters at the surface are at T_{ave} , and cross the whole mountain easily and with small heating.

Then into the Mt Blanc's depth there are essentially "mines" waters in thermal equilibrium with hot, deep rocks, whilst the deep Gran Sasso waters are essentially external waters, in equilibrium with the atmosphere.

Underground high temperatures are connected with good thermal insulations, then a tunnel, or a mine, can be excavated across rocks that are

very hot (high temperature) because, i) they have almost no contact with surface and ii) they have then acquired equilibrium with the geothermal flux. In this work we are going to discuss systems that have attained stationarity, i.e. they have assumed the asymptotic thermal configuration.

The problem of infiltration temperature

The formula (CELICO, 1986) that gives the minimum depth attained by a geothermal water is based on the assumption that underground does exist a first layer (heterothermic) in thermal contact with the atmosphere, below which the rock temperature increases in conductive regime (homothermic region). In the upper Earth surface layers the geothermal energy is intercepted by water that release it to the atmosphere at the springs.

The energy that comes onto a large surface A is $F_{gt} A$.

If the precipitation is P, the infiltration is P minus the part P_{out} "lost" outside due to evaporation. Then the enthalpy extracted from the system is $(P - P_{out}) \Delta T_{gt} A$, where ΔT_{gt} is the water temperature increase during deep flow. At stationarity this term has to be equal with $F_{gt} A$, then, calling P^* the infiltration in [mm y^{-1}], we can write

HERE GEOTHERMAL_FIG_1.JPG

$$\Delta T_{gt} = \frac{0.06}{4.2 \times 10^3 (P - P_{out})} = \frac{500}{P^*} [^{\circ}\text{C}]$$

The upper parts of drainage systems are almost exactly at T_{ave} , then the water is in general warmed of ΔT_{gt} between the lowest cave parts and the springs, that is along the flow in the phreatic systems.

In alpine karsts P^* is some 1000 mm y^{-1} and then the water average temperature increase is some 0.5°C. Bögli (BOGLI, 1980) estimates reasonably 0.2°C, Mathey (MATHEY, 1974) estimates a maximum of 0.55°C.

The problem

Nevertheless in karst we are dealing with conduits, not with plane water-tables. The scenario of a regular, flat, diffuse water table in general it gives wrong results in the internal rock temperature field estimations.

To study a more real model it is necessary to estimate the energy interception made by a finite system buried in a semi-infinite medium in which a thermal flux F_{gt} is flowing from infinite.

The temperature field at depth H below the surface is the given by

$$T(H) = T_0 + \left(\frac{\partial T}{\partial z} \right) H = T_0 + \left(\frac{F_{gt}}{K_r} \right) H$$

It is very natural to suppose that the energy intercepted by a deep structure is

$$W = AF_{gt}$$

It is a very natural assumption, but it is false. If we bury a system able to intercept and to evacuate elsewhere the energy, the whole temperature field in the rock changes and then the flux itself changes.

Let us at first discuss it qualitatively, drawing the constant temperature lines in the rock. The Fig. 1 shows a reasonable situation that respects the boundary conditions. It is possible to see two things:

1) The isothermal surfaces have a tendency to converge, then to be focussed, on to the cave;

2) They are "compressed" around the cave.

The thermal flux flows along the maximum T variation and that its value is proportional to the gradient of T then: i) the cave focus on itself the geothermal flux and, ii) in the rock surrounding the cave the geothermal flux is much more intense than the natural one.

The general solution

The problem of temperature and thermal fluxes calculations appears to be very difficult to solve, but there is a simple way to lead it to typical situations of thermal engineering.

Let us consider three different systems:

1) The real system, which we call from hereafter S (Fig. 1);

2) The system composed only of semi-infinite undisturbed rock, without caves and with external temperature equal to 0, which we call from hereafter S' (Fig. 2);

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3) The more complex system S", (Fig. 3), composed by a hot cave at a particular temperature T" buried in a semi-infinite rock, that releases energy to the surface at temperature T₀.

Let us assume that T" in S" is

$$T'' = T_0 + \frac{F_{gt}}{K_r} H$$

These three temperature fields are solution of the Laplace equation (note the stationarity!)

$$\nabla^2 T = 0$$

Its solutions are called "Harmonic Functions", and are among the most important and studied functions in Physics (CARSLAW, 1959), (NASH-CHOKIN, 1979).

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The field structure around S, that we have qualitatively shown, is our unknown term.

The field structure of the second S' it is obvious, it is composed by many horizontal parallel isothermal planes.

The third system is the most exciting. There are almost no lines all around unless in the region between the hot cave and the cold surface, a situation is a very usual situation for engineering: the "hot cave" can be a tube transporting hot fluid buried in some engine...

Now we can do the last step: it is possible to prove that the unknown T field of the system S is given by

$$T(x, y, z) = T''(x, y, z) - T'''(x, y, z)$$

That is, we can subtract the (very complex, but very common) T" field from the trivial T' to obtain our solution T.

The geothermal energy focusing on caves

We can do another step, about the energy flux. It is possible to show that

$$FA = -F_{gt}A - F''A$$

The term FA describes the flux outgoing from the surface in presence of the cave, F_{gt}A the total flux if it would not be the cave, and F" the flux in the system S". Then the energy flux captured by the cave is the difference between the two

$$W_{capt} = F_{capt}A = F_{gt}A - FA = F_{gt}A - F_{gt}A + F''A = F''A$$

In this way the problem of energy interception of a cold cave buried in an energy flux is reduced to the energy transfer between a hot cave and the surface.

The shape factor

The thermal transfer engineering uses a very effective approach to the problem of complex-shape systems, reducing the different geometries to a plane conductive wall, with

$$W = K_r S_F \Delta T$$

The term SF is the ratio between the surface crossed by the thermal energy and the distance between the two sources. It is a "length" that characterizes each system shape that exchanges energy among two sources.

This length is called "shape factor" in literature. Still in simple configuration its calculation is extremely difficult, but the heat-exchanges literature contains many shape factors worked out for the most common geometrical configurations (HOLMAN, 1996).

Table 1		
Semi-infinite medium and spherical cavity of radius R at depth H	$S_F = \frac{4\pi R}{1 - R/2H}$	
Semi-infinite medium with and disc of radius R at depth H	$S_F = \frac{4\pi R}{\pi/2R - \tan^{-1}(R/2H) / 2H}$	
Semi-infinite medium and cylindrical cavity of length L of radius R, at depth H	$S_F = \frac{2\pi L}{\cosh^{-1}(H/R) - R}$	
Semi-infinite medium and cylindrical hole of radius R drilled to a depth H.	$S_F = \frac{2\pi H}{\ln(2H/R)}$	
Semi-infinite medium with and plate (width W, long L, H>>W) parallel to the surface at depth H	$S_F = \frac{2\pi W}{\ln(4L/W)}$	

The geothermal cross sections of caves

Now let us apply these results to our problem: the equation that gives the power intercepted

$$W = K_r S_F \Delta T$$

with the assumed temperature for T", it is reduced to a very simple result

$$W = K_r S_F \frac{F_{gt}}{K_r} H = F_{gt} S_F H$$

That is

$$\text{Intercepted flux} = (\text{geothermal flux}) \times (\text{cave shape factor}) \times (\text{cave depth})$$

The shape factor is something 1-10 times larger that the scale-size of the structure.

The effective area (we shall call it "thermal cross section") for thermal flux absorption of an underground structure is not its geometrical area but instead S_FH, roughly 10 times the cave size multiplied the depth, then it is always enormously greater than the cave actual area!

The amplification is due to the lens effect created by the presence of cold fluids in the cave, that affects the whole structure and shadows from geothermal flux the above rock on enormous volumes (Fig. 4).

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The water heating in deep conduits

In the previous discussion was made the assumption that the water temperature in conduit does not change, because it is its low temperature T_0 that changes the whole temperature field of surrounding rock. This is equivalent to assume that the water flux is so large that the enthalpy intercepted by the conduit flows away in form of a small temperature increase of a very large amount of fluid. We have then that the maximum energy extraction efficiency (W_M) is obtained if T is almost equal to T_0 .

The opposite limit is if the warming is so large that the water temperature T becomes T'' , that of undisturbed rock, and in this case the conduits becomes completely "transparent" to the geothermal flux. The temperature field assumes a regular geothermal gradient not affected by the cave presence and, as a consequence, just few energy is intercepted.

The real cases are intermediate between these two extremes, the water really warms but, as a consequence, its capability to intercept geothermal energy is reduced.

It is possible to show that the "critical fluid flux" Q_c that divides these two scenarios is given by

$$Q_c = \frac{dM}{dt} = \frac{K_R S_F}{C_w} [\text{kg s}^{-1}]$$

With C_w water (or air) thermal specific capacity.

In the case of a conduit in limestone that drain water we have

$$Q_{c,water} = \frac{2.3}{4.2 \times 10^3} S_F = 5.5 \times 10^{-4} S_F [\text{kg s}^{-1}]$$

If the conduit drains air, the critical flux becomes

$$Q_{c,air} = \frac{2.3}{10^3} S_F = 2.3 \times 10^{-4} S_F [\text{kg s}^{-1}]$$

The shape factor is in general comparable with the conduit length, usually some 10^3 - 10^4 m, then the water flux able to create changes in the rock temperature fields is in general quite small.

The critical flux Q_c for air or water are extremely important for another reason: they are the air or water fluxes able to shadow the upper rock from the geothermal flux, forcing it near to the average yearly temperature of external atmosphere.

Geothermal power intercepted

It is easy to relate the actual flux Q to the output temperature T in terms of the critical shielding flux Q_c and the surrounding temperatures. With W_M maximum intercepted power and

$$q = \frac{Q}{Q_c}$$

We have with trivial calculations that the excess temperature above the "external average" T_0 is

$$T - T_0 = \frac{T'' + qT_0}{1 + q} - T_0 = (T'' - T_0) \left(\frac{1}{1 + q} \right)$$

And the actual intercepted flux is

$$W_{in} = W_M \left(\frac{T'' - T}{T'' - T_0} \right) = \frac{q}{1 + q} W_M$$

We have then these two fundamental equations that connect the internal drainage Q to the intercepted geothermal flux and the outgoing temperature.

The inverse problem

The problem of deducing the provenance depth of a hot springs is obviously of main interest. The traditional formula (CELICO, 1986) assumes essentially that a water flux at temperature T_w comes from a depth H_0 at which the temperature of undisturbed rock is T_w , that is

$$H_0 = \frac{K_R}{F_{gt}} (T_w - T_0)$$

With our equation we have that the evaluations made with the above formula are deeply underestimated, unless for very small discharges, because at stationarity the flux itself disturbs the rock. In fact it is easy to show that

$$H = H_0(1 + q)$$

Then the q -number is the "amplification" term of estimated depth H_0 .

The main difficulty in these formulas is the estimation of critical discharge Q_c , which requires the knowledge of the conduit shape factor. In case studies it is necessary to take into account the geological context to estimate the probable conduit shape to estimate the critical discharge.

Geothermics and phreatic conduit genesis

During deep flow the underground waters are warmed from their starting temperature T_0 up to the final T , that has a theoretical maximum at T'' as shown above. The consequence is that the typical warming is around the value of plane watertables

$$\Delta T_{gt} = \frac{0.06}{4.2 \times 10^3 (P - P_{out})} = \frac{500}{P^*} [^\circ\text{C}]$$

That in real cases is in the range between 0.2 and 3 °C, a temperature drop that water gains during flow between the cave bottom and the springs.

How does this warming affect the water chemical equilibria in these closed, saturated systems? The problem is very complex and depends on temperature and salt contents (FORD, 1985). Does it play a role in the phreatic conduit genesis? We guess that the answer is: Yes, it does.

Conclusions

The estimations of temperature fields inside mountains are very important for speleogenesis and for underground climate studies, but also for every cases that require an energy balance on a sub-geological time-scale: glaciers stability, geothermal springs studies, deep hydro-geological analysis and so on.

We have shown that these potentially cumbersome modelling can be reduced to simple calculations.

These results appear to be very important for studies of cave climates and phreatic speleogenesis.

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Perspective of development of maronia cave and the surrounding area (Thrace, Greece)

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Abstract

Protection and development plans of Maronia Cave are proposed. The speleological and architectural studies suggest part of the cave to be used for tourist visits, in association with a modern undermine building - museum of natural sciences and environmental studies. Suggestions extend to surrounding area (geotopes, flora, archaeological paths etc).

Maronia cave is located at Rhodope Prefecture, western Thrace, close to the homonym village (2 km NW) and the archaeological site as well. It is formed in a relatively thin formation of Nummulitic limestones of Middle Eocene age on top of schists. The decoration of the cave presents a great variability. Some of the speleothems are rare and impressive. The Cave and the district of SE Rhodope Prefecture have also a great archaeological interest, while it is related with the significant archaeological sites as old as 3,500 yr, which are spread around the whole region (Ismara mountain), making the area a huge open-air museum.

Our proposed master plan for the development of the cave and the architectural study suggest part of the cave (northern chambers) to be used for tourist visits, in association (cut and cover tunnel) with a modern undermine building - museum of natural sciences and environmental studies (Fig.1,2). Suggestions extend to surrounding area (geotopes, flora, archaeological paths etc) with a tower (Café, observatory) as a symbol of the cave and reference point.

The development of the Maronia Cave anticipates giving an alternative approach to the visitors in comparison with other developed caves in Greece. Visitors will have the opportunity to learn about the geology, paleontology, archaeology and the flora of the cave and the surrounding area. They could observe the fauna of the cave (in situ). Cameras situated in chambers of the cave, will make possible to see bats as they hibernate or breed as well as spectacular speleothems. Some of the endemic invertebrates of the cave could be observed in terrariums (Paragamian et al. 2004).

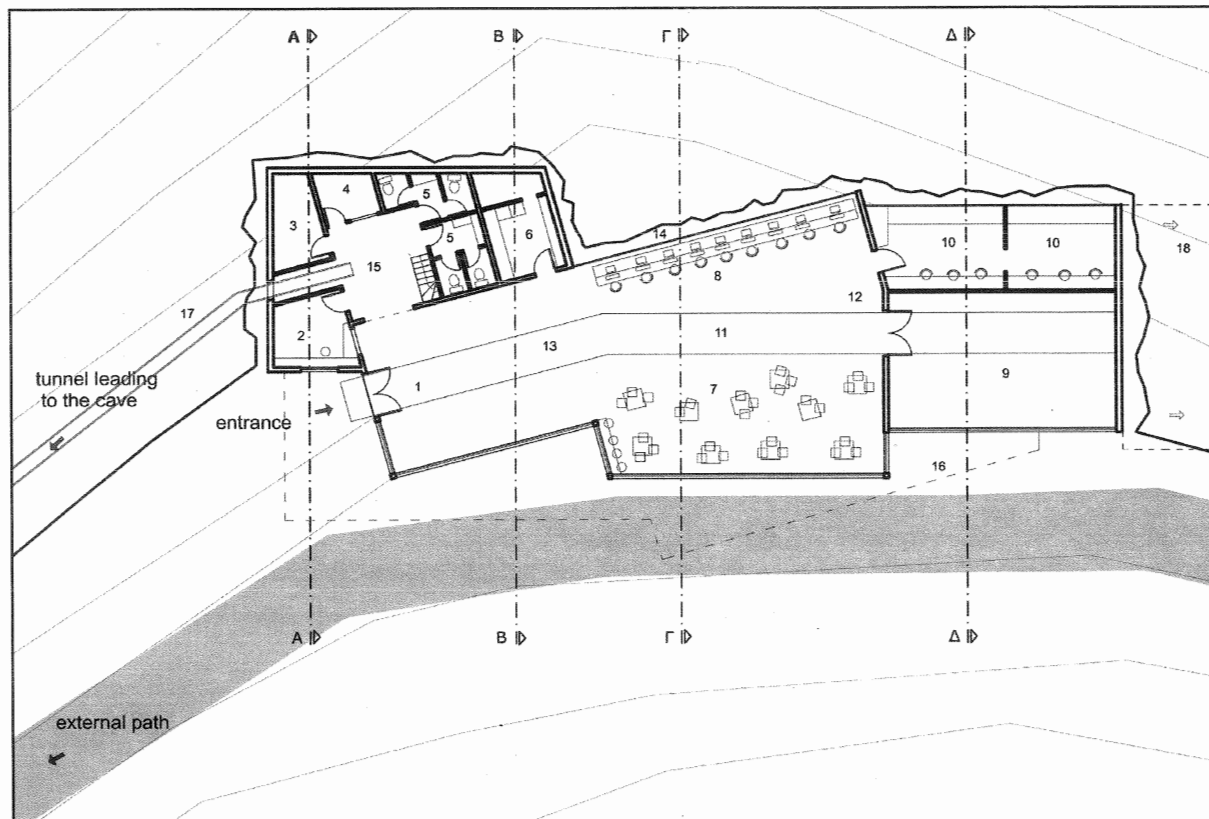


Figure 1. View of the ground plan of an undermine building - museum of natural sciences and environmental studies that communicates with the cave through a subterranean tunnel. The external path is also shown.

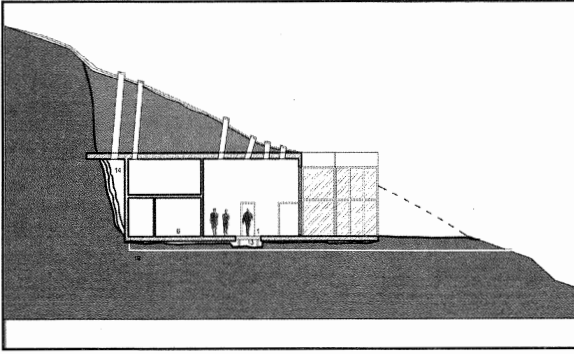


Figure 2. Vertical section of the undermine building. Part of the building will be constructed in the bedrock (mammulitic limestone) while the eastern side will be covered with glass. The building will be illuminated by natural light for the ceiling.

The building will be underground so that it will not fail the surrounding landscape. It is suggested that the visitors can only access the northern part of the cave through a subterranean tunnel (Fig.3), due to the presence of large number of bats on the southern part. Along the touristic path all the impressive speleothems will be illuminated. The intended path outside the cave will have marked locations where visitors can observe the cohesive bone breccia, calcite crystals and the main tectonic fault on the hill where the cave is situated.

Acknowledgements

Since the beginning of the speleological research, to the Maronia project, have been participated: O. Koukousioura, G. Lazaridis, M. Vaxevanopoulos (geologists), R. Pappa, Ch. Pennos (students of geology), S. Zachariadis (archaeologist) & Dr. F. López-González (palaeontologist). K. Ataktidis and B. Makridis (speleologists) were leading the speleological research. We thank them all for their contribution.

The Municipality of Maronia, the Prefecture of Rhodope and the Region of Eastern Macedonia and Thrace financed the Maronia project. We are grateful to the authorities that supported this research.

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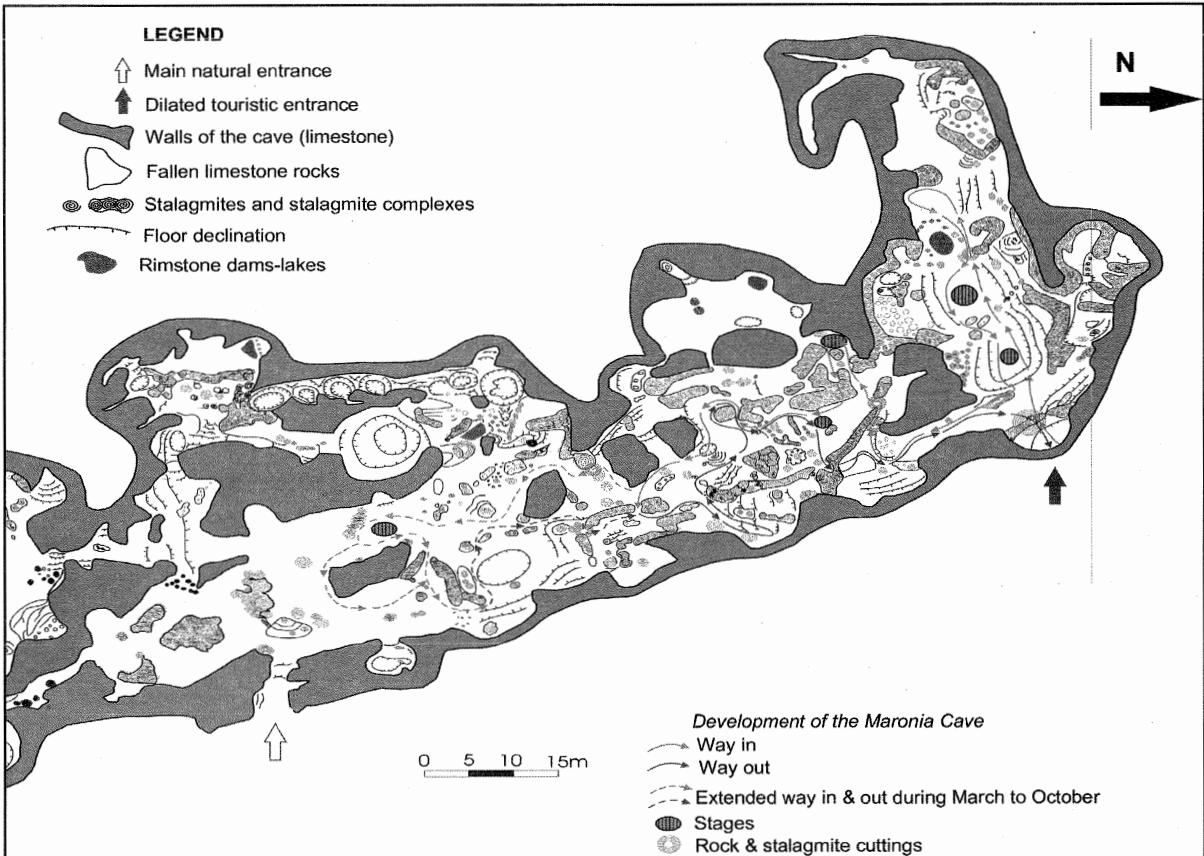


Figure 3. Drawing of the ground plan of the northern part of Maronia Cave based on the plan of A. (Petrochilou 1985). Arrows show the intended way in and out for the development of the cave. Location of the stages and rock and stalagmite cuttings are also marked.

O-198

Exploring Cave Interpretation: Towards a set of key principles for interpreting tourist caves

R. Black, P. Davidson

*Charles Sturt University, Albury, Australia***Abstract**

Contemporary consumers are demanding more from their tourist experience, they want to discover new experiences, to interact with the community, and to learn about and appreciate the destination at more than a superficial level (Jones 1999). Cave guides can provide tourists with interpretation and information which can enhance their experience. The field of heritage interpretation has a significant body of professional literature and practice (Ham 1992, Knudson, Cable, Beck & 1995) yet little relates to subterranean landscapes. Hamilton-Smith has described the history of cave interpretation in Australia (1995; 1999) and together with Rohde (1985) has critiqued current cave interpretive practice. Hamilton-Smith (1999) suggests that more effective interpretation can be developed

is by providing a wide range of interpretive experiences that meet the diverse needs and interests of audiences. This suggests that for cave guides to develop creative and inspirational interpretation they need a set of principles to build interpretive experiences that can contribute to visitor satisfaction. This research explores the guided interpretive methods used and experiences created to interpret Australian tourist cave sites. It taps the expertise of experienced Australian cave interpreters and managers to identify the current personal interpretive practices and then identifies some key principles for future cave interpretation. This study is qualitative in nature and utilised a participatory workshop of experienced cave guides and managers followed by a formal peer feedback process to develop a set of key principles for guided cave interpretation.

O-199

Caves of Isla de Mona, Puerto Rico

P. Kambesis

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Isla de Mona has the highest concentration of caves of any of the island in the Caribbean. The caves are significant in terms of cultural, historical and archeological materials. They are geologically important as world-class examples of flank margin karst development. Their formations, sediments and mineralogy contain geologic information not only about the caves themselves but also about the island in general. Eight expeditions

were conducted between 1988 and 2004 concentrating on the caves located at Playa Pajaros, the southeast side of the island. Over 30 km of cave passages have been explored and mapped in six major caves and over 30 smaller caves have been discovered and documented. Concurrent with the cave survey, extensive photography has been done not only to document the caves and their resources, but to also photo-monitor impact of visitation on the various caves in the area.

O-200

Caves and karst in Fengshan county, Guangxi, southern China

Ged Campion

*Twistleton Near Barn, Ingleton, Carnforth LA6 3JA, UK, ged.campion@talk21.com***Abstract**

The landscapes on the borders of the Fengshan and Bama counties in northwestern Guangxi, constitute spectacular fengcong karst. Large dolines, tiankengs, natural arches and caves, that all evolved largely through the Pleistocene evolution, feature spectacularly in the terrain. The British China Caves Project have been assisting the Karst Research Institute (in Guilin) and the Fengshan government in trying to achieve Geo-Park status; they have now surveyed 50 km of passage in the area, including 29 km in the extensive cave system of Jiangzhou Dong, which underlies parts of both Fengshan and Bama counties. This cave system, now recorded as the third longest system in China, would be the centre piece of a Geo-Park in Fengshan. However, the removal of speleothems from the caves over generations has resulted in extensive damage to a fragile environment, and this continuing problem will present a serious challenge to those involved in cave conservation in the area. This paper makes observations on the development of the karst scenery and the further potential for cave exploration in the area, and considers how the delicate balance between the needs of the population, tourism and conservation might be addressed.

Key words: Jiangzhou, cave, Geo-park, China

during the months of March and October. They were part of the British China Caves Project, which for many years has been an informal programme of co-operation between a variable team of British cavers, under the auspices of the British Cave Research Association and members of various Chinese research institutions.

The area involved in this expedition lies west of the Hongshui River, in the northwestern part of Guangxi Autonomous Region. The Fengshan karst is situated between the You and Hongshui Rivers, some 300 km west of Liuzhou. Access to this area was previously allowed only after receiving special permits from the Ministry of Land and Resources. However, more recently economic and tourist development in China has been accompanied by a considerably more relaxed approach to foreign interest in exploration in these areas.

Parts of Guangxi are considered to be some of the most spectacular karst areas in Asia. This much-eulogised scenery cannot fail to impress even the most seasoned traveller, with karst towers and dolines of spectacular dimensions. The vast area of limestone terrain is characterised by a sub-tropical climate, and has fenglin and fengcong karst at altitudes from 150 m to 2000 m above sea level. The Fengshan area is particularly striking, with an array of karst features that include the San Gu River, tiankengs, the Jiangzhou natural arch forming a gateway to the village of the same name, the huge fossil cave entrance of Jiangzhou Dong, and an abundance of fengcong conical hills.

Introduction

The two cave exploration expeditions to Guangxi in 2004, took place

Such is the potential of the area for scientific investigation and tourism development that the local government of Fengshan has applied for Geo-Park status. The 18th & 19th field programmes of the British China Caves Project (Gill et al, 1990; Waltham & Willis, 1993) have been assisting the Karst Research Institute (in Guilin) and the Fengshan government in trying to achieve this status. The China Caves Project has now surveyed 50 km of passage in the area, including 29 km in the extensive cave system of Jiangzhou Dong, which underlies parts of both Fengshan and Bama counties. This cave system, now recorded as the third longest system in China, would be the centre piece of a Geo-Park in Fengshan. Explorations were by 17 cavers from Europe, 8 members of the Karst Research Institute in Guilin, and members of caving clubs in Nanning.

Cave formation in southern China

Along with most of the caves in southern China, those newly discovered at Fengshan lie in limestone, the age in a sequence that extends from Devonian and Triassic. Karst development in the region is closely linked to the geologic and tectonic evolution and to the paleogeography. The limestones largely post-date the Caledonian orogeny, but were all folded in orogenic phases in the late Triassic and in Cretaceous times.

Palaeozoic palaeo-karst is known across large areas part of the limestone in China. From the early Triassic to the late Jurassic, most of southern China had a humid, tropical-subtropical or humid-temperate climate that greatly favoured karst development. Karst from this period is to be seen in many sites at Fengshan. From the middle Pleistocene onwards, the climate in southern China became hot and humid, and has remained so to this day. Karst therefore developed over very long periods of time. China has about 2.6 M km² of karst, with about half of it (and most of the mature karst) concentrated in the southern regions (Yuan, 1991; Zhu, 1986).

The Jiangzhou cave system

The cave system of Jiangzhou Dong underlies both Fengshan and Bama Counties in the hill area of Duyang Shan, in Guangxi. It lies about 24 km SSW of Fengshan Town and roughly 50 km west of the Hongshui River. The nearest large village is Jiangzhou, about 2 km from the south-west edge of the system; one of the entrances to the cave is close to the village of Longhuai, and another is just to the north of the scattered hamlet of Dalue.

Surface morphology

The multi-entrance cave system lies beneath a typical fengcong karst, with individual karst hills rising to about 500 m above a surrounding alluvial plain at about 300 m altitude. The main entrances and the fossil sections of the cave lie 50-100 m above the alluvial plain. The cave passages are breached by a spectacular doline, the Herb Garden, which houses a forest isolated by its perimeter cliffs. The karst hills are of two types. Fengcong cone karst, of the peak cluster depression sub-system, is dominant in this area. On the alluvial plains, there are some isolated fenglin towers, of the peak forest plain sub-system.

Limestone lithology

Jiangzhou Dong has developed in predominantly Lower Paleozoic dolomitic limestone, mostly of Ordovician and Devonian origin. In many parts of the cave there is evidence of more soluble varieties of limestone, and also gypsum, that have provided easy hydraulic routes. These beds fractured and dissolved more readily than the dolomitic rock, and provide some explanation for the impressive size of cave passages throughout the system.

Structure

The explored cave system comprises mainly very large fossil passages and chambers, the floors of which are extensively strewn with massive boulders. They are also decorated with speleothems, especially flowstone, stalagmites and large gourls, some of the most spectacular of which are located in the upper galleries in the far reaches of the cave (Hijack Passage). The typical passage in Jiangzhou is about 30-50 m high and wide. There appear to be no major faults in the area, and passage development has been controlled by percolation along joint planes, causing dissolution and the collapse of the intervening joint blocks. Percolation of rainwater landing directly on the karst surface has contributed to cave development, and accounts for the diversity of branch passages converging on the main trunk caves.

Hydrology

Underlying the fossil caves, there is an extensive active cave system which can be reached at various points from the fossil galleries by descending large elliptical shafts, some of which are over a 100 m deep (DW2 shaft). Some shafts also extend upwards to daylight (Skull and Crossbones shaft). The cave rivers pass through numerous flooded sections, so that only short sections of vadose river passage have yet been found. Rivers off the alluvial plains have transported large quantities of sediment into sink holes, often causing massive infill and blockages in the active passages. Within the fengcong, many dolines have floors choked with sediment at levels well above the cave rivers (Doline MF2502).

Man's impact on the caves

It would seem that generations of local villagers have explored many of the fossil cave passages, and have even descended some of the shorter vertical shafts (Hijack Passage), risking life and limb to remove speleothems for financial gain. This has left well-worn paths penetrating even the most remote parts of the system, and has inevitably caused despoliation of the speleothems and removal of many of the most impressive features. In the nearby cave of Yulong Dong, bamboo scaffolding has been erected to reach the finest stalactites located 30 m high on the passage roof. There is no evidence that Jiangzhou has been used for ritual purposes or for burials; however, substantial defensive dry stone walls in the Manfei entrance and the Herb Garden doline suggest there may have been turbulent times during the past, in this quiet part of China.

Conclusion

It is perhaps not unreasonable to be impressed by the understanding of karst held by the local people in China, given that their country has such an abundance of limestone and spectacular karst terrains. In Fengshan, the large dry fossil passages were easily explored by villagers, but were unmapped until the recent expeditions. Particular problems were encountered in the exploration of the river caves from the karst boundary, where sediment infill is extensive and frustrated exploration of passages that would otherwise be very extensive. There is almost certainly potential to explore more of this cave system further, both along remote passages and down undescended shafts into the river series. Nevertheless the size and volume of the fossil caves place Jiangzhou Dong among the most impressive in this part of China, and the cave is a fitting match to the spectacular surface geomorphology of natural arches, dolines and tiankengs in the fengcong and fenglin karst.

The damage to the caves at Fengshan is perhaps the single biggest concern from our appraisal and study of this remarkable karst. Local people have traditionally viewed the speleothems within the caves as a rich harvest to exploit, notably from Jiangzhou Dong and Yulong Dong. Gen-

erations of villagers have systematically plundered the caves to sell the speleothems in the markets of Guilin and elsewhere.

Other examples of cave exploitation are perhaps more acceptable where man and cave co-exist. The cave of Chuan Yan Long Dong has been developed as a factory comprising units for workshops, using the plentiful supply of water, the ventilation and the natural shelter to aid industrial enterprise. However, this is a short and unremarkable cave, with few speleothems, in the centre of Fengshan town.

In order to address the problem of speleothem removal from the caves, considerable work will need to be done in re-education of the local people. This must make them aware of the unique resource that they have in their possession, in terms of tourist potential, and also of the long-term economic benefits a Geo-park could have for the locality. Conversely, it is important to consider what impact increased tourism might have on the area in terms of conservation; it could bring some disadvantages, but it could for example promote better local roads and infrastructure. This is a delicate balance that has to be considered in any future planning at Fengshan.

Acknowledgements

The visits by British cavers under the auspices of the China Caves Project are grateful for the considerable help provided by many individuals at the Karst Institute at Guilin, in particular Prof. Zhu Xuewen, Dr. Zhang Hai, and Dr. Chen Weihai. Their knowledge and expertise was critical to the interpretation and understanding of the incredible karst scenery that abounds in Fengshan county.

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O-201

The Lebanese Perception of the Endokarstic Patrimony

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Abstract

The endokarstic patrimony is strongly threatened by degradation in Lebanon. Fault of being unaware of its value, the authorities appear indifferent regarding to this situation. The population aim for short-term profitability, often cause, by ignorance, irreversible damage in this field.

However, in other countries like France or Slovenia, the endokarstic patrimony represents, through tourist valorization, a socio-economic development factor. Why isn't it the case in Lebanon?

A survey that was conducted on 600 individuals has enabled us to apprehend on the one hand, the given meaning of the inheritance term by the Lebanese people and in the other hand, their perception of the karstic inheritance.

This communication discloses the first results of this investigation.

Keywords: Lebanon, karst, grottos, patrimony.

65% of the surface of Mount Lebanon is formed with karst and accordingly constitutes a considerable natural patrimony. It is undoubtedly the most important in the country. The first speleological club in Lebanon was founded back in 1951 and, ever since, over 500 underground cavities have been discovered and listed across the whole territory.

Amongst these cavities, 283 were found to reach above 20 meters of development. Whilst all the caves are relatively ignored by public institutions and by the public, certainly due to some unconsciousness towards their patrimonial aspect and value, only one cave is well-known to Lebanese tourism and considered as famous: the Jeita Grotto.

Moreover, this patrimony is highly threatened by degradation. Furthermore, authorities and officials seem indifferent to this situation. The population seeks short-term profits, thus causing irreversible damage to this site by unawareness or through the non-authorized exploitation of quarries.

However, in other countries like France or Slovenia, the endokarstic patrimony is viewed as a factor of socio-economic development, through the development of tourism. Why is that not the case in Lebanon? Is this due to the apparent indifference of the Lebanese people for the patrimonial aspect? Or is it caused by ignorance of the karst as a natural engine of national socio-economic development?

We wished to investigate further so as to better understand such a particular behavior vis-à-vis this inheritance.

A survey conducted on 600 individuals has enabled us to apprehend on the one hand, the meaning conveyed by the Lebanese people to the term "patrimony" and on the other hand, their perception of the karstic inheritance. This speech discloses the primary results of the investigation.

1. The Notion of Patrimony Amongst the Lebanese

In a country emerging from a Civil War, where officials seem totally indifferent regarding patrimony and make no effort whatsoever for its development, we have questioned the population about the meaning it conveys to this term.

It has turned out that first and foremost, patrimony is of historical nature. Out of 600 people enquired, 372 have mentioned the aspect. Other criteria follow: Patriotic (220), cultural (209) and hereditary (111).

As a statement of fact, the notion of patrimony amidst the Lebanese rarely or never includes the natural aspect; it has only been mentioned by 34 people, in other words 5.6% of the sample.

Only one person considers patrimony as an economic resource!

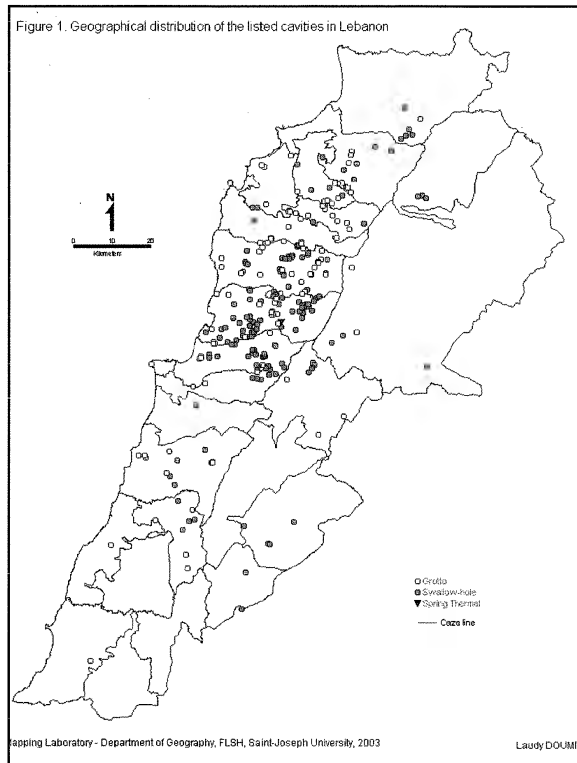
What is more, when asked about patrimonial elements in their region of origin or residence, 38% of the interrogated Lebanese answered that none existed! When they were capable to name any, they mostly men-

tioned either historical or archeological sites or regions and streets and houses of traditional nature or religious sites.

Nevertheless, having classified patrimonial elements in order of importance on the national scale in Lebanon, grottos come in third position (125 people) after archeological and historical sites, as well as after traditions and customs.

Be that as it may, this does not mean that the Lebanese acknowledge the real value of the grottos, for the most frequently mentioned element, the famous Jeita Grotto is a developed and promoted karstic site.

In fact, it is one of the most impressive natural sites in the Middle East, exploited by the State and a private company. It contains 2 galleries: in the upper gallery, 2200m have been explored, out of which 800 are fitted out. As for the lower gallery, 6200m have been explored, out of which 600 are open to the public.



2. The Lebanese and Grottos

Does the fact that the Lebanese people do not primarily think about grottos mean that they have no interest whatsoever for this kind of site?

2.1. Sites visited by the Lebanese

In our survey, we have asked people to name the activities and kinds of visits they undertake while receiving foreigners. Amongst the activities mentioned, visiting grottos came in third position (228 people), following visits to historical and archeological sites (460 people), and lunch invitations (429 people).

Once more, the Jeita Grotto prevails on other grottos. Indeed, 87% of the mentioned grottos belong to this one and same cavity. Only 9% include two other developed and promoted cavities in Qadisha and Kfarhim, but represent no competition for Jeita.

To what extent do these answers translate the real attendance to tourist grottos?

2.2. Underground Tourism in Lebanon

Out of 600 interrogated individuals, 436 (73% of the sample) have visited at least one grotto through their life. In order to complete this first information, we have also asked people who have visited at least one grotto whether they knew of other grottos then asked those who have never visited any grotto if they knew of one at the least.

a- People having already visited grottos

Out of 436 people who have already visited grottos, 209 know of other grottos, thus 48% (Figure 2).

Generally, the cavities they have mentioned are those developed and promoted. The same names turn out: Jeita (21%), Qadisha (19%) and Kfarhim (9%). Hence, the Lebanese seem to respond to promotions they are subject to.

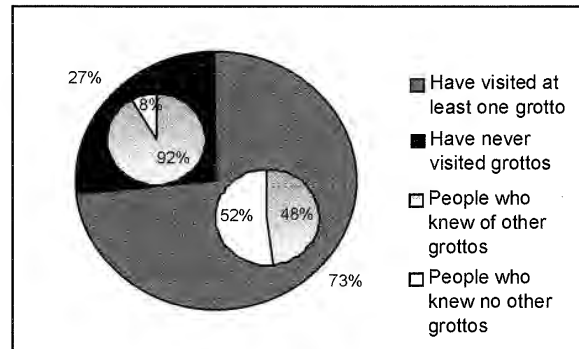


Figure 2 - Knowledge of the Lebanese about grottos.

Nevertheless, other grottos have been referred to (39%). In most cases, they are not well-known; they are scattered in various areas of the country, often close to the region of residence or of origin. For the most part, people are incapable of naming these cavities. They simply state the name of the region of location.

Only 1% of the Lebanese have visited grottos with social clubs and sports clubs or various associations. Predominantly, they organize these types of visits in groups of friends (39%) or as family (28%). In some cases, visiting grottos takes place in the frame of outings organized by schools for their students (12%). In other cases, Lebanese people accompany tourists throughout well-known tourist sites in Lebanon (7%).

The principal reason for visiting is curiosity (27%). It is followed by the reputation of the site (20%) and the wish to introduce it to other tourists (16%). Only 3% do it for the pleasure of sports activities.

Many reason leads them back to a grotto they have previously visited. In point of fact, out of 436 individuals who have already visited grottos, 293 have returned to the cavities many time. 25% explain their return through the aesthetic aspect of the grotto. 18% come back to accompany other people. These reasons are succeeded by curiosity (12%), natural causes (11%), and feeling like participating in organized outings (7%). 27% refer to other reasons: 17% of them explain that through the geographical location of the grotto and its closeness to their area of residence and 14% of them mention religious causes.

b- People who have never visited grottos

We have asked people who have never visited grottos to name the cavities they know. Indeed, 92% of them have named the most famous ones: Jeita 57%, Qadisha 10%, and Kfarhim 7%.

Eventually, out 164 individuals who have never visited cavities, 85% are interested by this sort of outing. However, various reasons have hindered them from doing so up until now: high visiting fees, lack of motivation...

2.3. Visiting non-developed grottos in Lebanon

Out of 436 people who have previously visited one grotto to the least, 145, thus almost one third of them admit having visited one or many non-developed grottos in Lebanon. Anyhow, only 6 of them have practiced actual caving. The rest were content with simply visiting the entrance of grottos (97 people) or with small non-technical visits (42 people). Still, all consider themselves as having visited non-developed grottos. In order to verify the accuracy of these results, we have asked the enquired individuals to list the necessary equipment for grotto visits.

In order to verify the accuracy of these results, we have asked the enquired individuals to list the necessary equipment for grotto visits. It seems that 108 have used no equipment whatsoever. 30 people had but a torch and only 7 people were fully equipped (helmet, torch, harness, ropes...)

Consequently, these results verify that the Lebanese do not practice professional caving. Those who venture in the underground do so with no technique. As for the satisfaction they get from the visits, out of 145 people, 129 have appreciated the visit and 104 are ready to start it over.

3. How the Lebanese describe Grottos

In order to better grasp the practice of underground tourism in Lebanon, and consequently understand the interest Lebanese people have in protecting and developing this milieu, we had to find out how they perceive these cavities.

a- The Grotto: a Tourist Site

98% of the Lebanese believe that a grotto can be a tourist site based on various criteria which attract tourists.

Out of 600 individuals interrogated about the criteria that allow a grotto to become a tourist site, 39.8% refer to its natural aspect. We have noted that just a small minority (5.6%) of the sample considered the natural aspect to be part of the patrimonial characteristic of a good: this discrepancy confirms the difficulty Lebanese people have to perceive grottos and karst as an inheritance.

Following this criterion come the artistic characteristic - notably aesthetic - (35.5%) and its historical characteristic (25.8%). 22% refer to the rare and unique aspect of a grotto and 15% refer to its picturesque aspect. 7% think that it is the development of a grotto which turns it into a tourist site. 6% believe that it is due to its relation to the country: it was formed within the territory and thus became a national symbol.

4 of the characteristics mainly cited by the Lebanese (artistic, picturesque, historic and natural) are present in the texts of the UNESCO, which set 6 criteria to apply patrimonial protection. The missing criteria in Lebanon are: legendary, named by only 2 people, and architectural, named by only 9 people.

Nevertheless, only 29 individuals spontaneously think of it as an inheritance, thus 4.8% of interrogated people. Also, only 11 consider the grotto as an economic resource, thus 1.8% of the sample. Accordingly with these astonishing results, we have sought to study the profile of the latter (Table 1).

Apparently, the majority are male. Despite the small size of the sample, we have come up with the following hypothesis: men are more sensitive to the economic aspect than women.

9 persons are between 20 and 49 years of age: they essentially belong to the working population.

We took notice of the fact that these people live in different regions of Lebanon. As for their professions, 4 are students, 3 have a liberal profession and 2 are tradesmen. They all belong to the intellectual class.

b- The Grotto: Country's Patrimony

We have asked people if in their point of view, a grotto could belong to a country's patrimony. 79% have answered "yes". As a matter of fact, it seemed as though the question dictated the answer.

These people consider the grotto as a patrimony due to its historical aspect (223), its patriotic (128), natural (123), artistic (65) and rare and unique (58) aspects.

One can see that the characteristics mentioned to show the patrimonial aspect of a grotto are quite the same as the ones listed to explain its tourist aspect (cf. § 3 a). However, the priority is not the same. A grotto is tourist first and foremost because it is natural and artistic and it is patrimonial due to its historical character. The Lebanese associate patrimony to everything historical, ancient and archeological. The legendary, architectural and picturesque criteria mentioned by the UNESCO are rarely or never cited. Moreover, Lebanese people are unable to see patrimony as an economic resource, since only 9 people mention this criterion, thus 1.5% of the population.

These people who insist on the economic role of patrimony are all males (Table 2). They also have a high social standing.

Table 1: Profile of individuals who believe grottos are touristic sites because they are an economic resource.

Number of individuals	Sex	Age	Mohafazat of Residence	Profession
1	F	15-19	Beqaa (except for Zahle)	Student
1	F	15-19	Saida	Student
1	F	20-29	Beirut	Tradesman
1	F	30-39	North Lebanon (Except for Tripoli)	Liberal Profession
1	M	20-29	Beirut	Liberal Profession
1	M	20-29	South Lebanon (Except for Saida)	Student
1	M	20-29	Tripoli	Student
1	M	30-39	Beirut	Craftsman
1	M	30-39	Nabatiyeh	Employee
1	M	40-49	Beirut	Tradesman
1	M	40-49	Nabatiyeh	Liberal Profession

Table 2: Profile of individuals who believe grottos belong to the patrimony because they are an economic resource.

Number of individuals	Sex	Age	Mohafazat of Residence	Profession
1	M	< 15	Beqaa (Except for Zahle)	Student
1	M	15-19	South Lebanon (Except for Saida)	Student
1	M	20-29	Outskirts of Beirut	Civil Servant
1	M	20-29	Outskirts of Beirut	Employee
1	M	20-29	Tripoli	Employee
1	M	40-49	Outskirts of Beirut	Liberal Profession
1	M	50-59	South Lebanon (Except for Saida)	Teacher
1	M	>= 60	South Lebanon (Except for Saida)	Retirement
1	M	>= 60	Rest of Mount Lebanon	Liberal Profession

In conclusion, the awareness of the Lebanese can easily be sought for the protection and development of endokarstic patrimony. They admit that a grotto is altogether natural, historical, artistic and unique... It has all the assets to be considered as tourist and patrimonial. The Jeita Grotto which attracts so many people is the ideal proof of the interest that Lebanese could have for this patrimony.

However, they are not aware that it represents an opportunity for economic activity and benefits. Consequently, they are unable to see the financial and environmental importance to protect this natural milieu.

At this point, one question should be asked: if the Lebanese are unaware of the importance of patrimony preservation, is that a direct consequence of their education? Would awareness to the importance of this phenomenon not be a sine qua non condition to ensure the success of any program of patrimonial development, especially when, in the words

Georges S. ZOUAIN (1999), this failure in the vision leads to an artificial dangerous and negative antinomy between patrimony and economic development?

Setting forth the potential of a lasting and realistic economic development of these sites, the locals could more concerned with preserving this environment and would take knowledge of the socio-economic risks linked to the disappearance of this patrimony.

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Sustainable Touristic Use of the Caves of Salado III (Chorriaca), La Laguna (Balsa Huitrín) and Los Gatos (Rincón de los Sauces). Neuquén Province, Argentina.

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Abstract

This project proposes the sustainable touristic use of the caves in an Ecotouristic modality through Speleotourism. It is stated to make touristic visits orientated by local speleological guides especially trained. With this touristic activity, it is thought to make a rational use of the caves, including environmental, social and economic aspects. The touristic importance of these caves is based on its genesis, morphology and its formations (deposition landforms). Within a particular geological landscape, as it is the one in Patagonia, they are the dominant elements to show how Nature works in those cases.

Necessary precautions are taken to prevent environmental impacts proposing as a management instrument the estimation of the Touristic Charge Capacity the preparation of the guides as environmental monitors and mitigate measures. For this it is established a continuous monitoring of the different variables which allow the registration of the possible alterations over the environment, and so act in consequence. In the same way, is developed a Contingency Plan to solve incidents with visits in the best way.

This implementation will bring an economical development in the caves surroundings zones, Las Lajas and Rincón de los Sauces, main cities that count on speleological groups and basic constructions.

The touristic competence will permit that these resources of a great

educational and environmental value and with an economic potential can reach the population.

Introducción:

Este proyecto se plantea para asociarlo a objetivos generales del desarrollo turístico de las zonas involucradas que garanticen la sustentabilidad del recurso espeleológico en el tiempo y que como todo proyecto de explotación turística implique que se desarrolle y cumpla con planes de ordenamiento y de manejo.

La importancia turística de estas cavernas se basa en sus génesis, sus morfologías y sus formaciones (espeleotemas) que dentro de un paisaje geológico particular, como es el de la Patagonia, son los elementos dominantes para mostrar como funciona la Naturaleza en estos casos. Su habilitación turística permitirá que estos recursos de gran valor educativo ambiental y con un potencial económico puedan llegar a la población.

La Espeleología es la actividad, para algunos ciencia, que tiene por principales finalidades encontrar, explorar, observar e interpretar las cavernas, teniendo como criterio de análisis el conocimiento de sus procesos de formación, medio donde se insertan y sus ambientes propiamente dichos.

Toda caverna está inserta dentro de una extensión de terreno cuya área está relacionada con los recursos bióticos y abióticos, superficiales y subterráneos, del ecosistema cavernícola. Ninguna está aislada ecológicamente, el medio externo actúa como una cuenca de recepción (incluso impactos) de donde la caverna recibirá los recursos (incluso la contaminación).

Por su dinámica la caverna es un gran laboratorio geológico y biológico que presenta condiciones de equilibrio. Por ello se transforma en un observatorio ideal de algunos de los procesos naturales que hay en estos ecosistemas donde se pueden ver como se modifican por acciones naturales, especialmente las antrópicas.

Espeleoturismo como actividad Ecoturística:

El Espeleoturismo es una actividad intermedia entre la Espeleología (estudio, exploración y conocimiento de las cavernas) y el Turismo (una actividad recreativa). Se lo ubica dentro de las actividades de Turismo Alternativo (Activo/Active Travel) ya sea en las modalidades de Ecoturismo o Turismo Aventura (donde a veces se lo denomina Espeleismo) lo cual depende de la oferta comercial del producto.

En el ámbito mundial el Espeleoturismo se comercializa como visitas a cavernas adecuadas al visitante y con habilitaciones ambientales otorgadas por los organismos competentes que velan por su conservación.

El perfil del turista para esta actividad se ajusta con el del ecoturista e incluso con el que busca turismo aventura. El producto se puede extender a la oferta del turismo tradicional siempre que se respeten las capacidades de carga y que las visitas sean con guías habilitados.

En el caso de estas cavernas, por lo menos en esta primera etapa, no podremos adaptar el Espeleoturismo al turismo masivo y mucho menos al turismo aventura (donde se buscan riesgos) debido a la falta de los estudios respectivos que indiquen los niveles de vulnerabilidad y de resiliencia de estos frágiles ecosistemas.

Al incluir el Espeleoturismo en la modalidad Ecoturismo y por ser una oportunidad recreativa centrada en la Naturaleza, donde se busca un muy bajo impacto en la misma, se halla como resultado, además de motivar al visitante potencial el deseo de conocer, el convertirlo en aliado de los objetivos de conservación que se le proponen. Por ello es de destacar que el Ecoturismo con sus demás actividades (trekking, fotografía, etc.) que se pueden desarrollar garantizarán el cuidado extremo que necesitan estos recursos. El impacto de este tipo de turismo es reducido y casi limitado a la sola presencia física, momentánea, del visitante. Dado que las estructuras (y los servicios) están en fuerte relación con el ambiente en el que se insertan propondremos un mínimo de ellas, aprovechando las existentes (Ej. los senderos) cuyas instalaciones y o adecuaciones no afecten al mismo.

Por lo tanto no se buscará adaptar las cavernas al turista (dado su impacto) sino adaptar al turista a las cavernas (reduciendo al mínimo el impacto) y en este tipo de cavernas esto es posible si elegimos la modalidad Ecoturismo ya que el Espeleoturismo, como actividad, busca la realización de excursiones hacia áreas poco alteradas o no contaminadas con el objetivo de interpretar, gozar o estudiar el entorno natural o específicamente alguno de sus componentes faunísticos, florísticos y geológicos así como también cualquier manifestación cultural presente o pasada. Como Ecoturismo se promueve y orienta las motivaciones conservacionistas además de despertar el interés por el desplazamiento a estas localidades con paisajes tan particulares.

Al tener en cuenta que las actividades recreativas previstas deben ser de muy bajo impacto u orientadas al contacto con la Naturaleza mantendremos un nivel bajo de intervención y se brindará una oferta centrada en la calidad ambiental original y en el carácter silvestre del área.

Al aprovechar que esta actividad se identifica fuertemente con el Turismo Naturaleza es prioritario transmitir el valor del patrimonio que se

expone, las razones que obligan a su conservación y las características que lo hacen distintivo.

Viabilidad turística de las cavernas:

Las cavernas consideradas para este proyecto fueron exploradas por el Grupo Azul de Espeleología y Montañismo del Neuquén, G.A.E.M.N. y el Grupo Espeleológico Lajeño, G.E.La., en la década del '80. Posteriormente fueron topografiadas por el Grupo Espeleológico Neuquino, G.E.Neu.

En la década del '90 comienzan a ser visitadas por grupos de turistas interesados en los paquetes ofrecidos por operadores con guías especializados.

La falta de infraestructura en las cercanías (agua potable, reparos, sanitarios, recolección de residuos, energía eléctrica) hace que la modalidad de turismo a desarrollar sea ofrecida como turismo en la naturaleza casi como de aventura.

Estos recursos constituyen una atracción importante y no son independientes de la oferta de la región turística donde se hallan. Como recursos naturales constituirán un motivo de visita cada vez mas frecuente dadas las características propias, que son una novedad en esta provincia.

Sus accesos por rutas asfaltadas y caminos consolidados, que pertenecen a corredores turísticos ya instaurados, son cómodos y seguros.

Por sus características son clasificadas como cavernas semiantropizadas, grupo 02, según clasificación de Lino (Marra, 2001) con solo senderos para atender visitas. En este tipo de cavernas su visita obligatoriamente debe usar casco, luz individual y ser orientada por guías especializados. Son conocidas como cuevas para aventuras.

Habrà que transformarlas en Cuevas con antropización moderada, grupo 3, según clasificación de Lino (Marra, 2001), es decir prepararlas al turismo con obras de infraestructura de mínimo impacto, sin obras externas.

El plan de manejo tiene una estrategia clara de seguridad y confort para el visitante donde será definido el número medio de visitantes para cada guía especializado. Son conocidas como cavernas para Espeleoturismo y no tienen iluminación fija o permanente. Deben tener supervisión y orientación por guías espeleológicos para pequeños grupos de visitantes

Ubicación y descripción de las Cavernas:

Caverna Salado III

Esta caverna se localiza a 20 Km al Sur-Sureste de la localidad de Chorriaca, Departamento de Loncopué, Pcia de Neuquén.

Sus coordenadas geográficas son: Latitud 38° 03' 19,4" Sur. Longitud 70° 03' 02,3" Oeste. Altura 972 m.s.n.m.

Esta se desarrolla en un banco de Yeso con Calizas intercaladas. De morfología mayormente lineal con una alineación casi Norte-Sur, tiene una longitud topografiada de 577 m.

Por su entrada, descendiendo una galería, se llega a una galería mas amplia que nos deja sobre el sendero interno para uso turístico y que nos conduce por la Galería Principal hasta aproximadamente unos 70 m.

Dentro del sector de transitabilidad turística se encuentran espeleotemas diversos como estalactitas, colgaduras (velos), columnas, concreciones tipo coliflor y formas pavimentarias. También al fondo de la caverna se puede observar una pequeña laguna intermitente.

Caverna de La Laguna

Esta se halla a 9 Km al Sur del paraje Balsa Huitrín, Departamento de Loncopué, Pcia. de Neuquén.

Sus coordenadas geográficas son: Latitud 37° 45' 01,1" Sur. Longitud 69° 56' 01,6" Oeste. Altura 913 m.s.n.m.

La caverna se ha formado en un banco de Yeso (Formación Huitrín) con Calizas intercaladas. Tiene un desarrollo horizontal predominante con un rumbo de 140° y una longitud de 215 m. Se accede por una sima de hundimiento de 30 m de diámetro y 12 m de profundidad en cuyo fondo comienza el sendero interno turístico de casi 130 m.

Aproximadamente en la mitad del sendero, a los 73 m, se halla una pequeña laguna que en algunas épocas obstruye el paso al sector Norte del sendero. En el fondo del recorrido se pueden observar algunas cristalizaciones sobre las paredes.

Caverna de Los Gatos

La caverna se ubica a 30 Km al Sudeste de la ciudad de Rincón de los Sauces, Departamento de Pehuénches, Pcia. de Neuquén.

Sus coordenadas geográficas son: Latitud 37° 33' 50,7" Sur. Longitud 68° 46' 23,4" Oeste. Altura 876 m.s.n.m.

La caverna se desarrolla en coladas basálticas (producto de las lavas que emanaban del Auca Mahuida). La entrada se halla en el derrumbe de la galería permitiendo solo el ingreso hacia el sector Norte. Tiene un desarrollo topografiado de 312 m.

La entrada tiene colocada una reja que no ha logrado su objetivo.

El sector transitable de 240 m se inicia con rumbo Este-Oeste y luego se curva hacia el Norte. A los 33 m de la boca de entrada, donde se inicia la curva, hay un desnivel de 3 m donde se debe hacer una escalera, ya sea del mismo material de la caverna o excavada en el lugar disimulando su construcción.

En algunos sectores se observan cristalizaciones sobre las paredes.

Capacidad de Carga turística:

Los sitios de visitas tienen un punto de saturación que está dado por su capacidad de ofrecer la misma calidad de experiencia a todos los visitantes (capacidad psicológica), la superficie disponible (capacidad física) y la capacidad del ambiente de absorber los impactos negativos que generen las visitas sin modificar los parámetros que lo mantienen en un equilibrio (capacidad ecológica).

El manejo de visitantes en un ambiente vulnerable debe ser rigurosamente planificado para alcanzar los objetivos de conservación por los cuales fue establecido y, a la vez, lograr que los visitantes tengan una experiencia de calidad y puedan satisfacer sus expectativas.

El establecer una capacidad de carga es relativa y a su vez dinámica porque depende de la variación de indicadores que según las circunstancias pueden cambiar. Esto obliga a revisiones periódicas, según el monitoreo de los sitios, y que aportaran a las decisiones de manejo.

Para esto es necesario establecer un sistema de monitoreo que evitara llegar a los umbrales límites para impedir se dispare una alarma ambiental.

Los parámetros a monitorear pueden ser la temperatura, la humedad relativa del aire y algún tramo interno mediante un relevamiento fotográfico para comparar erodabilidad en el tiempo.

Plan de Manejo del Área:

Para el plan de manejo del área se debe tener en cuenta los siguientes ítems:

- Planificación de estacionamientos
- Establecimiento de senderos externos e internos
- Señalizaciones (cartelera)

- Iluminación y seguridad
- Planes de contingencia a desarrollar en caso de emergencias
- Monitoreo de indicadores ambientales
- Control de la visita:
- Información al visitante.

Estudio de Impacto Ambiental:

Para la factibilidad de este proyecto se confeccionó un Estudio de Impacto Ambiental que contempla un Plan de Gestión Ambiental, el cual se compone de:

- Medidas y acciones de mitigación

- Se debe respetar lo establecido en cuanto a la Capacidad de Carga que el proyecto turístico ha estimado.
- Los guías deberán informar acerca de las restricciones para la caza y captura de fauna y recolección de flora cualquiera sea su finalidad. Tampoco permitirá el retiro de cualquier variedad mineral.
- Se informará al visitante que cualquier residuo generado debe ser trasladado a la localidad más cercana para su disposición.

- Ámbito Sociocultural

Es importante informar a los habitantes de las localidades de cabeceras, sobre los recursos que poseen para que sean ellos mismos quienes los protejan.

Las municipalidades y los organismos que correspondan deben mantener programas actualizados de los Planes de Contingencia para casos de accidentes y en especial en los temas relacionados con los rescates en cavernas.

- Plan de Monitoreo

Según lo establece el Proyecto serán los mismos guías quienes se encarguen del monitoreo de los indicadores elegidos, resultados que volcarán en la "Planilla de Control por cada grupo de visitantes". Para ello es importante la capacitación y actualización continúa en las diversas temáticas involucradas, por ejemplo: muestreos, manejo de instrumentos, interpretación de resultados, etc. Capacitaciones que deben ser proporcionadas por parte de organismos y/o profesionales idóneos.

Agradecimientos:

Grupo Espeleológico Lajeño (G. E. La.)

Grupo Azul de Espeleología y Montañismo de Neuquén (G.A.E.M.N.)

KARST Organización Argentina de Investigaciones Espeleológicas (KARST O.A.I.E.)

Sociedad Argentina de Espeleología (SAE)

Por el apoyo y la colaboración en la elaboración de este proyecto.

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Results of Bulgarian-Albanian Speleological Researches in Albania (1991-2004)

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Abstract

The work presents summarized data, most of them unpublished, collected in the period (1991-2004), when 13 Bulgarian speleological expeditions were undertaken in Albania.

The main explored territory covers an area of approx. 320 km² and is located in Southern and Central part of the Albanian Alps. Some explorations have been carried out also in Mt. Dejes and Mt. Gollobordes and in South Albania in Mali I Thate Mt. and its surroundings.

Two hundred and ten new caves were discovered and surveyed. The most important vertical caves are: BB-30 (-610 m); Shpella Cilicokave (-505 m) and B33 (-205 m). 13 other caves are deeper than 100 m. The most important horizontal cave is Shpella e Majes te Arapit with total length 840 m. The largest cave chamber is in Shpella e Gjollave with an area of 8875 m² and volume 443 750 m³. The deepest and longest explored karst spring is Syni i Sheganit (160 m long, 52 m deep).

The present article contains the main results of hydrogeological, lithological, speleo-climathological and bio-speleological studies.

Key words: *Albania, Bulgarian expeditions, speleology, karst, caves.*

1. Survey of the studies of karst and speleology in Albania

The first scientific researches of surface karst phenomena are made by the Albanian geographers Kristo, 1973, Gruda, 1981, 1985, 1990, Hoti, 1990 etc. The first archaeological and paleontological studies of Albanian Alps cave (Shpella Gajtanit) date back to 1923. This cave was excavated by A. Fistany in 1961, and in 1982 there were discovered fossil remains of Hominoids.

Numerous underground cavities have been distributed from the pioneers of Albanian speleology - Z. Ubani, M. Uruci, G. Uruci, K. Gjilbegu, A. Codra, H. Hasa etc. (Uruci, 1994). The beginning of biospeleological studies date back to 1914, when C. Lona from Triest, collects the first Coleoptera from the caves of Mt Cukali. Some other caves were explored biospeleologically by A. Bischoff, C. Lona and A. Winkler in the period 1922-1931 (Genest & Juberthie, 1994), and later - by the Czech zoologist Hanak (Hanak, 1964) and some Italian explorers.

Recently, starting from 1989, many foreign speleological expeditions have been carried out in different areas of Albania. The Italian and San-Marinian cavers had explored mainly the Albanian Alps, but some areas in Central and South Albania (Polisi, Kurvelesh, Tomor, Karaborun, Mali me Gropa etc.) were studied also. Due to the detailed and systematic investigation in the Alps were discovered many new and attractive caves. Among them are: Shpella e Pusit,

deep 370 m and long 5 km (the longest cave in Albania); Shpella Uomini umidi - deep 520 m (second deepest in Albania), and Shpella e Gjek Markut - 234 m deep.

The Dutch cavers made 3 expeditions in Mali me Gropa Mt. and Daiti Mt. British expeditions were held in 1992, 1995 and 1996. Some karst regions and caves were object of exploration from Belgian, Croatian, French, Polish and Slovak cavers and speleologists.

The obtained results are presented in over 150 publications, referred in Speleological Abstracts Bulletin (BBS) of U.I.S. and other bibliographical publications.

2. Geographical situation of Albania

Republic of Albania is situated in the west part of the Balkan peninsula, on the eastern littoral coasts of Adriatic and Jonian seas. Its North geographical latitude is 42° 39' (Vermosh), South geographical latitude 39°38' (Konispol) and Eastern geographical longitude 21° 40' (Vernik), West geographical longitude 19° 16' (Sazan).

The total area of the country is 28748 km². Geographical landscapes are significant with variety of forms. In Albania there are typical mediterranean landscapes on the west with visible continental influences on the east; passing landscapes in the central part, mountain landscapes and especially the Alpine ones, inside and in the north of the country.

Albanian territory takes part in the wrinkled alpine region, connected with seismic movements and various geological construction - sediments (mainly limestone and dolomite), magmatic and metamorphic formations.

The relief is mainly hilly-mountainous, with various surface forms. 23.4 % of the territory of the country lays on 200 m above the sea level. The altitudes 200-1000 m include 48.1% of the Albanian territory and over 1000 m - 28.5%. The two highest peaks of Albania is Korab (2751 m.a.s.l.) in the same Mt. and Ezerca (2692 m.a.s.l) in Albanian Alps.

The west part of Albania has Mediterranean climate, while in the internal parts of the country it is continental. In the high mountain regions there is alpine climate.

In general, the precipitate average is 1480 mm in a year. In total, the average annual quantity of the precipitation changes is from 600 mm to 2100 mm.



Fig.1 Albanian Alps - general view

3. Review of Bulgarian-Albanian and Bulgarian speleological explorations in Albania

The first reconnaissance expedition was carried out in Albanian Alps in November 1991, when the first five caves were explored by A. Jalov, N. Gladnishki and N. Landjev, kindly supported by the members of Albanian Speleological Association - G. Uruci (President) and M. Quku and K. Gjylbegu. The most impressive cave is Shpella Gjolave, near to Bratosh vill., Shkodra district.

From 24th July to 21st August 1992, the Bulgarian Federation of Speleology and the Albanian Speleological Association held their second joint expedition in the west part of Albanian Alps, especially the massifs Velechik, Pultina, Maja Zez and Maja Arapit. Over 100 caves were discovered, of which 52 were explored. The most interesting exploration took place in Shegan karst spring, which was explored to a length of 60 m and depth of 28 m.

The third expedition was held between May 19 and June 11, 1993. The main exploration area was located in Bridash massif. Thirty eight, mainly vertical, caves were surveyed. The deepest was Shpella e Cilikokave, which was explored down to 390 m. The team went to Shpella Majes te Arapit to continue exploration from 1992. After diving of terminal sump (length 60 m), including some new discoveries, the total length of the cave reached 840 m. A second attempt was made to Shegan karst spring, where the explored length grew to 160 m with depth - 52 m. The sump continues, but its full exploration needs mixed gas for further diving. This expedition started the systematic geological and biospeleological studies of the area. In the end of expedition the team worked in the area of Merkuth vill., North West slope of Lura Mt., where were explored two caves.

In September 1993, the 4th expedition ended with a depth record of - 505 m. This was the deepest point of Shpella Cilikokave, discovered and explored down to 390 m during the previous expedition in May, the same year.

In June 1994, a group of eight cavers realized the fifth Bulgarian-Albanian expedition. Its object was the exploration of the Drugomiri massif. Twenty four vertical caves were explored. The deepest of them was BB-1 (Ice Cave) with depth 162 m. During the expedition some geological and tectonic trips were made along with biospeleological and speleo-climatological studies. In September the same year, the 9 members from speleo club "Studenetz", Pleven, went to Bridash to continue the work in the cave BB-30. They discovered and explored the cave to the limit - 60 m in 1992. The cave was explored to - 260 m depth without reaching the end. 25 new caves were discovered and mapped. Later the expedition team worked few days near Small and Bid Prespa Lakes in South East Albania, where were explored 3 new caves.

In September the same year, an interclub team consisted of 5 well experienced cavers from Sofia (N.Gladnishkir, N.Landzhev, V.Peltekov, P.Deltchev and S.Tashevskaja), made detailed exploration of the Mali I Thatë Mt. (2287 m.a.s.l) - South East Albania. Being near the Albanian-Greek and Albanian-FY Republic of Macedonia, the most of the discovered cave-entrances were armed. The cavers explored few little caves.

In June 1995, a team of nine Bulgarians, supported by G. Uruci, worked on the caves of Korinotit and Muriqelles massifs. There were discovered and surveyed 28 new caves, the biggest of which is V-21 with 110 m deep. Some of the caves were explored biospeleologically.

From 8 to 24 September 1995, the members of SC "Studenetz"-Pleven worked again in BB-30. The superb efforts resulted in discovery of few undescended pitches to the depth 570 m without end - new depth record in Albania - and 26 new caves.

The next Bulgarian expedition was held in August 1996, when were discovered and explored 26 new caves in the massifs Korinotit, Muriqelles, Drugomires and Bridash. The deepest of them were K14-148 m; Vb11 -112 m and K21-110 m. During the expedition were made hydrogeological, lithological, speleo-climatological and biospeleological studies.

From 8 to 15 July 2002, A. Jalov and N. Gladnishki explored the karst area of Malësia e Gollobordes (Golobordes Mt.) in Central part of East Albania. During the trip were discovered several, but mapped only 2 caves.

In August 2003 (10-28), 6 members of SC "Studenetz"-Pleven, led by O. Kolov, worked on the prolongation of the cave BB-30 in Bridash massif of Albanian Alps. The expedition ended with a depth record of 610 m. The cave BB-30 became the deepest cave in Albania.

The last Bulgarian expedition was held from 27 July to 4 August 2004, when 7 cavers from SC "Helicitit" and 1 caver from SC "Urvitch", both from Sofia, explored the karst area of Malësia e Gollobordes (Golobordes Mt.) in the Central part of East Albania for the second time. During the expedition 10 new caves were discovered and 7 of them were explored. Some caves were explored biospeleologically.

4. Scientific Results

Caves

The eight expeditions, undertaken in Albanian Alps, resulted in discovery, exploration and surveying of 198 new caves. Most of them are vertical and can be divided into vertical ranges as follows: deeper than 100 m - 19 caves (table 1); from 80 to 90 m - 9; 70-80 m - 7; 60-70 m - 4; 50-60 m -12 and 147 caves in the range from 10 to 50 m deep. The longest caves are: Shpella ne Majes te Arapit - 840 m and denivelation + 58 m, Shpella Jubanit - 255 m and K20 -205 m. The largest cave chamber is that of Shpella e Gjolave with an area of 8875 m² and volume 443 750 m³. The deepest

and longest of the three karst springs which were explored is Syni i Sheganit, respectively - 52 and 165 m. The hypsometrical distribution of 126 of all explored caves is, as follows: 300-400 m a.s.l. - 2 caves; 500-600 -2 caves; 1000-1100 -1; 1400-1500 -13; 1500-1600-21; 1600-1700-16; 1700-1800-19; 1800-1900-41; 1900-2000-11.

During the two expeditions in the Big and Little Prespa area there were explored 6 new caves, the longest of which is Spella Ujkut, near Proger vill. (200 m).

The expeditions in Malësia e Gollobordes explored 10 caves and discovered several new caves. The longest cave in that region is Gur I Jaut near Borova vill. (161 m).

N	Name	Alt.m a.s.l.	Depth m	Length m	Year of explor.
1.	Shpella BB-30	1940	610	-	1994-2003
2.	Shp. e Cilikokave	1840	505	124	1993
3.	Shp.B-33	1880	205	165	1993
4.	Shp BB-1	1460	162	-	1994
5.	Shp K-14	1630	148	-	1996
6.	Shp B-24	1870	135	-	1993
7.	Shp VB-50	1550	131	-	1992
8.	Shp K-21	1830	126	-	1996
9.	Shp VB-11	1610	112	-	1996
10	Shp.e Majes te Zeze	1520	110	-	1992
11	Shp V-21	1520	110	-	1995
12	Shp.Jubanit	410	110	225	1991
13	Shp.Uruchit	1560	108	-	1992
14	Shp BB-11	1850	106	-	1993
15	Shp . Qafa Pejes	1680	105	54	1993
16	Shp. Fushe Zeze	1500	105	-	1992
17	Shp. B-42	2000	104	80	1993

Tabl. I. List of the caves deeper than 100 m, explored during the Bulgarian expeditions.

Geology, tectonic, hydrogeology

The expedition in Albanian Alps in 1994 collected some structural-tectonic information. The main goal of these studies (Shanov, 1996) was to investigate the influence of young tectonic processes on the karst formation. The analyzed information, concerning the karstic massif in Albanian Alps, situated NE from Boga vill., shows, that the massif is built up of Jurassic limestone, deformed at the end of the Eocene. The tip of water-bearing system is jointed-karstic. The direction of the principal tectonic stress axes σ_1 , σ_2 and σ_3 , having acted on the massif from Early Jurassic time up to present days, have been determined by analyzing the dispersion of the pairs conjugate shear joints, as well as tectonic striations and one fault-plane solution from an earthquake near the region of our investigations. The Pyrenees tectonic phase deformations led to the opening of joint systems, striking at NE-SW. The deformations in neotectonic phase have formed secondary joint systems, striking at NW-SE. Faults play a control role about atmospheric waters drainage, as well as about mechanical transportation of debris and deep up to several hundred-meter precipices, open around them mainly in brecciated zones. The erosion velocity is dominating on process of massif uplift during the Quaternary, and many of superficial karstic forms are filled up by diluvial material. This systems of fractures determinate the development of most explored caves. The speleological as well as structural-geological investigations in the karstic massif to the North-West of Boga settlements clarified additionally some problems and showed a strong significance of the fault tectonics as a factor for precipices and caverns formation in the most fragmented zones by young displacements. The analysis of direction of development of 77 explored caves pointed that 39% are developed in NE-SW; 25% in NW-SE; 16% in E-W and 20% - N-S. The development of surface karst relief is dominated by karst corrosion unlike the subsurface karst forms, which are mainly of erosional-tectonic origin.

One of the aims of the expedition, carried out in the Alps in 1996, was to investigate the relationship between geological, tectonic, climatic and hydrogeological conditions in the karst region Boga-Kozhnia (Ivanov, 1999).

Because of the short time, it was possible to cover only an area of about 10 km², so our results are not conclusive, concerning the whole karst massif. At the same time the research, which has been carried out and the data that are currently available, are insufficient for complete description of the hydrogeological framework of the region. It will be possible after an additional and more prolonged and profound further studies. The conclusions we can draw from the research are primarily of practical importance for our speleological studies of the Albanian Alps and especially explored area. The basic conclusion is, that the lithological and tectonic setting of the massif creates favorable conditions for the

formation of gigantic karst systems with elevation range of over 2000 m between the zones of supply and drainage. The strong tectonic activities create prerequisites for the occurrence of large cavities, especially in the lower parts of aeration zone, near to local tectonic fractures. The marked tectonic dissection implies the division of the stream into multitude of trickles, its a fast drainage and as a consequence, insufficient time for corrosion activity. Unfortunately, this also means that below certain depths the cavities will be too narrow for speleologists to get through. Practical experience has shown this to occur 500-600 m below the surface. We hope that the future will give us the opportunity to made more detailed researches so to confirm once more or to disprove this inference.

The speleological investigations gave us a chance to find some meteorite particles in the sediments of two karst caves placed North-West of the village of Boga, in the Albanian Alps. According some Bulgarian authors (Stoev & Muglova, 2000), the interpretation of their origin is like follows: The massive is formed in the Jura and in the Trias limestone and is deformed in the end of the Eocene. Meteorite particles derive as a result of ablation and paleometeorite collision. Many individual representatives were precipitated, separated from the basic meteorite (in the Jurassic sea). That is the reason of their limited number in the volume of becoming karst massive. As a most probable mechanism of ablation is proposed the spraying of meteorite substance as a result of liquefying the surface meteorite layer. The breaking to pieces is under the form of spheres and flaskets with characteristic morphometric dimensions of $10^2 - 10^1$ cm (the representatives found are with dimensions of 10 cm to several mm).

The secondary meteorite particles ablation is considered. There is a process of karst collectors formation after water - mechanical precipitation of meteorite substance in the process of massive becoming karst. The velocity of water flow transported and precipitated mechanical particles has been estimated. It is in the interval of 0.8-5.5 m/s and progressively decreases in time.

Chemical analysis of six meteorite pieces show that the basic chemical composition Fe (91%), Ni (8.4%) and Co (0.5%) as well as the class of the fallen paleometeorite-ferrous-nickel.

Cave's Climate

The carrying out of speleoclimatic studies was the goal of the expeditions in the Alps in 1994 and 1996. Then micro-climatically observations of 39 caves were made (Stoev, Muglova & Stoev, 1997). Applying classical methods of microclimate investigation in the caves from the region data for basic microclimatic parameters have been obtained. Comparatively low air temperatures in the interval of -0.8 to $+4.4$ °C have been registered. The temperatures as well as the availability of snow and ice masses of many years determined the examined caves as ice-caves. The snow, firm and ice accumulation, are favored by the large initial vertical caves deeper than 20 m. The age of blocks of snow and ice could be estimated using measurements about their annual layers. For example in a section of a block from K25 cave nearly 365 snow layers has been registered and in cave K25A they are 286. Probably this stratification shows limited age of blocks - about 400 years. The zone of thermostatic air begins from the place of the first snow accumulation which imbalances the microclimate of the caves and they become colder than the others at the same sea level and climatic zone. In the zones with constant temperature the relative humidity is 60 to 80 % and in most of the caves the flowing and dropping water is too little. Shift-flowing draughts with high velocities are not typical of the air exchange in caves. The standard equalization of both cave barometric pressure and that one outside ground air layer creates weak draughts outside and inside without anomalies of the velocity or their direction. Taking into account that the caves in the region are developed mainly in zones of vertical-going down, passing and horizontal circulation of the underground waters, it is natural to associate part of the air exchange with karst massif clefts connected with surface. Velocities of the order of 0.005 to 0.020 m/s were registered. The air quantity coming in the caves from the massif is 30 m³/h for isostatic caves and 20 to 25 m³/h for dynamic ones.

Zoology

Thanks to the Bulgarian-Albanian expeditions and cooperation a significant amount of cave and external zoological material was collected. During the expeditions were collected important series of cave and external fauna from different groups (Crustacea, Araneida, Opilionida, Chilopoda, Diplopoda, Coleoptera, etc.). Most of them is still under study in Bulgaria and by foreign specialists and will be described soon so here we will try to make a review of the determined animals up to date.

During the expedition in 1994, eight species of Cyclopoids from underground water of North Albania especially Shkodra district were collected and reported by (Pandurski, 1997). One of them, *Diacyclops paolae* Pesce & Gallassi, is stygobiont specie and is new for the Albanian fauna. Four new for Albania harpacticoids were collected also from the karstic groundwaters of North Albania: *Nitorca bibernica* (Brady); *Bryocamptus* (*Br. minutus* (Claus)); *Bryocamptus* (*Rb.*) *spinulosus* Borutzki, *Parastenocaris* sp. (APOSTOLOV, 2004).

In 1995, during the consecutive expedition, zooplankton samples from eight stations were collected. From all of the investigated waters 14 taxa Rotatoria, 11 taxa Cladocera and 6 taxa Copepoda were established (Kozuharov, 2000). The *Cladocera Daphnia galeata* and the *Cyclopoids Tropocyclops prasinus* and *Acanthocyclops vernalis* are also new for the Albanian fauna.

The collection of Arachnida from all expeditions contains 12 species of Opiliones belonging to four families and two species of Scorpions (Euscorpidae). Ten of them – the *Opiliones Paranemastoma titanicum* (Roewer), *Trogulus napaiformis* (Scopoli), *Opilio saxatilis* (C.L.Koch), *Metaplathybunus strigosus* (L. Koch), *Metaplathybunus carneltutii* (Hadzi), *Lacinius dentiger* (C.L.Koch), *Amilenus auratiacus* (Simon) and *Mitostoma cancellatum* (Roewer) (Mitov, 2000) and Scorpiones - *Euscorpius carpathicus* (Linnaeus) and *Euscorpius beroni* Fet are new for Albanian fauna and the last one is new for the science (Fet, 2000).

Sixteen centipede and twenty two millipede species of cave and external fauna are also collected during speleological campaign in different areas of Albania. Six Chilopoda - *Eupolybothrus* (L.Koch), *Lithobius schuleri* (Verhoeff), *Lithobius latro* (Meinert), *Cryptops rucneri* (Matic) and *Lithobius (s.str.) stygius* (Latzel) are new to the fauna of Albania (Stoev, 1996; Stoev, 2001). Among the Diplopoda new for Albania are *Leptoiulus macedonicus* (Attems), the troglobiontic species *Macrochaetosoma troglomontanum* (Absolon & Lang), *Acanthopetalum albidicolle* (Verhoeff). *Acanthopetalum subpatens*, *Typhloiulus beroni* is new specie for the science (Mauries, Golovatch & Stoev, 1997; Stoev, 2001).

The contribution of biological researches during all joint expeditions resulted of discovering of 19 new species to Albanian fauna, including one new specie for the science.

As a conclusion of the zoological part of this report we must note, that some of the most interesting are the discoveries of new beetles.

During the expedition in 1993, we explored also the cave of Merkurth (Shpella Merkuth) near Kurbnesh- Rreshen District. There P. Beron and B. Petrov collected two new species for the science: *Albanotrechus beroni* Casale et Gueorguiev (Coleoptera: Carabidae) (Casale&Gueorguiev, 1994), and *Albanodirus beroni* (Giachino) (Coleoptera: Cholevidae)(Giachino&Vailati,2001). Two more new species for the science were collected by A. Zhalov, Zh. Petrov and K. Stoichkov from Speleo Club "Helictite" – Sofia, during the expeditions in Golo Burdo Mt. in 2002 and 2004. They are *Duvalius (Euduvallius)* sp. (Coleoptera: Carabidae: Trechini) (Guéorguiev, B., in press, personal communication of A.Zhalov and *Ceuthophyes* sp. (Coleoptera:Leiodidae) (Guéorguiev, B., in press, personal communication of A. Zhalov).

5. Media presentation to the public

The expeditions in Albania and their results found wide reflection in the Bulgarian periodicals, speleological and specialized scientific journals in Bulgaria and abroad, which could be seen from the bibliography below. Our cooperative work and joint efforts were in the focus of attention of many European Speleological organizations and their journals, like: "Spelunca" (France), "Speleologia"(Italy), "Caves & Caving" / later "Speleology" (UK), "Regards" (Belgium), "International Caver", "Svet" (Ukraina & Russia), etc.

A visual presentation of Albania to the Bulgarian public was made in 1993-1994. The studio "Chaplains Film" (director K. Maslarski and cameraman P. Panchev) created a 5-series film, which presents in a popular way the nature, history and culture of Albania, as well as the work of the expedition in 1993. The film was shown several times on the Bulgarian National Television and took part in the International Festival of Speleological Films in Barcelona in 1994.

Meanwhile, in 1996, the National Museum of Natural History and Bulgarian Academy of Science, organized a photo-exhibition "Albania and Indonesia through the objective of the Bulgarian Speleologists". The exhibition included 33 photos, which show the work of expeditions, the people, nature, folklore and historical sites in Albania (author A. Zhalov). Later the exhibition was shown in the Museum of Speleology and Bulgarian Karst in Chepelare, the Paleontological Museum in Assenovgrad and in the National Museum "Earth and Man" in Sofia.

These activities contributed to the wider presentation of Albania to the Bulgarian and international public and increased the interest in this beautiful country and its people.

Acknowledgments

I would like to thank the members of the clubs of Bulgarian Federation of Speleology, who supported me during all expeditions and for their cooperation in the exploration of Albanian Alps and Malësia e Gollobordes. I am very obliged to my friend and colleague Prof. Gezim Uruçi - the President of Albanian Speleological Association, for his cordially friendship, selfless help and proverbial hospitality. I would like to thank my friends and colleagues A. Benderev for the useful suggestions during the writing of this text, A. Stoev, B. Guéorguiev, D. Kozuharov, I. Ivanov, I. Pandurski, P. Mitov, P. Muglova, and others, who kindly offered me the result on their work, and M. Stamenova, who help me to translate to English this report.

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Historical data for karst Phenomena in the province of Macedonia, Greece (XVII-XX C.)

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Abstract:

The present article aims to look over some little known historical and geographical data about the karst phenomena and caves in particular, in the region of province of Macedonia, nowadays Greek territory. This information is extracted mainly from travel notes of local and foreign voyagers and explorers (Ottoman, French, Russian and Bulgarian authors), who used to live and travel in the European part of Ottoman Empire, i.e. the Balkans, from 17 to 20 Century.

Key words: karst phenomena, caves, travel notes, Greece

In the course of millions of years the geological and geographic conditions had formed various karst phenomena on the Balkan Peninsula. The most typical and well known of these karst formations are the caves in particular. They can be seen as an integral part of our common natural and cultural heritage and always have drawn the attention not only of scientists but of common people as well. The caves appeared to be objects of religious, knowledgeable and exploration interest for local people and foreigners since the remote past. In the course of time, the exploration of karst and caves became more intensive and the descriptions of objects became more detailed, accordingly to the achievements of the science at that time. The availability of such data increases since 17 c, when more and more local and foreign explorers (mainly Ottoman, French, Russian, Austro-Hungarian and British authors) began to travel, write and publish their impressions about the European part of Ottoman Empire, i.e. the Balkans. The descriptions of karst phenomena appeared mainly in the travel notes of the explorers and voyagers of that period. They are different in topics and style, depending on the point of view of the authors – they vary from general passing descriptions of places and sites, to detailed information about certain karst objects. In such context, this work is an attempt to present chronologically some of the above mentioned data about karst phenomena in the South-East part of the Balkans - the province of Macedonia, nowadays Greek territory, which appeared to be little known in the speleological community. (*map?*)

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First data about karst and caves in the period 17-20 c. we could find in the books of Evlia Chelebi – one of the most famous Ottoman voyagers, who lived and worked in 17 century. His numerous wanderings were described in 10 parts of manuscript travel notes. His books became popular and were fully recognized as a historical source only after their publishing in the end of 19 and the beginning of 20 c. According to the Bulgarian translation (Chelebi, 1972: 168), a part of volume VIII of the travel notes is dedicated to Chelebi's journey from Istanbul to Thessalonica in 1667. Here the author describes the mountains west from Seres and mentions that he saw there "one big high rock, called Gerdek-kaià, where are many hundreds of caves", without giving further information about the site.

New contribution in enlarging of the knowledge about the karst in the area, we can find in the book of 2 volumes of E. M Cousinèry: "Voayage dans la Macedonie, contenant des recherches sul l'histoire, geographie et les antiques de ce pays", published in 1831 in Paris, which we treat according to the interpretation of Bulgarian authors in the present article (Shopov, 1907: 784, 788-789; Tsvetkova, 1975: 375-376). The author was a general consul of France in Thessalonica in 1773, 1783-1785 and 1786-1792. During this period he travelled many times in South Macedonia (he visited the regions of Thessalonica, Seres, Drama, Kavala, Edessa). He was interested in history, geography, archaeology, geology, etc. and was a member of many scientific institutes and organisations (the French Institute, the Munich Kings Academy, the Marseille Kings Academy and the Antiquity Society in France, etc). Concerning karst phenomena, here Cousinèry gives elaborated data about beautiful stalactite caves near Voden (now Edessa), but in more details describes a spring cave, which used to be an ancient sanctuary. The Chapter II of his work presents an emotional description of Cousinèry's voyage to this cave, which in the old pagan times used to play an important role in the cult of the local tribes. This cave was situated in foots of the mountain Zmiinitza (probably now Menikio). To reach the cave, Cousinèry from Drama went to Prosechen (now Prossotsani), and then he was traveling one hour along the stream of Panega to the Mt. Zmiinitza. The entrance of the cave was small and almost fully covered with big stones. Cousinèry had to kneel and crawl in order to enter the cave. When he went inside, he was rewarded by a view of a shrine, where some unknown nymph appeared to be worshipped in the old

times by the local people. The cave was round. Its upper part had a shape of almost regular vault arch, twenty five steps long and fifteen steps high. On the left side were situated rows of big stones, similar to these on the entrance of the cave; it seems that they were used for seats for the spectators of the cult ceremonies. Inside there was a spring of clear water, which flew through the cave. Cousinéry noticed also an old construction, made under an opening, from which inside the cave penetrated mysterious light. Probably this construction was designed for a staircase, through which people used to enter the cave, where the nymph was worshipped in the past. Cousinéry knew well how the ancient people respected the springs and the rivers and that is why he was sure that this cave was a temple for worshipping of a deity of the water. Cousinéry presents here interesting data about the continuation of this cult in 17 c. and stated, that the population of the surroundings still respected this cave as an ancient sanctuary. Close to the cave Cousinéry discovered also ruins of massive old buildings, which could be remains of ancient settlement. In spite of the statement of the author, that this cave was situated in Mt. Zmiinitza (now Menikio) near to the stream of Panega, the available data gives us reason to suppose, that here Cousinéry describes the cave Maara, which is situated in the foots of Mt. Bozdag (now Falakron), near Drama, Greece. It seems that Cousinéry's work is also the first known written source, which reports about the existence of this famous water cave and which explains the origin of the waters flowing inside the cave.

Apart from the information of the above historical site, in the same description, Cousinéry mentions about another karst phenomenon - "losing of surface waters". Based on the story of the Thessalonica bishop, Cousinéry writes about a small river, situated one hour far from Nevrokop (now Kato Nevrokopi), which was losing its water in the sand in this region. The same river, according to the legend, was flowing under the mountains and appeared again in Drama eparchy, in the above mentioned cave, the same ancient nymph shrine. The Thessalonica bishop assured Cousinéry, that local people were curious to know where this river flows underground, that is why they threw millet seeds in Nevrokop, where the river disappeared. After three hours these millet seeds were spotted in the spring of the mentioned cave, by people, who stayed there exactly for this purpose. This information, which gives us Cousinéry, shows in practice the experiment, now known as "water tracing". These data are the first known ones of such experiment at the time of 17 c.

Looking at the book of Cousinéry in the above context, his work appears to be among the first printed known sources, which gives us more detailed information about the karst phenomena and historical caves on the Balkans.

The description of karst phenomenon - "losing of surface waters" can be found also in the travel notes of the Russian national Petar Ageev (monk Partenii) from 1839. In its Bulgarian translation (Kozuharova, 1986:193-194) we find a description of the travel of Petar Ageev from vill. Perelik, Blagoevgrad district, Bulgaria, to the monastery St. Joan Predtecha (St. John The Forerunner)(unknown Greek name) in the surroundings of the town of Seres:

"We were walking in the foothills of the steep mountain through the gorge: on the right there was a deep abyss, somewhere down was running fast a big river and the water was babbling... After that we went down to the valley, where flew the river, passing below a stone bridge. We looked under it - we could not see even a drop of water and we were very surprised why. Up there was coming plenty of water and here there was no even a drop. Where this water flows? We were very surprised of this fact. We went down again. Now from our right side was the mountain and from the left - a dry valley. Walking on our way, we were wondering at this phenomenon - why on the top was flowing a river and down everything was dry".

Unfortunately in these travel notes there are no data, according to which we could exactly localise the mentioned phenomenon. Knowing the terrain, we could suppose that the losing of water happened in the region of some of the mountains Orvilos, Vrondou or Menikio in Greece.

The Russian national Egor Yuzakov, gives us data about cultural remains in a cave, related to Christian religion and probably dated back to the mediaeval times. He was a collaborator of the prestige Russian magazine "Suvremennik" (Contemporary) and in 1860 published his travel notes "One Month in Bulgaria". Here he describes in details his visit to a small cave church 5 sazena long [1 sazena - 2,134 m], situated on the hill Byala charkvã (i.e. The Hill of the White Church)(unknown Greek name) near to the town of Kukus (now Kilkis), (Kozuharova, 1986:291):

"The entrance of the cave was so low and small, that we had to fold ourselves in order to enter. Anyway, we entered the cave with candles... According to the legend here used to live someone hermit, even before the conquering of the country by the Turks. The walls of the cave were painted (probably the hermit was an artist) with images of the saints in human size. The images and inscriptions were almost deleted. In the cave on the right, half of its height, there was a niche - probably there was the bed of the hermit".

Unfortunately, this description again does not give us enough data, according to which we could localise the site, described in these travel notes.

The famous Bulgarian historian, ethnographer and geographer Vassil Kanchov publishes different editions series of articles, which could give us an idea about his research activity in the regions of Macedonia, still remained in the confines of Ottoman Empire. The published materials present rich and extremely interesting information about caves near Razlog, Prespa and Ochrid lakes, as well as for cave churches near Struga. Besides this, the author reports about his visits of karst

terrains and describes typical limestone rocks, sinkholes and springs. For instance, in (Kanchov, 1891: 47-52, 93-101) the author describes the sinkholes of the water in the Big Prespa's lake and points on the presumed underground connection between the lake and the karst spring near the monastery "St. Naum", Ochrid region. The cited work presents also the local legend explaining this phenomenon, which shows the various interests of the explorer. In other work (1894:237-247) V. Kanchov competently describes the movement of the karst waters in the south slopes of Ali Botush/Slavianka (now Orvilos) and Bozdag (now Falakron) near vil. Zarnevo (now Kato Nevrokopion) and Lissa describing the sinkholes and cave springs and there, including also the famous cave-spring Maara near Drama. The contribution of V. Kanchov to the karstology and research of the caves not only in Bulgaria, but also on the Balkans deserved to be a subject of a separate work.

More full and detailed descriptions of karst phenomena gives us the book of Herman and Karel Scorpil, published in France: "Sources et pertes des eaux en Bulgarie" (Springs and sinkholes in Bulgaria) (Scorpil, H. et K., 1898), where as a result of specific terrain explorations are presented over 100 karst phenomena (uvalas, caves, springs). In the book are included also 21 figures, which clearly illustrate the hydrogeological connections in the explored karst regions. In this remarkable book there is a very interesting chapter: "Panega in Macedonia". This chapter is worked over the information of the French geologist O. Viquesnel, published in his book "Voyage dans la Turquie d'Europe", Paris 1868. II. Here the author reports, that near vill. Lissa in the north foots of Bozdag (Falakro) there is a sink hole, where the Eleshka or Lissa River loses its waters. After passing the underground distance of 5 km, the river, called Panega, flow out of a cave in the south foots of the mountain Nort-West from Prossotsani (Drama region). The French geologist mentions that, the mountain is formed of limestone and the sink hole, called Eleshki Douпки is situated on 610 m a.s.l., but the cave is on 134 m a.s.l. According to the author, the falling of the underground river is about 100 m for 1 km distance, which shows the existence of big waterfalls. There was a story, that three peasants went into the cave and after three hours walking along the bank of the underground water, they reached a waterfall, which thunder was heard for a long distance. There is no doubt, that the publication of Viquesnel, respectively of K. Scorpil, tells us about the cave Maara near Drama. These, who are interested in this information, could find more details in the book of K. and H. Scorpil and in the original publication of the French author.

After the Berlin congress in 1878, the united efforts of the Great European powers at that time led to returning of territories from the newly liberated Bulgarian lands again under the Ottoman domination. These territories were situated mainly in the regions of Macedonia and Odrin Thrace. The Bulgarians from Macedonia and Odrin Thrace began their own organised armed struggle for liberation from Ottoman yoke. Several revolutionary organisations were established (1893 - the Internal Macedonian-Odrin Organisation; 1895 - the Supreme Macedonian-Odrin Committee), which took the leadership of these liberation fights. In some occasions, the organised groups of rebels used the caves for shelter or depots, for which we have information in the archive documents. Maybe one of the most interesting data is related to the cave Kape near Krushevo (now Aladohorion), where in 1898 and from 30 January to 6 February 1903 were looking for shelter the rebels, led by the famous vojvodes (leaders) Gotze Delchev and Yane Sandanski. A description of this cave and the events related to the above process, we find in the works of Bulgarian authors (Miletich, 1927: 39, 147; Javorov, 1965: 145-152). More information about availability of caves in the near by area - next to vill. Banitza (now Karie), situated in the East slope of the mountain Sharlia (Ori Vronodus) can be found in the memoirs book of S. Takev (Panajotov and all. 1978: 186). In other memoirs from the period of the liberation fights in Macedonia are mentioned caves on the bank of the Great Prespa Lake, connected with events in the time of Ilinden-Preobrazene uprising in 1903 (Miletich, 1926: 71).

In 1993 in Bulgaria was published the book of P. G. Mandzukov "Forerunners of the storm"(Mandzukov, 1993: 241-231). The author, who was an anarchist, describes his life, part of which was connected with the fighting for the liberation of Macedonia from Ottoman domination. The memoirs of Mandzukov, dated back to the summer of 1899, present interesting information, which has direct link to the topic of this article. On the first place we have data about the existence of many caves in the surroundings of village Guyredzik (now Granitis). Here we find again descriptions of the karst phenomena cave-sinkhole, karst marsh, spring cave on the south slope of Ali Botush (Mt. Orvilos). Much more important is the profound information of the karst phenomena in the mountain Bozdag (Mt. Falakron, Greece) The author reports about numerous conical uvalas on the plateau parts of the massive and about the penetrating of the band he belonged to, in a big and beautiful cave below the peak, called Kalam Bourgas (probably now Hinotripa, 2232 m a.s.l.).

In the period of the Balkan wars (1912-1913) and the First World War (1915-1918) were undertaken several complex scientific expeditions, led by the famous Bulgarian archaeologist Bogdan Filov and were occasionally explored two caves. The first one is located close to vill. Elefteres, close to Eleftheroupoli, the region of Kavala. About this cave the author writes:

"We were told also, that close to one of the neighboring peaks, named "Orlov vrah" (Eagle's peak) was situated some cave, which seemed to be used in the prehistoric times. Here the local people used to find fragments of broken pottery and a plate with inscription, from which I was promised to receive an imprint" (Filov, 1993: 35).

The location of the next described cave is in the surroundings of Ludzha vill. (probably Thermes, south from Xanthi),

where is situated the ancient Trayanopolis. About this site the author writes:

"Half an hour walking above the village in Sarelski dol (Coomb of Sarel) there is a prehistoric cave, which we visited and inside of one of its branches we found fragments of Neolithic pottery" (Filov, 1993: 101, 113).

We do not know which are the caves mentioned here and whether they are explored by speleologists and archaeologists. At the moment we do not have any data about undertaken explorations of these sites and we suppose that the future efforts in this field would be very useful.

The archive and published materials, examined in the present article, could be used as an additional source of information for availability of caves in the region of the province of Macedonia, Greece, inhabited from 17 to the beginning of 20 c. with mixed population of Bulgarians, Greeks and Turks. The detailed analysis and careful consideration of these data could widen or even find a new starting point for various exploration initiatives of the karst in the area, which is still little known from speleological point of view.

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The speleological researches in South-West China of the Museo Civico di Storia Naturale di Verona (Italy)

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Abstract

The collaboration between Italy (Museo Civico di Storia Naturale di Verona) and China (Guizhou Provincial Science and Technology Department and Guizhou Normal University of Guiyang) was established in 1994. In fact, in 1992 the Geology and Paleontology Department of the Museum of Natural History of Verona had already initiated a series of studies on hydrogeological and karst development in South Western China; initially in Guangxi (1992) and, since 1994, in Guizhou. Eight scientific expeditions were carried out by the Department of Geology-Paleontology and Zoology of the Museum of Verona between 1994 and 2004. During these research campaigns numerous speleological, hydrogeological and biological data were collected, most of the latter are unpublished,

which allowed the identification in the areas of Hong Lin (Qianxi County) and Libo County, of the most suitable and interesting areas for the development and integration of the researches begun in the previous years. The last researches in Cina (2003 and 2004) was co-financed by the Ministry of Foreign Affairs of Italy. The research project is named "Quality of the most important reservoirs of karst waters and of the subterranean environments of Guizhou". In this two years more than one hundred caves was explored and a lot of cave fauna was collected for study. As part of the project an internet site has been set up (www.progettoguizhou.it), structured in many different parts. This has been an excellent tool for communication and the diffusion of information at a national and international level both in the phases prior to the investigations as well as afterwards.

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The saga of the Boston Grotto

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The Boston Grotto of The National Speleological Society

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Abstract

The Boston Grotto, chartered January 26, 1952, is the 18th oldest grotto in the NSS. In 2002, in recognition of the 50th anniversary of the Grotto, members reviewed historical records, contacted original members, and then presented the history at the 2002 NSS Convention in Camden, Maine. This club's story is typical of many caving organizations and may help other clubs gain perspective on their history.

The grotto started when students at Harvard and MIT, led by Tom Barr, decided that visiting caves would provide excitement and adventure in locales far from Boston where there are few caves. In the late 1950's, when the core student members graduated and moved away, it fell upon a new member, Roioli Schweiker, to resurrect the club. She did this by recruiting from among working professionals, most in technical fields. To involve the new members in the club she started projects to find caves. One of her first projects was the first guidebook to the caves of Schoharie County, New York. Eventually, Schweiker's leadership passed to other chairmen, some of whom did not actively promote membership in the Grotto. By the late 1970's, it fell upon John Evans to resurrect the club. He did it by appointing each grotto member to a responsible position in the club, and involving the Boston Grotto in the 1979 NSS Convention held in Pittsfield, Massachusetts, particularly when locating and mapping caves in New York, Vermont and Massachusetts prior to the convention. The two subsequent chairmen, Kevin Harris and Steve Stokowski, continued this caver recruitment and retention model with caving projects in Massachusetts, Maine, New Mexico, New York, and Rhode Island, including cave mapping projects before the NSS Conventions in New York and Maine.

Grotto members contributed significantly to cave mapping and exploration. A map of Mitchells Cave, NY drawn by the Grotto graced the first NRO (Northeast Regional Organization) Bulletin, and club members produced the first maps of some of the longest caves in New Hampshire (MDBTHS) and Maine (Enchanted Lake Cave). Grotto members wrote or contributed important material for the publications Vermont Caves, Caves of Massachusetts, and NSS publications for the Pittsfield, Schoharie, and

Camden conventions. Grotto members also made important contributions in the exploration of Ellisons, Fisher Ridge, Lechuguilla, Mammoth-Flint Ridge, McFails, Mystery, Peña Colorada, Rio Camuy, San Agustin, and Scott Hollow caves.

Two Boston Grotto members died while caving. Jim Mitchell, the grotto vice-chairman, died from hypothermia in Schroeders Pants Cave, NY in 1965. The NSS named the James G. Mitchell award after him. Eric Tsakle passed away because of rock movement in Fullers Cave, WV in 1985. These fatalities led to increased safety and rescue training, which prevented incidents and resulted in better outcomes for later accidents.

Many members of the Boston Grotto subsequently went on to prominent positions in the NSS and the National Cave Rescue Commission, received significant awards from the NSS, or completed significant and widely-recognized cave-related scientific and engineering accomplishments in biology, computer science, electronics, geology, and medicine.

Introduction

The Boston Grotto, chartered January 26, 1952, is the 18th oldest grotto in the NSS. Given the extent of karst landscape or lack thereof in the Northeastern United States, it is a true testament to the motivation of a handful of people that the Boston Grotto ever came into existence and thrived for 6 decades. From the very beginning, the major challenge that faced its members was the need to organize long distance caving trips to places like West Virginia and the TAG country, to find the spare time to do it and to do it safely. The holiday weekend trip to West Virginia from Boston, Massachusetts is not an extraordinary occasion for our members. It is part of life. The unofficial #1 rule of the Grotto is this: if your caving does not exceed in hours your round trip driving then it is not worthy. That is not to say the Boston Grotto members snub at what New England and the Northeast have to offer. They are the main force behind a systematic effort to identify, explore and survey all karst formations in the Massachusetts area, while extensive mapping and conservation efforts have been un-

dertaken in the upstate New York, New Hampshire, Maine, Vermont and Rhode Island coastline areas. At the same time, the cosmopolitan character of a major urban area like the city of Boston ensures an international spirit amongst our members who have organized extensive international trips. To the best of our knowledge, the 14th UIS in Athens marks the first occasion that two Boston Grotto members, Emily Davis and Emmanuel Pothos, will be caving in Greece, although George Ehrenfried was known to pay a non-caving visit in the 70's. The commitment of our members to caving is tragically illustrated by the fact that the Boston Grotto is the only caving organization in the NSS and maybe the only one in the world to have an acting vice chair killed in caving action. His remains are still entombed in the cave where he fell. The incident is described in more detail below.

The 1950s

Most of the information in this section is based on an interview with George Ehrenfried (NSS# 2099R) which took place in his house (Cambridge, MA) on June, 2005 and on personal notes provided by George Ehrenfried and Roioli Schweiker. It was a group of students from Harvard and MIT with interests in geology, cave biology and simply caving that put together an application to the NSS for a new grotto in the Boston area. Thomas C. Barr, Jr., the founding president, was notified of the granting of the charter on March 10th, 1952. The charting date was January 26th, 1952. Tom's thesis was on bat hibernation. Soon thereafter, a fellow working for Polaroid by the name of George Ehrenfried happened on the Sportsman's Show from February 4th to the 9th. Dexter Hinckley (from Schenectady, NY and a member of the MET Grotto) had put together the NSS exhibit there. George was impressed with the elaborate tunnel and the artificial speleothems and when Dexter told him about the grotto he decided to join. After a February 21st Grotto meeting in the Harvard Biology Laboratory, George participated in one of the first caving trips to Duaneburg, N.Y. led by Duane Featherstonehaugh. As George remembers, the whole party stayed in Duane's family barn and "shocked the puritanical women of the family". Some of the caves visited include Wards, South Bethlehem, Hailes and Church. Early trips of the Grotto also visited the Twin Lakes (or Bashful Lady) cave, Schroeders Pants, Bensons, Eldons and Sunderland. Clarksville Cave, one of the perennial and convenient favorites for the Grotto was visited on November 2nd, 1952 according to the diary entries of George Ehrenfried. The first Grotto meeting on international caves was on November 7th, 1952 and focused on a presentation by Pierre Agiron of France on French caves.

Some of the notable activities of the early Boston Grotto include the participation in the American Association for the Advancement of Science meeting in Boston in December 1953. NSS was an AAAS affiliate and George Ehrenfried reported on the NSS section meeting in Science magazine. Around that time, the long time affiliation of the Grotto with the town of Schoharie, N.Y. was initiated with an underground research project to find new water sources. While a pair of still unidentified members discovered a connection between Bensons and Secret Caverns, it became apparent that the then famous waterfall was not running at night. It was simply an artificial stream turned on and off by the guide just before a group of visitors were to show up. Finally, it should be noted that the first recorded accident in the Grotto took place when the mother of a Grotto member put a pair of caving jeans in the washer without realizing that a can of carbide was left in a pocket. Pieces of the exploding washer went through the ceiling.

A number of remarkable cavers were active with the Grotto during the 50s. Tom Barr, the first Grotto chair, was elected president of the NSS (NSS News, 1965, vol. 23, p. 96) and later became state speleologist in Tennessee. Rane Curl was one of the early chairs, a good organizer and prominent in NSS later as President. Don Peters was one of the most creative chairs of the Grotto and distinguished himself in games, songs and

paintings. He published the booklet "Songs of Cavers" in 1954, while his trip in Boca del Diablo (the Devil's Throat), Mexico made the headlines as he was marooned for three days by high water and rope trouble. In the November 1957 issue of the NSS News (p. 129) we read an article by Don Peters on how he and a party of three decided to explore this famous cave southwest of Mexico City where bandits roaming the Sierra Madre disposed of their victims. Except that this time the danger came from elsewhere. Some fifty feet from the bottom of the pit (total length was estimated at 300 feet), the rope snagged through an "eye" in a rock ledge and snarled badly. As they worked into the evening trying to salvage as much of the twisted rope as they could, a thunderstorm broke loose and the ensuing downpour trapped them into the cave for at least 20 hours. No skeletons at the bottom of the pit, just piles of Pepsi Cola bottle caps!

As creative as Don Peters was, membership was fizzling out, organization was deteriorating and finances were not in good shape. Enter Roioli Schweiker, who made a strong effort in reviving the Boston Grotto. She started as a competent rock climber and member of the Pittsburgh Grotto around 1955. She soon moved to Boston when she was a pen pal of Don Peters on the "Songs of Caves", so she joined the Boston Grotto upon arrival. In the Spring of 1956, Roioli was recruited as the Grotto's secretary-treasurer by the then Chair Don Grandly. Soon after, chair and vice-chair left the area, only to drop the Grotto's fate in the hands of Roioli. Theodore Uhlman was elected chair, but both he and Roioli were not from the area and had little topographical information on the local caves. Piece-by-piece and visit-by-visit to relatively nearby areas (Schoharie County, N.Y. for example) with a new baby in arms, Roioli started the New York State Cave File. Regular exchanges of material with other Grottos were initiated and the list of caves to be explored soon expanded. Cave information poured in and the Northeastern Regional Organization was impressed enough to start a cave survey of New York. The July 1957 issue of NSS News (p.82) features an article by Roioli on the winter caving activities of the Boston Grotto in January 1957. She describes her visit on Mt. Mansfield, Vermont, and the Cave of the Winds and the conquest of its last 20-foot drop and the visit to Adirondack Stone Bridge and Caves in Pottersville, New York. According to the diaries provided by George Ehrenfried, the first recorded trip to West Virginia occurred in June, 1957. George Ehrenfried and Roioli Schweiker were present along with Frank Maher, Ted Zillman, Hans Fritschi, Henry Oakum, Carol Weston, Jean Doren and Don Peters. The West Virginia trip went to Mouth of Seneca, Glue Cave, Stratosphere Balloon Cave, Smoke Hole Cave, Sinks of Gandy and Sinnetts Cave. By 1958, John Fisher and Dick Anderson were instrumental, along with Roioli and Frank Maher, in making the survey of Schoharie County an official NSS project. The purchase of Schoharie Caverns and Balls Cave by Jim Gage (who renamed Balls Cave as Gage Caverns) gave Grotto members a campsite and meeting place at the cabin and field of Schoharie Caverns. By 1959, Loessers Woods, Lasells Hell Hole, Porcupine Cave on Terrace Mountain, Acks Schack, and literally every single reasonable lead in Schoharie County was located. Jim Fisher, Hugh Blanchard, George Ehrenfried and others held the first recorded conference on the bylaws of the Grotto on May 4th, 1959. Soon after, Walter Webb of the Museum of Science joined the organization and the decade closed with a rather difficult trip to Purgatory Pit due to ice on the rope and a challenging ascent.

The 1960's

It was a decade of continuous caving activity and tragedy for the Boston Grotto. The then active members included Mike Carlucci, Hans Fritschi, David Gandel, Bob Fenichel, Joanne Roberts, Sue Griggs, Gloria Goldberg, Gay Lorraine, Jim Fisher, Dan Hoyt, Roioli Schweiker, George Ehrenfried, Francis Kuhn, Frank Kreider, Alan Budreau, Mark van Baalen, Stuart Peck, John Dunning, Emily Davis and others. The diaries of the Grotto refer to the following caves as sites that Grotto members vis-

ited: Surprise Cave, Rhodes Cave, Bentleys, Pettibone Falls, Eldons and various unnamed caves in Alabama, Puerto Rico, California and Iceland. A party of 5 including George Ehrenfried and Alan Budreau discovered about 600 feet of virgin passage in Surprise with impressive new formations and exercised good judgement in keeping it secret until protection could be arranged. The first documented cave diving trip by the Grotto apparently occurred in 1968 in Knox and McFails and involved Brian Pease, Barry Allen, Art Palmer, Peg Palmer, Peter Williams, Ed Miller, and Alan Budreau, with the first two being the divers and the rest being coolies. It is almost certain that numerous other caves not mentioned above were visited in the 60s and are simply not referenced in records.

James Gentry Mitchell, NSS No. 7157, was the first fatality of the Boston Grotto in Schroeders Pants Cave, Herkimer County, New York (NSS News, March 1965, vol. 23, No 3, pp. 35 and 95). The incident took place on Sunday February 14th, 1965. James was a chemistry graduate student at M.I.T. residing in Winthrop, Massachusetts at the time. He was part of the research team on the Gemini Space Project. His caving activities originated in St. Louis when he was an undergraduate. His parents Mr. and Mrs. James G. and Winalee Mitchell of Waterville, Ohio and a brother who was also a caver survived James. His parents have instituted the James Gentry Mitchell Memorial cave Research Fund in care of the NSS.

James was the vice chair of the Boston Grotto at the time of his passing and an enthusiastic and likeable young caver. During the fatal trip, he helped Hedy Miller and Charles Wagner up the rope and out of Schroeder's Pants cave. The ascent out of the cave exposed the cavers to a small entrance stream waterfall. Upon attempting to exit the cave himself, James became hypothermic, quickly lost consciousness and died. In a special note that his parents published in the NSS News (ibid), it is emphasized that the temperature of the water was very cold and James had only a few minutes to react before he was in serious circumstances. The short reaction time left and the lack of appropriate equipment and experience by the other cavers to lift James's body over the top led to the tragic outcome. His remains are still located where he fell, while the cave has been closed

since authorities used explosives to make it collapse and fill the pit. Reports of unauthorized visits since then have prompted the Boston Grotto to consider the option of recovering Jim's remains for burial.

According to Alan Budreau, the death of Jim Mitchell energized the Grotto because of the notoriety. Dan Hartline, with help from his friend Beth and his brother Peter, created a well-organized, safety conscious club. Definite qualifications for "horizontal caver" and "vertical caver" were introduced after much training and rescue practice. Will Crowther worked out an ingenious pulley arrangement that would allow any small caver to pull almost anyone up and most of the members learned it.

The 1970s

The previous decade set the pace for the Boston Grotto members and defined West Virginia and New York as the areas most frequently visited by members outside of New England. The shared long car drives were by now the norm. Accidents were reduced but not altogether eliminated. In 1975, a falling rock injured Boston Grotto member Carl Traina as he was negotiating the bottom of the Thunderbolt Climb in Schoolhouse Cave, West Virginia. As it was Thanksgiving weekend, hundreds of rescuers showed up. Led by Boston Grotto members, the rescuers pulled Carl up the climb and across Nick-of-Time (over a 150-foot deep pit) out of the cave. He did suffer a broken hip.

One of the notable active members in the 1970s were Jerry McCollum, one of the few blind people ever to cave frequently. He was trip chair for many years, and had a great sense of humor. He did not let his disability impede his explorations in the least, and was active in conquering all caving obstacles: climbs, water, chimneys and tight squeezes. His nemesis was traveling over rough breakdown, but he flew in crawlways.

Other active members in the '70s were Dave Allured, Peter Quick, Jeff Barry, Wanda Metcalf, Bob Warshow, Steve Stillman and Henry Schnieker. Dave move to the west and became one of the discoverers of

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Boston Grotto in the Early Years

Top Left: Don Peters and Jean Doren in Simnetts Cave, West Virginia, June 15th, 1957. Photograph provided by Roliol Schweiker. **Top Right:** George Ehrenfried in Onesquethaw Cave, Clarksville, N.Y. December 7th, 1957. Photograph provided by George Ehrenfried. **Bottom Left:** Roliol Schweiker in Delaware, undated photo. Photograph provided by Roliol Schweiker.

Lechuguilla Cave. Peter led the exploration and mapping of caves in Vermont before graduating from UMass (Amherst) and moving to Michigan. He later became one of the principal explorers of the Fisher Ridge Cave System in Kentucky. In 1974 John Evans moved to the Boston area and joined the Boston Grotto, in which he would serve as Chair from 1975 to 1986. John was the only Grotto member familiar with vertical caving when he joined. Over the years, John has participated in expeditions to Mexico, and visited caves in over 25 states. He has become proficient in cave surveying and mapping, vertical caving techniques, and a certified cave diver. Kevin Harris joined the Grotto in 1977 and became vice chair until 1986. John and Kevin emphasized an "egalitarian" philosophy, where the Grotto led lots of novice, training and intermediate trips and didn't concentrate on aggressive exploring. Emily Davis, later Mobley, also became increasingly active with the organization, especially in the New York area. Emily would eventually establish Speleobooks and invest her efforts in cave conservation in the Schoharie County area and elsewhere. The decade closed with the successful organization of the NSS Convention and publication of guidebook by Boston Grotto in Pittsfield, Massachusetts.

The 1980s and 1990s

George Ehrenfried made several trips to Iceland in the '70s and '80s. One trip in 1985 included Kevin Harris, and was noteworthy as an exploration of an old, partially collapsed lava tube disclosed a sequence of 28 "caves" and 42 "natural bridges" in a row over a 2 mile stretch of ground were discovered.

Starting in 1980, John Evans became involved with cave rescue. He currently is Regional Coordinator for the National Cave Rescue Commission of the NSS and organizes courses to train both cavers and rescue agency personnel. As a culture of caving safety became paramount for the Boston Grotto, undeserved bad luck did not abandon its members. The second caving fatality occurred in West Virginia in 1985. A shifting breakdown block crushed member Eric Tsakle in the Fuller cave entrance to the Culverson Creek Cave System. Hundreds of cavers had passed the rock before the incident and none had suspected that the 8-ton rock could easily shift and cause serious injury. This tragedy affected the grotto greatly: several long time members dropped out and disagreements over safety and editorial policy in the newsletter sapped energy. Only the eventual addition of several energetic new members eventually brought the grotto back to its former level of activity. In 1986 (and until 2001) Kevin Harris became the new chair with John Evans as vice-chair.

The increased emphasis on safety training eventually paid off. In 1991, Beverly Schwartz got trapped in a very tight crawlway in Clarksville Cave, N.Y. Gary Lau called for cave rescue assistance and Bev was freed after 20 hours. In 1998, Craig Douglas (not a Grotto member) slipped while negotiating a tight fissure passage at Keyhole Cave, N.Y. He ended up hanging upside down from his leg caught in the fissure. Buster Miller, a Boston Grotto member, attached a chest harness on Craig and pulled him into a horizontal position. John Evans, Morrie Gasser, Jeff Zinc, Chrissy Frotten and other Boston Grotto members directed an effort of 100 people for 2 days that led to Craig using an air chisel to free himself. Also in 1991, the Grotto was heavily involved in the organization of the NSS Convention in Cobleskill, New York (50th NSS Anniversary).

On November 15th, 1996, former Grotto member Joanne Van Sambeek (formerly Roberts) was killed instantly by a reckless car driver in the land of the bicycle, the Netherlands. Editor of the Boston Grotto Newsletter, predecessor to The Massachusetts Caver, Joanne was an accomplished international caver and butterfly expert who inspired others with her outdoor activities in the caves and mountains of New England (The Massachusetts Caver, January-February 1997, vol. XVI, no. 1).

A major grotto project at the end of the 1990s was the editing of the

1996 NSS "SpeleoDigest". This NSS publication is always edited by volunteers from the contributed grotto newsletters from all over the USA and foreign grottos. Sheilarae Lau led a tremendous effort of coordination of selecting, re-entering, and editing one of the most successful Speleodigests ever. Its print run is now sold out at the NSS bookstore.

The New Millennium and Beyond

Although the trips to nearby New York, West Virginia and international locations continued, a systematic effort to identify, explore and survey caves in Massachusetts was launched by new chairman Steve J. Stokowski in 2001 and is ongoing up to this day. Steve is a geologist who has caved in 28 states, starting in Maryland, and abroad. His ambition (or desperation) to locate as many caves as possible in the area has also expanded into Rhode Island and Maine and a systematic effort to locate sea caves in the New England coastline. Former chair Kevin Harris has trained several new members in surveying, quite often by ingeniously using "formations" and "speleothems" made out of gardening tools, all types of pots and cans and garden trees in his own backyard. It is one of the challenges the Boston Grotto has to face: how to train cavers in surveying in a region without many caves of appropriate size.

Our former vice-chair (2001-2005), Kevin Flanagan, deserves special mention. Maybe in a tradition worthy of the old pioneering trips of Roioli Schweiker and company to survey the New York area, Kevin has become a significant contributor to the Germany Valley Karst Survey (GVKS) in West Virginia. His goals include exploration and survey of new passage in Memorial Day Cave and other old and newly discovered and dug caves in that famous valley. At least once a month when the caves are open, Kevin would drive south for a long weekend to dig and survey for 24-48 hours at a time. Updates on his progress constitute a large part of our monthly meeting.

In 2001, the Boston Grotto helped the Boston Museum of Science market the IMAX film, "Journey into Amazing Caves." The museum's goals were to increase attendance and interest in the film. The Grotto's goals were to support the museum, to attract local individuals in the caving community who were not in the grotto, and increase club camaraderie. To achieve the goals, the Boston Grotto contributed large photographs of caves, a display of caving equipment on a mannequin, posters of grotto activities in speleology and caving. The members attending included Steven J. Stokowski, Stephen Hulbert, John Evans, Anne Fletcher, Morrie Gasser, John Hannon, Gary Lau, Joanne Pacheco, Karen Potter, Sybille Rex and Chris Taylor.

At the NSS Convention in 1997 in Missouri, Peter Jones of Camden, ME recruited Kevin Harris as co-chair and they began planning in earnest for a successful NSS convention bid in 1999. Kevin passed on the Grotto chair's position to Steve Stokowski and Peter and Kevin worked almost exclusively on the planning and logistical work required for hosting the NSS at this remote corner of the country, along with a massive amount of work by other members and regional cavers. The 2002 NSS convention was a big success with over 1000 attendance, very unusual for a non-central convention and a fitting celebration for the 50th anniversary of the Boston Grotto.

In the following year, Boston Grotto organized the Fall 2003 Northeast Regional Organization meeting in Barton Cove, Massachusetts. Several members contributed in writing a detailed guidebook on caves of Northern Massachusetts, Berkshire, Southern Vermont and the Taconic Mountains. They also led caving trips to Rattlesnake Gutter Cave in Leverett, MA; Bears Den in Greenfield; Sunderland Ice Cave, Sunderland; Barndoor, Serpent and Hermits Cave in Erving; Bakers Quarry and Coon Hollow Cave in Lanesborough; Natural Bridge and the Hudson Brook Chasm in North Adams. Grotto participants included the NRO staff (Steve Stokowski, Chair; John Evans, treasurer; Sybille Rex and Dan Hoyt,

guidebook editors) and members Bob Dion, George Ehrenfried, Morrie Gasser, Kevin Harris, Steve Hulbert, Katherine Lea, Jim Moore, Alan Plante, Emmanuel Pothos, Peter Quick, Hubert Shen and James Keary.

As of Summer 2005, the Boston Grotto officers are Steve Stokowski, Chair; Steve Philbrick, Vice-Chair; Rich Lester, Secretary; John Evans, Treasurer; Kevin Harris, Editor of the Massachusetts Caver; Chris Taylor, Activity Chair and trip coordinator; Morrie Gasser, webmaster. The reader is encouraged to visit our website (www.bostongrotto.org). An online version of the Massachusetts Caver is also to be found there. In our monthly meetings at M.I.T. we report on and plan our trips in nearby or distant regions, with West Virginia and upstate New York being the most frequently visited. International trips are on the ascent with members reporting on trips to Belize, Vietnam, China, Mexico, Italy, France, Great Britain and, surely to follow, Greece. And our cave diving interest is picking up with the help of members like John Hannon.

Over the years, many well-known cavers were Grotto members: two NSS Presidents (Barr, Curl), three Honorary NSS Members (Barr, Curl, Palmer); numerous NSS award winners (i.e. 35-year lapel pin to George Ehrenfried in 2001); many NSS Fellows (Barr, Curl, Pease, Zawlocki, Davis, Evans, Harris, Stokowski); cave photographers (Ehrenfried, Bosted, Downey); cave researchers: history (Hauer), hypothermia (Kreider), diving (Fisher), karst geodynamics (Curl), and biology (Barr); Caver's Digest creator (Lussier); Speleobooks proprietor (Davis); "Adventure" computer game creator (Crowther -one of the originators of the Internet); LED caving light designer (Schneiker); Speleology for Caver's organizer (Stokowski), and northeast coordinator for the National Cave Rescue Commission (Evans). Grotto members contributed significantly to mapping and exploration. For example: 1) the Grotto's map of Mitchells Cave, NY graced the first NRO Bulletin, and, 2) the longest caves in New Hampshire (MDBTHS) and Maine (Enchanted Lake) were first mapped by members. The authors of Vermont Caves and Caves of Massachusetts were members, and the Grotto participated heavily in the NSS Conven-

tion Guidebooks for Pittsfield, Schoharie, and Camden. Grotto members also made important contributions during the exploration of Ellisons, Lechugiua, Mammoth-Flint Ridge, McFails, Mystery, Pina Colorado, Rio Camay, San Augustine, and Scott Hollow caves. So, there is more caving in Massachusetts than you think! Only look for the cavers first, then for the caves when you visit the area.

Acknowledgements

Many thanks to George Ehrenfried, Roioli Schweiker, Steve Stokowski and Kevin Harris for providing access to necessary material and resources. Please contact the authors, the Boston Grotto officers or other copyright holder before reprinting any text or photographs from this article.

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Boston Grotto

Snapshots across 20 Years

Top Left: John Evans (seated) and Peter Quick in Nickwacket Cave, Mt. Vt., 1985. Photo provided by Steve Stokowski.

Top right: Eric Tsakle at top of Crow Hill Cliff, Westminster, 1981. Photo provided by George Ehrenfried and Steve Stokowski.

Bottom: Adam Dobson, James Keary, Emmanuel Pothos near Mystic Cave, West Virginia, July 2004. Photo taken by Chris Taylor, provided by Adam Dobson.

O-207

The international speleological expedition to Tanzania - organisation pre-during-post expedition

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The idea to set up an international speleological expedition to Tanzania was realised by setting up an action plan. The items of getting a team together, organising the contacts in the target country and preparing the actual expedition have been entirely prepared over the internet.

A website was designed and written in php and consisted in two layers. A public part would introduce the project, the participants, the target country, the sponsors and links to related websites but also a public visitors' forum.

A second part would only be accessible for the prospective expedition members. The most important feature of this private area would be a correspondence engine to enable the members to communicate and prepare the expedition in a mixture of forum and e-mail style. When a member has posted a message to the group forum, it would arrive in all members' mailboxes automatically. The feedback was done through the group forum by clicking on the weblink in this e-mail, so any replies on this topic would appear in the forum, with copies of the updated information sent to all members of the group. This system avoids missing out messages that get sent to an incomplete or outdated list and is a very transparent way of communication.

No email addresses are stored or shown in the web pages, but clicking on a name would open a server-side script fetching the email address from

a database to prevent spammers from getting these email addresses.

After logging on to the administration page with various levels of access for prospective members, participants and the expedition leader, one could enter, review and change their personal details for various purposes as participants and passport lists, vaccination, etc. This administration part was also used to publish news and articles on the public website during preparation and actual expedition phases. It will also serve in the post-expedition phase for publication of the results and the preparation of future follow-up expeditions.

The system was built in less than a month during spare hours and is customisable for any similar project. The actual preparation of the expedition took about 10 months. Only half a dozen of in perso meetings were held occasionally when some participants' paths would cross somewhere around the world.

This expedition website really made it possible to set up an expedition with members of a dozen countries of whom most did not know each others before the actual start of the expedition and has helped to make this speleological project successful.

O-208

Lukina jama-Manual II (-1392 m), Slovačka jama (-1320 m), Meduza (-707 m) and the share of the Slovak cavers at discovering some of the deepest abysses of the world and of underground super verticals in Velebit (Croatia) in the years 1990-2004

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Abstract

Directly along the beautiful Jadran riviera there is more than 150 km long mountain area of Velebit, of which not an extensive territory at the North, the limestone wilderness, where there are huge holokarst mega-depressions and karst pits, it became in incredibly short time literally a world term in discovering more than thousand meters deep caves, mainly with immensely deep shafts and verticals. What is less known, and what is necessary to emphasize, is that on the exploration results of this area is considerable, if not the substantial share of young members of Slovak speleological society (SSS), who started with the systematic works, basically as the first ones (since 1990) and since then they performed 14 expeditions to here, in fact with fantastic results. By this contribution we would like to introduce to you the objective history of the first discovering of the deepest caves in Croatia, the systems Lukina jama-Manual II (-1392 m) and Slovačka jama (-1320 m), which belong also to the deepest of the world, and also the look at the discovery of the abyss Meduza (-707 m), with its giant underground shaft, at least 450 m deep, which is the second deepest underground shaft of the world.

Rožanski and Hajdučki kukovi

Velebit culminates with its height at the south, with the point Vaganski vrh (1757 m). But also in the northern wildly dismantled limestone zone of this mountain area, the peaks reach relative heights from the sea level more than 1650 m. (The highest peak here is Gromovača, 1676 m.) This amplitude is at the same time the possible potential of the altitude



A view on the Rožanski kukovi, photo: I. Demovič

difference of the not so long ago discovered, more than 1 km deep, and to all that immensely vertical cave systems: significant part of the massif is build by Jurassic limestones and by carbonate Paleogene cover (Jelareccias), it is drained by huge springs in the sea under the sea level (so called vrulje).

The central part of the northern Velebit, not an extensive territory (18 km²), where two partial massifs Rožanski kukovi and Hajdučki kukovi, seem to be the most perspective from the speleological view. Their most characteristic feature are huge depressions (it could be said collapse areas), commonly with the depth over 100 m and with the diameter more than 200 m. In the massif of Rožanski kukovi there is about 60 of such huge mega-depressions. They are ended by extensive block areas at the bot-

toms, in the areas of significant thermal inversion there is snow cumulated during the whole year. The interior of the depressions is often complete holokarst, it is hardly penetrable, often with vertical walls between the levels. The external edges of the depressions are covered by spruces or by impenetrable scrub. The individual depressions are separated from each other by cone-like peaks, walls, rock towers, or by compact cones (kuk, toranj), while 50 of them is higher than 1600 m. From the microforms there are groovy scarps here, often perfectly created.

The carbonate bedrock in this area is strongly damaged by the tectonics. The most often vertical faults are evident directed NNE-SSW. Just on these ones the intensive corrosion took place (and is going on), there was created enormous number of slots, cracks and abysses, from which there is explored maybe more than 250 today. The overwhelming majority of them is relatively not deep, couple of tens meters, ended by icy or snowy enclosures. But few of them belong not only to the deepest in the country, but also to the deepest all over the world. For these abyss cave systems the deep, relatively homogenous but mainly direct shafts and verticals are typical, which are close to each other, often separated from each other only by narrow rock barriers and by windows, or connected with each other by curving meanders. There are also huge domes in the abysses. The underground shafts are mostly without calcite decoration, but almost always in the zone which is close to the surface (100-200 m) they are very strongly filled with ice (icicles, monoliths), and therefore they are also really dangerous. The exploration is also limited by the season: in the top summer, when theoretically no rains can be expected, eventually in the winter, however in the winter there appears the problem with the access to the area.

The abysses and the systems in the northern Velebit are of significant alpine character, with low temperature (from minus to maximum 3-4 °C). The exploration of the deepest of them required connection of bigger teams of experienced cavers and speleoalpinists, as well the exploration demanded establishing remote underground camps.

The first expedition of slovak cavers to velebit in 1990

Slovak cavers were present at the territory of Rožanski and Hajdučki

The pioneers of caving in North Velebit Mts. lower from the left: B. Šmída, E. Kapucian, upper from the left: Z. Ágh, M. Griflík and M. Vrábel



kukovi since 1990. Until then it was almost completely unexplored area. Though the entrances to some deep abysses are visible literally from the tourist paths(!), nobody neither visited them, nor explored them. The only explorative activities until this time were only short journeys of the cavers from the Croatian speleological club „Ursus spelaeus“ who in 1980 and 1981, in the area of the peak Crikvena (1641 m), explored several abysses, the deepest of them (Crikvena 1) to -120 m (Ostojić, 1999). Beside this the huge collapse area of the cave Varnjača was known here for a long time (after our explorations in 1996 it was explored up to the depth -120 m) and the tiny abyss filled with ice next to the road, called by the local meteorologist from the Zavižan station, Vukušić jama.

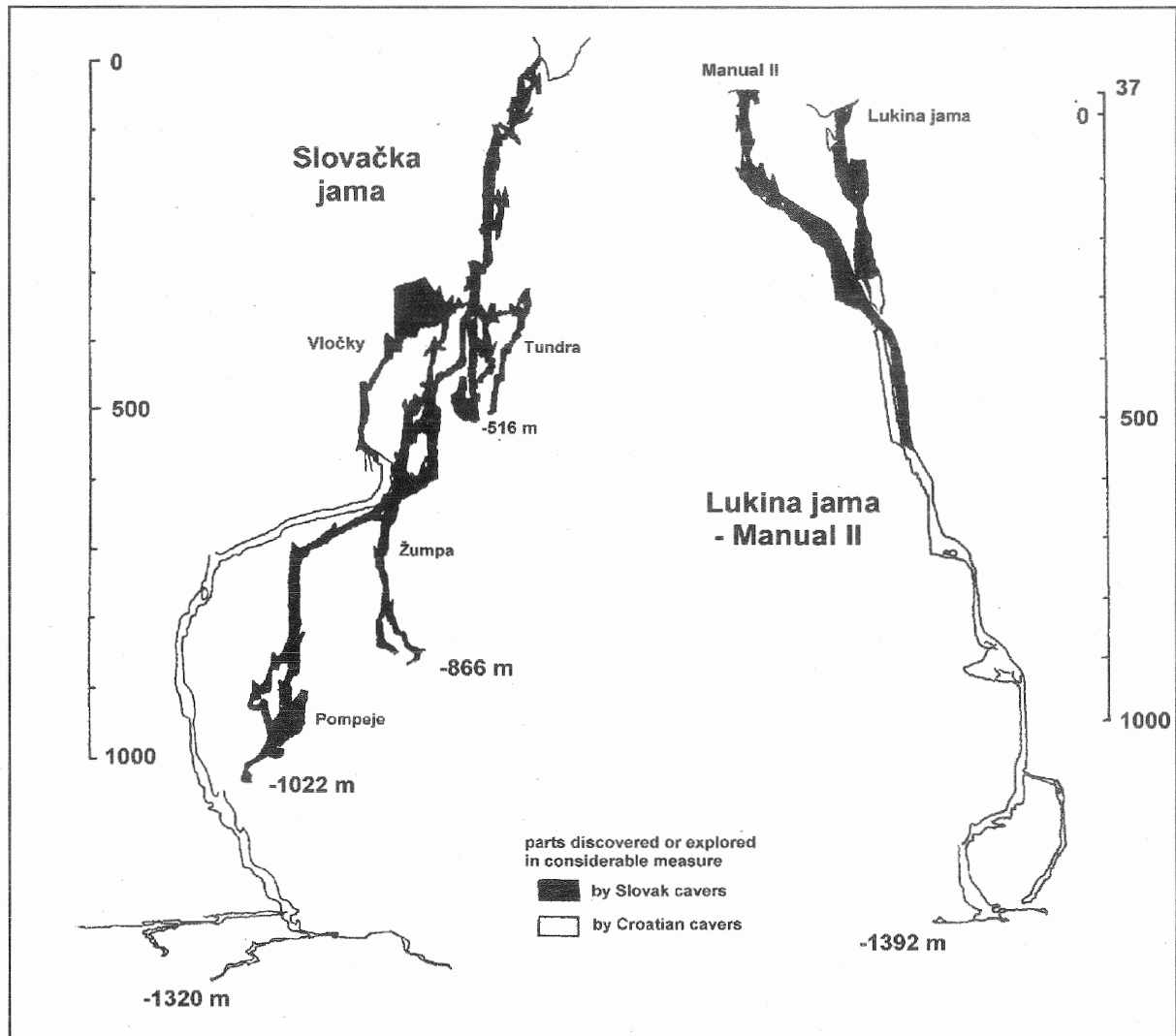
Our first 12 days of actions from 4th to 15th August 1990 where participated (it could be said the pioneers of the discovery of this worldly known speleological terrain): Branislav Šmída (the head of the actions), Zoltán Ágh, Erik Kapucian, Marcel Griflík, Mário Vrábel and Igor Poláček (our average age was only 19 years in that time!), brought in that time mainly introduction knowledge and unexpected perspectives (Šmída, 1991): in the massif Rožanski kukovi we did recognizant actions to already known abysses around Crikvena, but we did discover also new ones, from them the deepest for now became the abysses Plathá (-96 m) and in the huge 150 m deep depression Jerković dolac, directly on the opposite side from the little cottage Rossijeva koliba, there was Punoleda uniquely filled with ice (-157 m; in the year 2001 we did recognizant action here after more than 10 years). During one day of this pioneer expedition on 9th august 1990, we in a group of five visited also the virginal territory of Hajdučki kukovi, while by the descent from it's logical peak (in 1650 m) we got into the terrain (B. Šmída and M. Griflík) some 150 m from the entrance to today's system Lukina jama. Of course we did not even anticipate it in the time...

Lukina Jama-manual II (-1392 m)

The massif Hajdučki kukovi was before our first visit in 1990, in spite of the incredible possibilities absolutely untouched by the speleological means. In addition, what is paradox, one of the first entrances which we localized here, was the lower entrance to the tenth deepest cave today...

It was 28th September 1992, when we during the second expedition of Slovak explorers to Velebit, the group of five: Zoltán Ágh, Stanislav Gajdošík, Marcel Griflík, Erik Kapucian and Branislav Šmída, started from the hollow basin Lomska duliba, basically „blindly“ during intensive rain, to NE slopes of the massif, and here, in the oblique step-like area scratched by scraps, in the altitude 1438 m, we found huge crevice well, where the thrown stones fell without hearing the sound... and where we could see at least 80 m into the depth. On 29th September for the first time E. Kapucian abseiled into this shaft. On 30th September he repeated the abseil together with J. Meluš and with S. Gajdošík and they proceeded up to -145 m. As the autumn rain season was culminating, we determined the further exploration again to 2nd October (Z. Ágh, S. Gajdošík, B. Šmída and E. Kapucian), when we reached the depth -240 m, pendulating to side snowy meander. Under us a never ending abyss appeared, at least 200 m deep... however after exploring the abyss we did not continue exploration at this action. Strong rains ejected us from the mountains, with flowing dangerous waterfalls underground carrying pieces of broken ice. This fact discouraged us. Neither the last abseil on 5th October 1992 (E. Kapucian, Z. Ágh, S. Gajdošík) was not more successful - the explorers were caught in the depth -230 m by such an intensive sudden stormy inflow, that they barely climbed out of the abyss... (Šmída, 1993, 1996).

We informed the local cavers from the club Željezničar, on the way back through the city of Zagreb, about finding the perspective abyss, which we assigned technically as SO.1 and we named it as Manual (or Manuál). These cavers came here during the next summer in July and August 1993, then they organized national expedition, where about 60 cavers



from many Croatian clubs participated. Because the abyss Manual continued quite freely and at the same time immensely vertically, the depth -1355 m was reached very quickly by the help of two bivaks in -748 m and in -958 m (in huge dome 50 x 100 m).

We learnt about this action and about the unbelievable progress in fact accidentally, just at our passing through Zagreb in the autumn 1993, when we planned to continue in Velebit in the started explorations. It was a real surprise for us... The abyss Manual was at the same time renamed by the Croatian cavers to Lukina jama, by O. Lukić, who died in war.

However it could be said that our Slovak team managed to make an excellent tricky success just at the expedition in the next summer 1994. By the entrance which we had known from two years ago (it was discovered by Erik Kapucian and by Branislav Šmída, on 4th October 1992), in the altitude 1475 m and about 120 m from Manual (Lukina jama) to SE, and we had assigned is as SO.2, we managed to deepen the system, in fact by the higher branch, the common system got deeper up to -1387 m! As the first ones abseiled to this location, named for certain symbolic as Manual II, on 23rd July 1994 Z. Ágh and M. Griflík, they reached the depth -190 m. After 5 days of exploration we then managed to lower at the end of 160 m deep Monzúnová šachta (Monsoon shaft), up to the depth -582 m, where on 27th July 1995 the trio Z. Ágh, M. Griflík and D. Kotlarčík found the

connection to the shafts of Lukina jama (Šmída, 1994a, b, c, d).

(Next to this we would like to emphasize that though the Croatian cavers sometimes call the branch Manual II also as Trojama, it is not correct, neither ethical, because none of them, during the first explorations, and in fact neither till now, did visit the cave, neither passed through it. It should be thus used the correct name and also by us fully accepted name of the common system: Lukina jama-Manual II.)

During the same expedition in 1994 we helped to Croatian cavers also at the exploration of the branch of Lukina jama itself, by the work progress (transport of the material for diving) by the lower entrance to the system, 1355 m deep, up to the lakes and siphons at the bottom (1st-3rd August 1994, the group of five: Z. Ágh, E. Kapucian, M. Griflík, B. Šmída and J. Vykoupil). After the diving of T. Barišić and Z. Stipetić the system Lukina jama-Manual II became -1392 m deep (Jalžić et al., 1994).

Slovačka Jama (-1320 m)

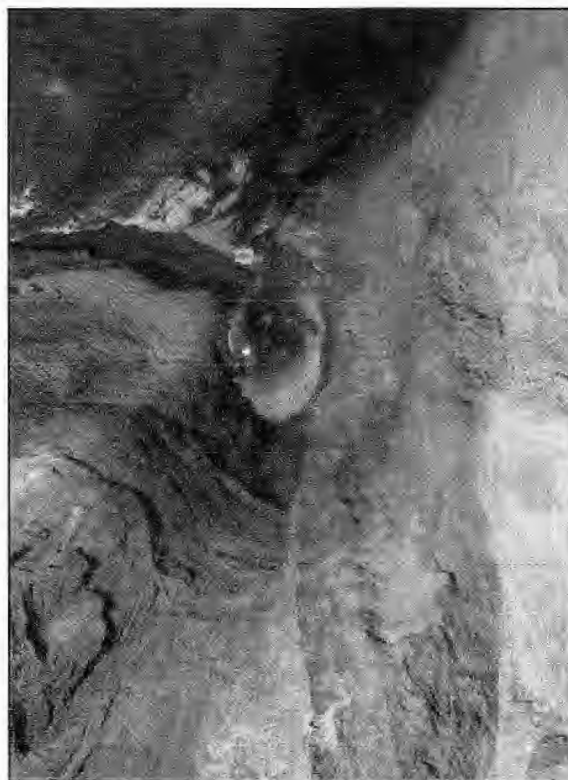
The entrance to the second cave in Velebit, which is more than one kilometer deep, discovered by Slovaks, we found on 28th July 1995, by the duo Branislav Šmída and Marcel Griflík. The entrance is positioned in the altitude 1520 m, not far from the cone elevation Mali kuk (1565 m),

the relative altitude is about 250m from the meadowy hollow basin Veliki Lubenovac, where the basic camps of all the expeditions were since 1995, while exploring in the close area. The entrance is little bit untypical for the Velebit conditions: it lays in the side wall of the depression and it's introductory, not big collapsible zone, did not tell the appearance (except the strong pulsating draft) that this could be once some exceptionally deep system... On the 29th July the same duo, B. Šmída and M. Griflík, removed from the entrance squeeze (Fučák) couple of boulders and abseiled to compact vertical Pokojná (P55). The cave led freely only to -96 m in the time. On it's bottom there were however two narrow branches with evident draft and pizolits. At first we decided to dig in the higher branch (with the help of an ascender as a shovel), but after pulling out big blocks from the meander of the lower well Grepová (P11), finally at the third day of the exploration (30th July), the lower narrow allowed some progression (participants of the probing: Z. Ágh, M. Mišík, K. Kýška a M. Griflík). The spaces then misled us incorrectly down, to the blind meander and even the exploration of the window in the hall above was not successful... Just on 31st July 1995 the group in the composition: E. Kapucian, M. Mišík, K. Kýška and B. Šmída, widened another narrow passage above S5, and E. Kapucian and B. Šmída pushed themselves through ascending edges of the meander, to the position above the huge 194 m deep well (Cez celú zem, Through the Whole Earth). The preliminary bottom of the cave, in the depth -516 m, was reached then by the duo E. Kapucian and J. Vykoupil, on the 2nd August 2005. At the mapping of the lower giant well of the location, named Poseidon (direct vertical P213) on the 4th August B. Šmída noticed an important window, which he estimated as a perspective one for the further exploration. The new deep cave was named to the credit of our explorers as - Slovakia (Šmída, 1996, 1997a).

One year later as the Croatian cavers recommended to us to change the original name of the location to the new one - Slovačka jama (what we accepted), we organized another very progressive expedition to the cave. The mixed team was formed from 14 Slovak and 7 Croatian explorers (who performed 78 / 13 abseils altogether). The breakpoint was already the third day of the expedition, the 22nd July 1996, when J. Vykoupil and Z. Ágh did traverse to the window mentioned before, and they discovered there some whole maze (Koridor) of big domes and more abyss branches. We then based an underground camp, in the depth -360 m, from where the pairs of the researchers started every day to the two sub-branches (so called Črevo-Intestine and the branch of Kankula). Though in the branch of Kankula, where the two brothers J. Kankula and M. Kankula widened the narrow little window, with the help of a drill and bullets (Vločky), our explorers stopped above in fact free continuation, above the great meander with an echo (the deepest point about -600 m, J. Vykoupil and M. Sova), they did not abseil deeper, because we needed to support our team in the neighboring branch. In the other branch, after some days, we managed to pass through lengthy and pretentious narrows (Šaleny meander, Crazy meander) and we managed to abseil under the next enormous vertical, Patkov skok (P170), on the 3rd August 1996, up to the depth -1000 m (D. Kotlarčík, J. Vykoupil, B. Šmída and M. Sova), where a huge oblique dome Pompeje was discovered (Šmída, 1997a, b, c; Bakšić, Šmída, 1999).

On our expedition in 1998, the Croatian cavers continued in the exploration of the branch of Kankula, where they managed to abseil from -600 m to -1268 m. We, as the Slovak team deepened the branch Črevo to -1022 m (J. Stankovič, J. Kankula, B. Šmída and M. Griflík), while the second remote bivouac was placed in the depth -1000 m, and we explored also the side shafts around the first camp, where we reached -504 m in the branch Tundra (Bakšić et al., 1999).

We concentrated our efforts during our last expedition till the next time, which was allowed to us to perform in 1999, to the branches of Hermanova studňa (reached depth -530 m) and Žumpa, the continuation of which was found directly under the bivouac I. by M. Sova. (Originally it was „the place where we left the remains of our metabolism...“ at the



The shaft Galeje (P80) in Meduza, photo: M. Andy

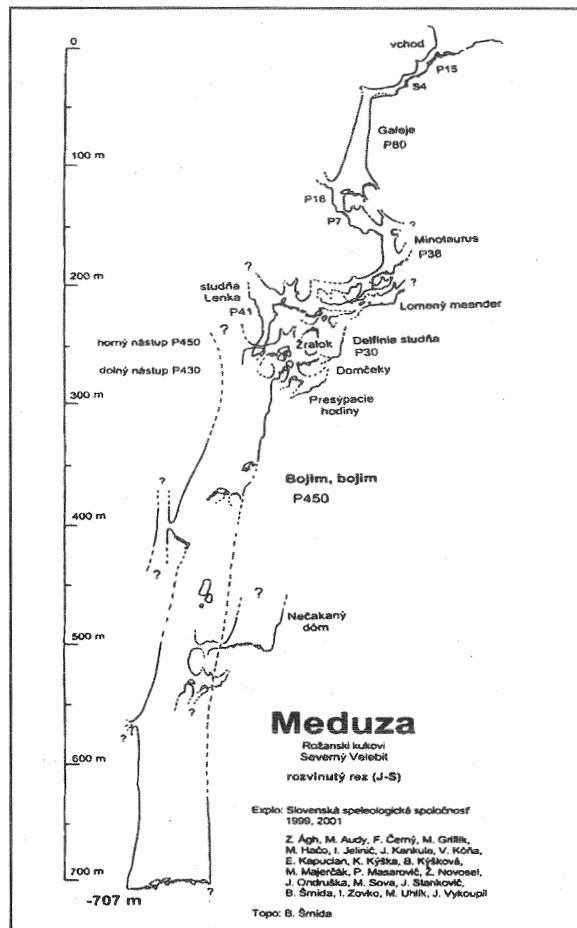
bivouac I.) Here we reached the depth -850 m (on 4th August, P. Medzihradský, M. Griflík), and -866 m (5th August, J. Ondruška, B. Šmída). In this branch there is another great shaft created, 156 m deep Adriána (Šmída, 1999).

Slovačka jama has the total depth -1320 m today, which was reached by the cavers from Zagreb in the summer 2002, at the bottom of the Kankula branch. It is necessary only to remind that thanks to the endurance, high enthusiasm at the widening of the rock narrows, finding the decisive points and generally to the whole effort of the Slovak explorers, who discovered about two thirds from today's extent of the location, which is more than 5,5 km(!), and that because of that, Slovačka jama today still belongs to the twenty deepest abysses of the world... It's name is thus absolutely truthful and for us it is the best, fully deserved reward.

Meduza (-707m)

This cave, today the 4th deepest cave of Croatia, was also discovered, the first time climbed and in fact completely explored, almost exclusively by Slovak cavers. The entrance to Meduza (by the way quite resembling to the entrance of Slovačka jama) we found on 28th July 1999 by the duo Branislav Šmída and Jozef Ondruška. The entrance is situated at Rožanski kukovi, couple tens of meters from the touristic path Premužičeva staza, in the side of not a deep depression, in the altitude 1580 m. The first abseil to the broken entry little shaft of Meduza, to the depth about -30 m, was performed by M. Griflík during the same expedition. The progress was blocked there by a squeeze, from which however some intensive draft blew.

During the next pretentious winter expedition we widened this squeeze with the help of a drill and bullets in the days 16th-17th January 2001, in



the composition: J. Stankovič, V. Kóňa, M. Griflík, B. Šmída, E. Kapucian and Z. Ágh (all six from Slovak speleological society), while B. Šmída abseiled further through dimensional shaft (P80), where at its bottom, after short raking among blocks, he got to position where he was above another smaller step (P7) in the depth -145 m, where the cave evidently continued by the hall-like widening and by the black crevice.

During the next summer, during the complex expedition we continued in the detailed survey of the abyss Meduza (as the original work name we used at first also the name „The second“). On 7th August 2001 B. Šmída and K. Kýška abseiled to -200 m. The first one managed to pendulate at the bottom of the impenetrably narrow shaft to a window and he managed to climb from there through some pretentious squeezes to the beginning of some meander with long echo... The next progress was performed on 8th August by the Moravian photographer M. Audy, who continued alone through the narrows to the labyrinth of passages and lower areas behind the Žralok meander, up to depression collapse halls (Domčeky, Houses) in -260 m. F. Černý with K. Kýška on 9th August found in the narrow of the bottom of these halls the entry to a very deep well... On 10th August this, really immensely deep, and somewhere really big-profile (up to 15-20 m) well was passed through for the first time by J. Ondruška and by P. Masarovič, who used about 300 m of ropes in it, but in spite of that they did not barely see any bottom... The abyss was called for its enormous dimensions as „Bojím, bojím“, or I am afraid, I am afraid (Šmída, 2002a, b).

The bottom of this monstrous shaft (in the profile up to 15 x 50 m!), which is also the definitive bottom of the abyss Meduza in the depth -707 m, was reached the first time by B. Šmída and by K. Kýška, on 11th

August 2001.

During this actions we performed also the making of a remote bivak at the bottom of the abyss: M. Griflík, J. Ondruška and M. Uhlík, who tried to probe in the debris of the bottom, but without any success, and on 15th August B. Šmída with P. Masarovič pendulated to the windows which were positioned somewhere in the depth under -500 m. These windows were later explored by M. Sova, again with the assistance of P. Masarovič (16th August), when the bottom of the parallel well Nečakaný dóm was found. In the same day B. Šmída and F. Černý found the higher entrance to the well Bojím, bojím.

Croatian cavers with the assistance of the French cavers re-explored the abyss Meduza in the year 2003. However without progress further to the depth, neither in other aspects this numerous action to the abyss Meduza, reportedly of 59 members, did not bring any remarkable progress. (The participants reportedly did not even find the upper entrance to P450 Bojím, bojím.)

The shaft Bojím, bojím (P450) is today the second deepest direct vertical inside a cave in the world. (In the time of the discovery it was even the first one.) The deeper one is only the shaft so called Divka Gromovnica (P513), which was found in the abyss Jama Velebita (-580 m), accidentally just in the neighboring massif Crikvena, by the cavers from Zagreb in 2003.

However! Above the upper entrance to the well Bojím, bojím (the lower has the vertical P430 deep) there is a high chimney (in fact a shaft, just aiming upwards...), where it is possible to illuminate it at least further 30 m to plus...

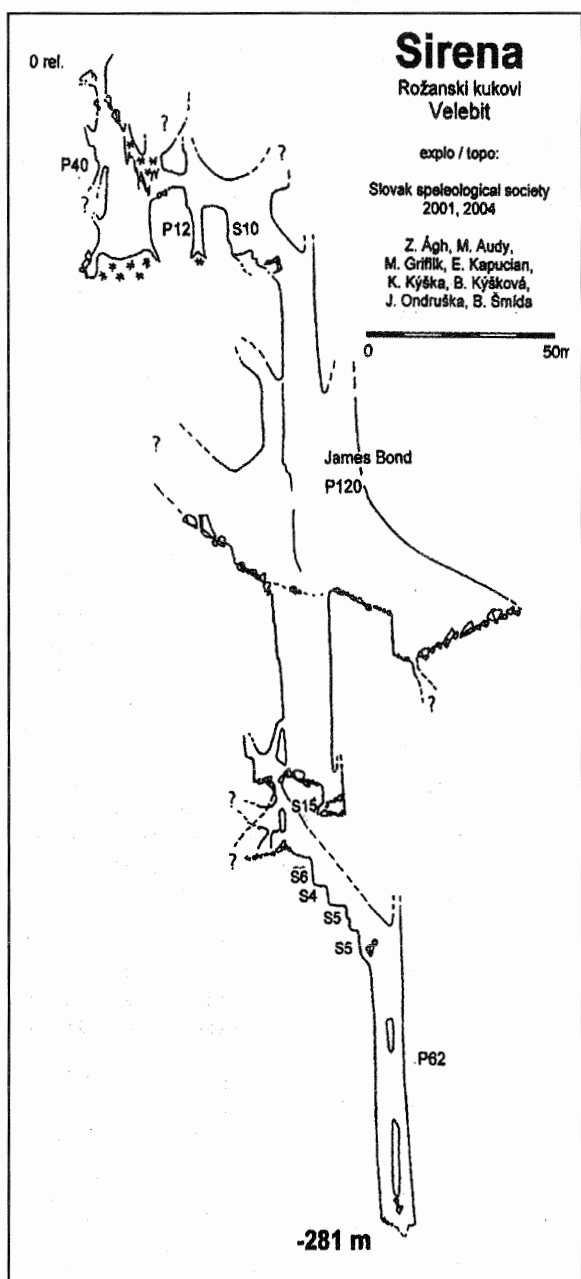
Sirena (-281 m)

Also the entrance to Sirena this was discovered by Slovak cavers. It was 13th August 2001 when B. Šmída climbed through one of the depressions of Rožanskí kukovi and he got to some kind of valley where there was cold air flowing out of there and where some more alive moss grew. (By this moss the work name of the location was „Moss slope“). The first exploration was done here by B. Kýšková and K. Kýška, they abseiled only to about -30 m. More serious exploration of this location again by the team composed almost exclusively from Slovak cavers (Z. Ágh, M. Griflík, E. Kapucian, J. Ondruška, B. Šmída, plus the Moravian caver M. Audy) was performed during the next pretentious expedition in the days 5th-8th January 2004. The bottom of this abyss was reached in the depth -281 m by J. Ondruška, on the 7th August (Šmída, Audy, 2004).

Ledena Jama (S.U.K.)

U Lomskoj Dulibi (-536 m)

In 1992 we found at the bottom of the hollow basin of Lomska duliba also extensive cave depression (50 x 60m). This abyss was preliminarily explored before us, longer time ago, however only into the depth of -62 m where the progress was blocked by the icy filling. However we found holes and passes in this icy cone melted after time by the draft and so on the 6th October 1992 the trio Z. Ágh, I. Ághová and E. Kapucian abseiled even deeper, to about -90 m, to the place where there was a huge deep well with an unknown depth... This 180 m deep shaft, somewhere over 20 m wide in profile, was penetrated by the duo Z. Ágh, M. Griflík (on expedition 1993). There is a huge dome down there, 50 x 80 m, with the ceiling impossible to illuminate, and at its end there was a series of smaller wells, where we reached the depth -432 m, during this action, after three abseils, on the 18th September by the group of four M. Griflík, Z. Ágh, L. Plučinský and B. Šmída (Jalžić et al., 1994). The abyss was re-explored later by cavers from Karlovac, who in 1996 penetrated through the bottom narrow to another well (P63) and they introduced the final depth -536 m (Jelinič, 2001).



Other remarkable results of Slovak cavers in Velebit

Another important location, which was discovered and explored by Slovak cavers at Rožanskí kukovi (partial massif Vratarski kuk, 1676 m), is also the abyss Xantipa, -323 m deep (Šmída, 1994a). It's unusually great entry, in the form of giant mega-depression with the outer diameter almost 300 m and depth 150 m was found on 23rd July 1994 by Ján Vykoupil and Branislav Šmída. The abyss in which there is the well 210 m deep, dangerously covered with ice, was explored by us in 1994 and in 1995. Another interesting abyss named Marianna (-250 m) was found by Erik Kapucian and by Croatian female caver Sanja Cirić. In the year 1996 the brothers J. and M. Kankula widened some narrows here, and so they made available the pass to the 210 m deep shaft, which had the diameter almost 30

m at the bottom. The bottom was reached on 23rd July 1996 (B. Šmída, J. Kankula). The other relatively deeper abysses in the reservation Rožanskí and Hajdučki kukovi, which were discovered by Slovak cavers, and which we did not mention yet are: in the year 1992 - Pavúčia (-112 m); 1993 - Brutál (-108 m), Dvojvchodová (-102 m); 1994 - Uhu (-111 m); 1995 - Obor (-124 m), Hnedá (-101 m), Pri dvoch smrekoch (-100 m).

Until today Slovak cavers, members of the Slovak speleological society from more clubs (mainly however from the Speleoclub of the University of Comenius Bratislava) explored about 150 caves and abysses in the northern Velebit (which is at least half of the total number!., if not more than half of the number of all the know localities here...). These results were published in the complete monograph (Šmída et al., 1999) as well as in ten articles, in Slovak, Croatian, Czech, French, or English speleomagazines, from which only the most important are mentioned here (in chronological order):

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The deepest abysses of Rožanski and Hajdučki kukovi

	Depth	The first year of discovery
1. Lukina jama-Manual II *	1392 m	SSS (1992)
2. Slovačka jama *	1320 m	SSS (1995)
3. Meduza *	707 m	SSS (1999)
4. Jama Velebita	580 m	SOV (2003)
5. Patkov gušt	553 m	SOV (1997)
6. Ledena jama S.U.K. *	536 m	SOŽ (?)

7. Olimp	531 m	SDK (1998)
8. Lubuška jama	521 m	SBŽ (2000)
9. Xantipa *	323 m	SSS (1994)
10. Sirena *	281 m	SSS (2001)
11. Marianna *	250 m	SSS (1995)

* - abyss discovered or explored in considerable measure by Slovak cavers

SSS - Slovak speleological society (Slovakia), SOV - Speleološki odsjek PDS Velebit (Croatia), SDK - Speleološko društvo Karlovac (Croatia), SOŽ - Speleološki odsjek HPD Željezničar, SBŽ - Speleoklub „Bobby“ Żagań (Poland)

P-1

The karst in the mezdra structural-denudation depression (Bulgaria). Assessment of natural and anthropogenic processes and hazards

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Abstract

The objective of this study is the karst in the Mezdra structural-denudation depression. The Mezdra structural-denudation depression was formed as a morphostructure at the background of the deformed edges of the Moezian platform and the Stara Planina Mountain chain during the Plio-Pleistocene as a result of an extension. For this reason the karst in it is of the relict type and exhibits the features of the Austrian, Laramian and Illyrian collision orogenes, as well as of the plain karst of the autochthone to paraautochthone elements of the Moezian continental microplate. The karst was formed in limestone complexes with different CaCO₃ content and tectonic position in time and space. The contemporary karst formation started after the Plio-Pleistocene extension and was connected with the stages of the Iskar River valley development in this part of its gorge section and with the entire valley system in the Mezdra depression. The karst is typical structural one and was developed along faults that crossed the gorge in transverse direction or were parallel to it. Caves have been established at the levels: 130-135 m; 110-115 m; 80-90 m; 30-32 m; 17-18

m and 7-8 m. The karst formation is an uncompleted process. Rejuvenated plateau-like karst type is formed on the denudation flattening areas of the residual plateau with inverse relief with respect to the tectonics. Disturbances in the natural karst relief are observed in the investigated territory as a result of seismic events, occurring during the historical stage and before it. Neolithic, Eneolithic and Bronze Age graphics are found in the cave complex from the region of Tzarevetz village. Schemes of astronomic and mathematic signs obtained as result of accomplishment of purposeful systematic observations are traced in some of these graphics. Some of the prehistoric finds are destroyed by the man in the newer historic epochs. Their protection is very important for the Bulgarian history and world history as well. Close to these finds are located facing limestone quarries. The mining activities created new fractures in the rock massif and lead to destructive exodynamic processes increase within it. An assessment of the natural and the anthropogenic processes and hazards in one of the most interesting regions in Bulgaria from geodynamic point of view is made with this work.

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P-2

Ethnospeleology: The study of the cultural manifestations of ethnic groups and their relations with the caves

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Abstract

Since its beginning, humanity has interacted with the cave environment, sometimes using it as habitation or shelter, sometimes as "centre for worship". Archaeological materials such as pictures on the walls, bones, fire traces, broken pieces of pottery, and other materials are vestiges that still now can be found in its interior. All over the world, many peoples have created caves related mythology. In Brazil, several indigenous groups still preserve their legends, superstitions, myths, and ceremonies. This knowledge has been passed down from generation to generation through oral tradition. During the last three years the Brazilian Institute for the Environment and Renewable Natural Resources (IBAMA), through its Centre for Cave Study, Protection, and Management (CECAV), has

contacted several ethnic groups in Mato Grosso province to record their caves related cultural manifestations. Until now, we have registered manifestations from Waurás (kamukuaka cave), Parecis (Haholiaquá cave), Nhambiquaras (Kaninindú and Taihantesu caves), Bororos (Xibae-lari cave), and Xavantes (Uu-Eterê cave). In general, these peoples consider that caves are holy places where heroes are born, where living people find shelter, and where dead people is buried. For some cultures, caves are related to the world creation and for others they are the place for the battle between good and evil. Because of this so huge cultural universe related to the caves, we propose a new speleology subject: the ethnospeleology, here considered as the study of the ethnic groups cultural manifestations and their relationships with the caves.

P-3

Fossil tooth of a second human from Petralona cave

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The famous Petralona skull was found during 1960 in a small cave chamber named Mausoleum. It belonged to a male, whose age at death is estimated to be ~35 years. Excavations showed that it corresponds to the 11th layer of the cave stratigraphic sequence and has an age of about 0,7 m.y.a. The crown of an upper right 4th premolar, probably with a single root, of another human has being unearthed by the author in the same cave chamber. It comes from a depth of about 1,5 below the level where the first human was found, corresponding to the 16th layer of the above sequence.

The premolar is fragmented below the crown. Evidently this happened since its soil deposition, because no marks of excavating damage are present. The enamel is well preserved and the cusps are only slightly worn, indicating an age at death of about 16-18 years. The tooth dimensions are somewhat smaller (mainly concerning width) than the initially found (at 1960) male complete skull, indicating that it may belong to a slender individual (e.g. a female or a young or perhaps slender male). The crown height is however similar to that of the complete skull. The morphometric teeth similarity of the two humans from Petralona Mausoleum indicates a close genetic relationship between them, which most probably was preserved for the entire time span from the 16th up to the 11th layer, at least. It is worth mentioning that among other Lower - Middle Pleistocene hominids, Petralona presents the smallest teeth with resemblance to those of modern man.

The above evidence supports the previous conclusion, drawn mostly from the Lower Palaeolithic stone and bone tools, that the Petralona Archanthropus is autochthonous.

Introduction

Almost half a century ago, Petralona cave was discovered (1959) followed by the identification of animal fossils and a skull (1960) within its sediments. Initially the skull was considered to be of an Upper Pleistocene age, belonging to a Neanderthal woman. During 1965 Dr Aris N. Poulianos, motivated by a desire to re-empatriate anthropology to its motherland started investigating the site, among other scientific studies in Greece as well. His conclusions led to a total reconsideration of hypothesis heretofore held in palaeoanthropology. Through systematic excavations and collaboration with notable scientists (p. ex. Drs Björn Kurtén, Miklos Kretzoi, Motoji Ikeya and others), he showed that the Petralona Archanthropus was: (1) a male and not a female, (2) europeoid and not africanoid, (3) prae-neanderthalian and not neandrtalian, and (4) of an age belonging to the Lower-Middle Pleistocene and not to the Upper Pleistocene. That is, Petralona man represented the first known European, who developed his own palaeolithic culture, using fire as well.

Many people have been reluctant to accept these revisions and consequently two rather long interruptions of Poulianos research have been experienced. The first interruption was achieved through a foreign guided military dictatorship (1968-1974), while the second one occurred more recently (1983-1997) in democratic times, but on the basis of the same logic as the first interruption. Unfortunately, during both interruptions - particularly the 2nd - excavating data was stolen (e.g. excavated objects,

notebooks, catalogs), indicating that medieval mentality still survives even within scientific circles. Justice reversed the situation and Poulianos returned to the Petralona cave and the Anthropological Museum, which is built at the site on his expenses.

Since 1997, new catalogs of the findings are being developed in a digital form. This process is going on with no State support and under adverse conditions. Because nobody knows when war-like barbarians will strike again, to this purpose the all effort of the Anthropological Association of Greece is directed. These are the main reasons why many finds are still unpublished and the present paper represents only a small percentage of the work in preparation.

The human tooth

The famous Petralona skull was found on September 16th, 1960 in a small cave chamber named Mausoleum. It belonged to a male whose age at death is estimated to be ~35 years. Excavations showed that it corresponds to the 11th layer of the cave stratigraphic sequence and has an age of about 0,7 m.y.a. On the 9th of August 1977, the crown of an upper right 4th premolar (No: M' 77 - 287), probably with a single root, of another human was unearthed by the author in the same cave chamber. The molar came from a depth of about 1,8 m below the "mixed soil" level, 1,2 m below the ground stalagmitic flowstone and 1,5 m below the position the first human was found, corresponding to the 16th layer of the cave stratigraphic sequence.

The premolar is fragmented 4 mm lingually and 7 mm labially below the crown and as referred above this happened since its soil deposition. The enamel is well preserved and the cusps are only slightly worn, indicating an age at death of about 16-18 years. Its has the following dimensions: length 8,2 mm, width 9,1 mm, crown height: 8,2 mm internally (lingually) and 7,0 mm externally (labially). It has somewhat smaller dimensions than the complete male skull (mainly concerning width), indicating that it may have belonged either to a female or to a slender individual. The crown height and tooth's length is however similar to that of the complete skull. Because of its morphometry, its stratigraphical position, and since both 4th premolars are present on the complete skull, there is little doubt that the new find belongs to another individual. This conclusion is also strengthened by the fact that the teeth of Archanthropus skull were initially covered completely by sinter, since the cranium was discovered hanging above the stalagmitic ground and attached by a stalagmitic column to the cave's wall. On the contrary the isolated tooth was found free of stalagmitic material, since it was unearthed from the soil of the 16th laeyer.

The morphometric teeth similarity of the two humans from Petralona Mausoleum indicates a close genetic relationship between them, which was therefore preserved for the entire time span from the 16th up to the 11th layer, at least. It is worth noting that among other Lower - Middle Pleistocene hominids, Petralona presents the smallest teeth and and resemble most those of modern man

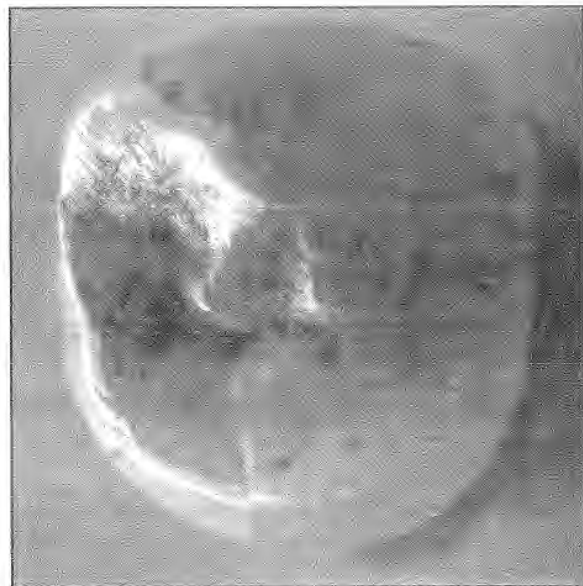
The above evidence supports the conclusion that the Petralona Archanthropus is autochthonous.

Table 1: Comparative measurements of upper 4th premolars of the two humans from Petralona Mausoleum.

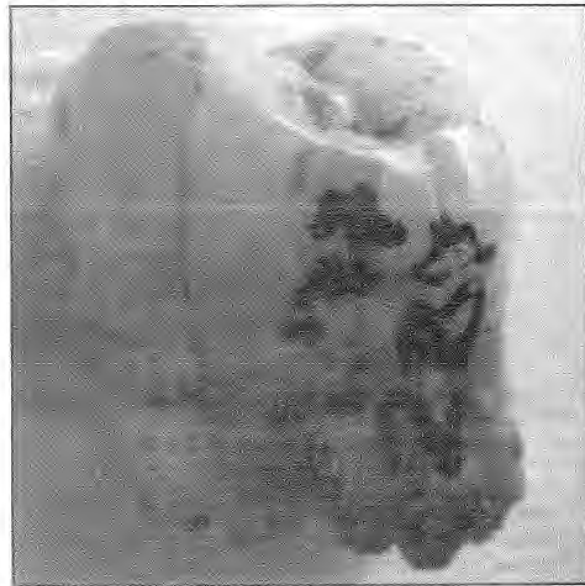
Archanthropus skull				
P ⁴	dex.	length	7.5	mm
P ⁴		width	11.5	mm
P ⁴	sin.	length	7.5	mm
P ⁴		width	11.2	mm
isolated tooth				
P ⁴	dex.	length	8.2	mm
		width	9.1	mm

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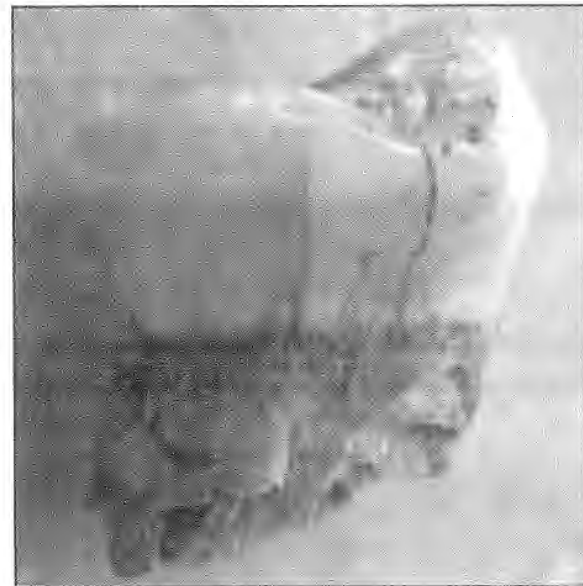
Nickos A. Poulianos (1995) - "La Grotta e l' Uomo di Petralona". Edited by Professor Brunetto Chiarelli at the Florence Institute of Anthropology, in recognition of the palaeoanthropological importance pertain to Petralona research.



Picture 1: The referred human p4 - top view.



Picture 2: The referred human p4 - distal side view.



Picture 3: The referred human p4 - proximal side view.

P-4

The Discovery of VII-XII cc Underground Churches and Settlements in Qasharagh by the 2002-2003 Expedition of ASC

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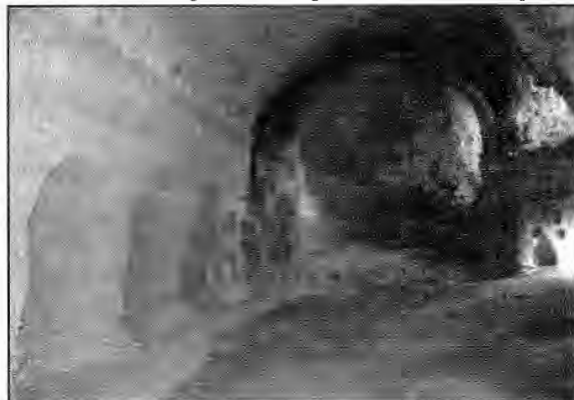
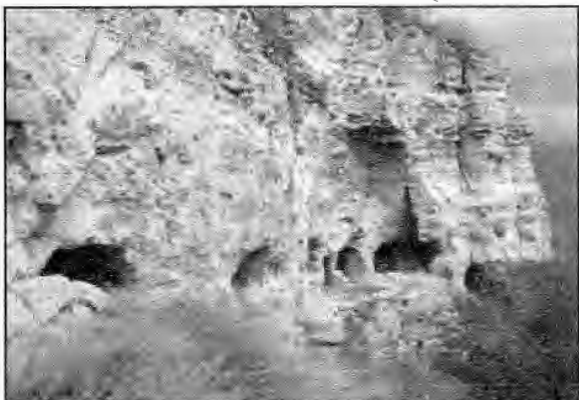
Abstract

The ASC expedition of 2002-2003 discovered and marked five rock-hollowed churches, four rock-hollowed protective complexes, over thirty dwelling complexes in Qashatagh (former Lachin). Here of significant importance are the monastic complexes of Qron and Hochants, of which evidence the Armenian Medieval historian Stepanos Orbelian (XII c) and the VII c cuneiform cave.

The inscriptions coming from the assumed Roussa II king of Van kingdom and the Medieval rock-hollowed Hochants and Qronk churches are

of great archeological importance, as here is situated the I c Tsiternavank, the most ancient famous Christian church of Armenia.

The temple of Hochants is situated near village Hochants, 20km towards northeast from Goris. Two big halls have preserved from the big church complex, evidenced by the medieval Armenian historians, among them Hovhannes Draskhanakertsi, Movses Kaghankatvetsi, Stepanos Orbelyan, etc. The temple has had two more halls, of which only ruins have preserved. There are numerous pilgrimages around the temple, different settlements and buildings of civilian significance. At first the temple was



The Temple of Hochants

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two-story, but later, in the XII century it was remodeled into a one-story big construction.

The inside of the church is typical to the XI-XIV cc Armenian churches, (for comparison see Geghard, Kobayr monasteries).

The cave was discovered on July 23, 2002. It is situated 18km towards south from Berdzor, on the left bank of the river (near the settlement called "Stroyka"). On the right side of the cave entry there are relief inscriptions, one of which is from Van kingdom period, 720BC, cuneiforms, and the inscriptions reminding of some letters are thought by some scientists as Aghvan letters. As a consequence of many battles from Karabagh war, the cave has suffered greatly. During the 90 years of exploring the caves of Armenia, there have been but few caves discovered with inscriptions. Caves containing non-Armenian inscriptions do not exceed 10. According

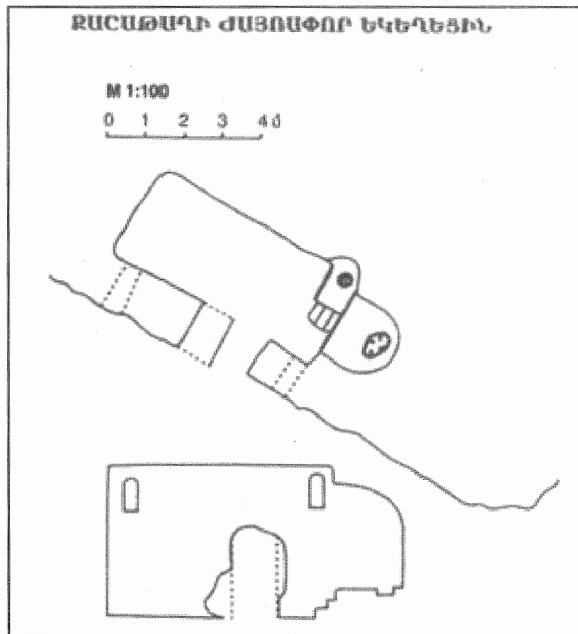
to the studies it may be supposed that; 1. The cave has been a small mausoleum, VIII c B.C., 2. Next to the cuneiform inscriptions new letters were inscribed, 3. During the Christianity period, the altar of the above picture was dug, 4. in XII-XIVcc the rest of the territory was dug.

The Church of Qashatagh

This small, but very beautiful church is dug into sediment hard rocks. In the geological layers there is much carbonates. The church was dug in one attempt, the builders had the plan in their mind and closely followed it. The area selected for the construction is isolated and unique. The church was dug in separate rock pieces, taking into account the peculiarities of the surroundings and of the landscape. Towards southwest, on the bank of the river there are dug halls, traces evidencing that here once has



The holicave of Kingdom of Biaina (720 B.C.)



The Temple Krunk (from Tsakhkaberd)

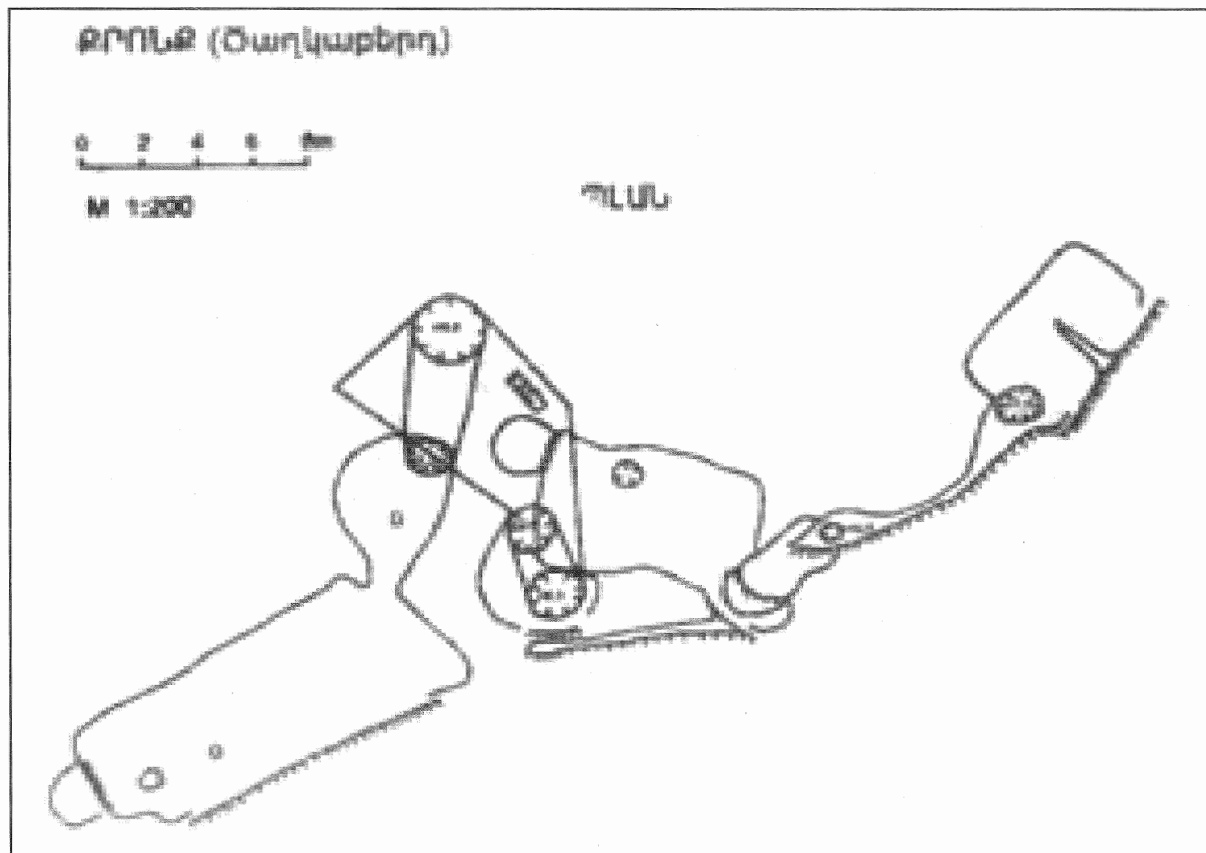
This rock-dug complex is situated on the right bank of Hakari river, 2 km towards south-west from Tsaghkaberd village. Over the rock-walls open numerous cave openings, of which are worth mentioning the inhabitable cave complex and the small rock-dug church on the slopes of the opposite rock. With a high roof and correct geometrical synthesis, the church was built with an excellent knowledge of the area. It seems like the church was built in one attempt with a detailed plan from the beginning. Every single detail on the church evidences that the person who ordered it was someone in power and was far-sighted.

been a religious place. It joins the church harmoniously, making a unique ensemble.

In 1994 the Armenian Speleological Center expedition with Samvel Karapetyan in the head have carried out different works on the cave.

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P-5

Cave Man of XXI c

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Abstract

The last cave-dwellers of Armenia moved to regular houses in 1961. Though recently an interesting phenomenon is observed. At least 40 cases are known when people, who have houses with all the modern conveniences, return to cave life again. In fact, some of them dig large, comfortable and multifunctional constructions according to their taste and intentions.

The resident of Arinj village Levon Varazdat Arakelyan started digging potatoes and cabbage in his cellar for protecting from cold and forgetting about the primary intention, continued digging.

With no modern digging or punching instruments, using only chisel, pick and hammer, today he has already dug 7 rooms, 26m deep, with

500m² total surface, which are connected to each other by tunnels and staircases. In fact, the central big hall is 12m high and is built in the form of a church.

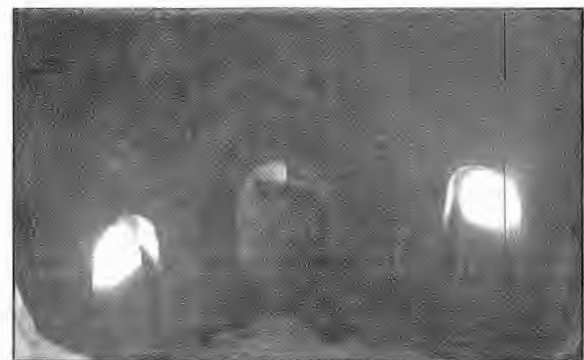
It's noteworthy that this latter day miner has secondary education and has never dealt with engineering sciences; he doesn't know geology, geophysics, mining, topography, geodesy, etc.

Nevertheless, this has not hindered the corridor labyrinth to connect to the rooms to millimeter's exactness.

Levon Arakelyan insists that his activities are conditioned by communicating with the Holy Spirit and he is sure that till the end of his life he will have dug 100 rooms.



The staircase goes down 27m deep, where the temperature is never higher than 9° C. The corridors lead to over 10 different rooms. The length of the corridors is over 200m. All this was dug by one person in the period of 20 years without using any techniques. It has now become a sightseeing place as for the locals, so for the foreigners to come and admire the amazing cave work. In 2005 Levon Arakelyan was awarded with the title of a deserved cave-expeditors.



In 1985 Levon Arakelyan, as he himself states, had a dream saying that he had to dig a cave. This was the strange beginning to latest cave-building.

After that Levon Arakelyan, without any electric or mechanical machines, using only chisel and hammer started digging rooms. Even if he wanted to, he couldn't have used electricity, as at that period there was no electricity in Armenia; Armenia was occupied.

The biggest hall that he has dug is 10m high and 15m diameter at the basis. The big hall is dug in three layers.

The top layer Q₄ holocene volcano-sediments, the middle layer Q₃ (pleistocene) clay, that have marine origination, and the lower layer conglomerate of clay sediments.

P-6

Temporal earthpyramids in caves. An example from Zesta Nera cave of Sidirokastro, Serres (Macedonia, Greece)

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Zesta Nera cave is located in the Krousovitis Basin, where the homonymous river is flowing, in the region of Sidirokastro town (Prefecture of Serres). The region geologically belongs to the Rhodope massif. The cave is a Travertine Bridge of 130m in length. In the cave sediments, conical formations made by sand deposits, covered by pebbles, were noticed. These formations are usually reported outside of the caves and they are called earthpyramids. In the present paper, the conditions and the process of their creation inside the Zesta Nera cave are analyzed.

Introduction - Geological setting

At the northern region of Serres Prefecture, in central Macedonia (Greece), close the town of Sidirokastro (Fig. 1) a number of caves have been recorded (Lazaridis, unpubl. data) in the Krousovitis basin, since 2001. In particular, the systematic cave exploration began in 2001, by members of the Department of Northern Greece of the Hellenic Speleological Society. In 2002, researchers of the School of Geology of Aristotle University (Thessaloniki) continued the study of the area by a project sponsored by the Serres Prefecture.

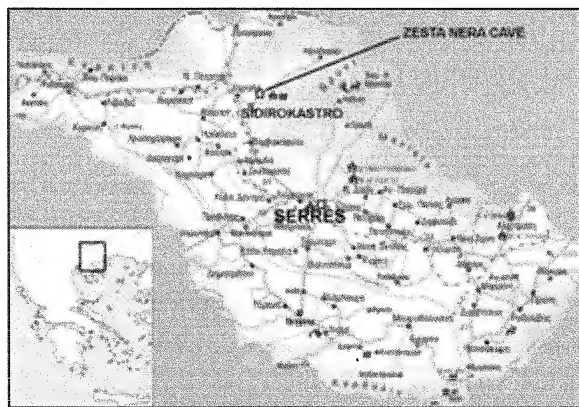


Figure 1. Map of Greece with the Serres Prefecture and the location of Zesta Nera Cave depicted

The Krousovitis basin strikes NE-SW and intervals the mountains of Orvilos, Angistrion and Vrondou. This basin is filled with Neogene and Quaternary sediments (Karystinaios, 1984, Papaphilippou-Pennou, 2004) that rest onto a pre-alpine and alpine basement that belongs to Pangeon Unit of the Rhodope massif (Mountrakis, 1985). This basement mainly consists of crystalline rocks such as gneisses and marbles, as well as large granitoid bodies of Tertiary age that intruded into the former, such as the well-known Vrondou granitoid.

The older sediments in the basin are from the Neogene period, deposited in lakes or from rivers. These depositions are mainly conglomerates, sandstones and marls, where sometimes lignites are interposed. The Pleistocene sediments include brecciated marbles (olistholiths) and travertines. Olistholiths came from the northern part of the basin as result from the glacial periods of Pleistocene (Sotiriadis, 1966). The travertines are deposited in small lakes or cascades. At the south part of the Krousovitis basin holocainic depositions appear.

In the central part of the basin there are hills of low altitude. The olistholiths show a characteristic view in the area because they are more

resistant to erosion and they occur on the hilltops. Streams terminating in the Krousovitis river have N-S direction and they are of a V shape (in cross sections) by down-cutting.

Various types of caves have been distinguished, according to their lithology and development. The most interesting cave of the area is that formed by travertine deposits and belongs to the cave category that is well known as Travertine Bridge. This natural bridge (Zesta Nera cave) is created in Zesta Nera area, above the Krousovitis River and is the unique reference in Greece.

Zesta Nera area is located 2 km NE far from Sidirokastro, close to the Mavros Vrachos hill. The name Zesta Nera (=warm waters) derives from a thermal spring, which appears there. The deposition of the travertine is due to the calcite-saturated water of this spring. The main research is focused in the travertine bridge, where special formations in the cave sediments were observed, formed by the drip water erosion after the deposition of the sediments. This phenomenon always takes place after every new deposition followed by erosion.

Morphology of the Zesta Nera cave

Zesta Nera is a SW-NE striking cave with two entrances, four chambers and of length about 130 m. The river enters the cave from the SW entrance and outflows from the NE entrance. The height of the cave ranges from 0,5 to 12 m and the breadth from 0,5 to 15 m. The chambers are connected by small passages. Most of the passages are short and wide except the last one at the NE part, which is high and narrow (Fig. 2).

Along the river into the cave brecciated marble (olistholiths) at the lower parts of the sidewalls and travertine at the higher ones were observed. Sediments from the river cover the floor of the cave. In the chambers, sometimes there are places where terraces are formed by sediments.

At the entrances of the cave there are two cascades about 15 m of height. The water comes from the thermal spring of the area and deposits the travertine, in which the cave is formed. An uplifting of the basin is the main fact at the beginning of the speleogenesis. After this, an intensive down-cutting resulted in a narrow valley with height difference between Krousovitis River and the stream derived from the thermal spring. The first cascades that deposit travertines up to now were formed in the area as consequence. The deposition started close to the spring and by the time it was forwarded to Krousovitis River. After the formation of a travertine bridge over the river, the deposition along the valley resulted in lateral extension of the cave up to the length of 130m.

Travertine Bridges are rare landforms with few references all over the world. Two well-known cases described by Bayari (2002) are referred in Turkey. Bayari concludes that the major factors were lead to the formation of these natural bridges, are the height of calcite-saturated springs above river level and the width of the valley section. He also mentions that the lateral distance that can be accessed by a travertine rim depends on the tensile strength and the grain density of the travertine.

Special forms in the sediments of Zesta Nera cave

In some places in the cave when the river flow is normal, there are sediments higher than its level deposited as terraces. One of these terraces is located at the east side of the first south chamber of Zesta Nera cave. In over-flow conditions, the deposition in this place can overpass the two meters of height. At this side of the river, mainly sand with few pebbles is

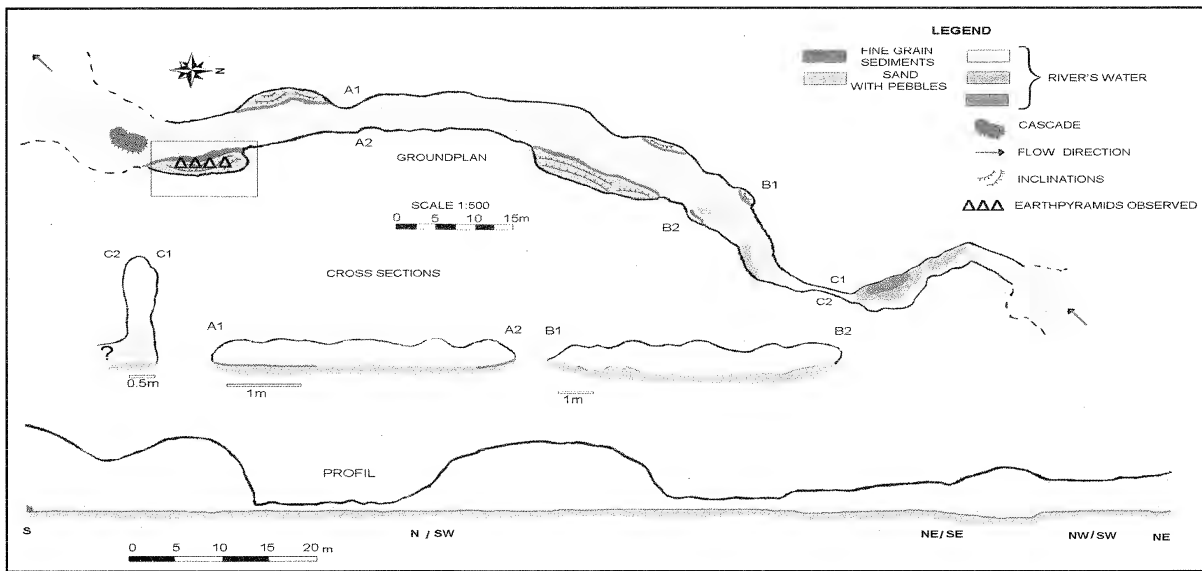


Figure 2. Ground plan, cross sections and profil of the Zesta Nera cave (Sidirokastro, Macedonia, Greece). The place where earthpyramids have been observed is also depicted.

deposited. Opposite, at the west side of the chamber, pebbles are mainly deposited, in over-flow cases. The east side is more interesting because after the over flow event, the erosion gives special formations on the sediments that are not cemented. These formations were formed by the same sediment (silty-sand), and they have a conical shape. It is notable that on their top there is always one pebble. The sections parallel to their base follow the shape of the pebble on their top (Fig. 3b).

The formations appear only where water drips from the ceiling that is 12 m high. Drip water erodes the sand very fast in contrast to the erosion of the pebbles. This water derives either from the thermal spring or from the rain and comes in the cave trough the travertine's porosity. In this way there is dripwater in the chamber during the year, almost independent from the rainfalls. The drip water can take volumes between 2,5 ml/(min x cm²) or less and 12,6 ml/(min x cm²).

At the beginning small holes on the sediment's surface are made by the

drip water (Fig. 3a). Afterwards the erosion builds up these formations by the removal of the sand (Fig. 3b). The pebbles protect the sediment below them from the drip water erosion. Usually their dimensions are less than 20 cm high and 10 cm wide, mainly depended on the thickness of the sediment, on the surface's inclination and on the pebble's dimensions.

b) A group of them formed on the sedimentary floor of the cave.

The development of these formations is very fast. They can be formed in some days after the over flow fact while their initial creation starts immediately after the deposition. On the other hand, their destruction is fast too. They have a lifetime span between two over flow events and they can be described as a temporally and repeating phenomenon.

Similar formations, known from outside sediments of the caves, are called earthpyramids. These are erosional formations with conical or column-like shape, made by sediment with a pebble on their top. Their formation is due to the erosion by rainwater of not cemented sediments like

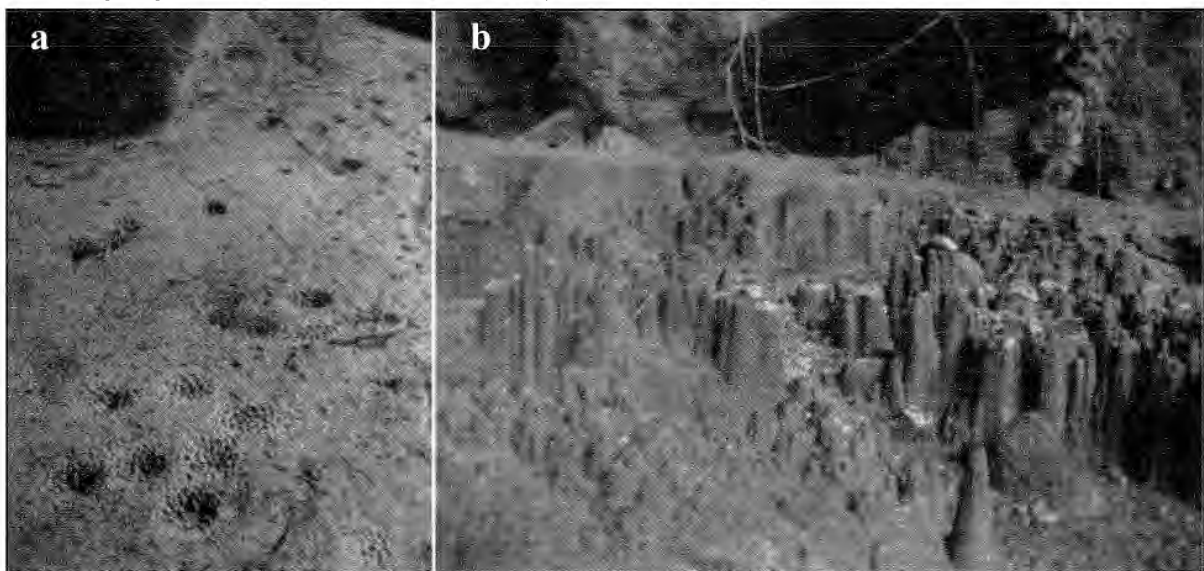


Figure 3. Earthpyramids from Zesta Nera cave: a) Initial stage of their formation in places where the water drips.

moraines, rich in pebbles and blocks (Becker, 1966, Dorrenhaus, 1966). The creation of the earthpyramids is easier in inclinational slopes. During the erosional activity in the area, earthpyramids have been formed up to their complete destruction.

Some formations by mud or sand are also the "sandsicles", formed when a high proportion of sand, silt or dust in flowstone or dripstone, produces sharply pointed ends, somewhat like the denticle of a saw blade. Other formations are composed almost entirely of mud, sand, detritus and organic matter. The most common of these are mud and sand stalagmites, as well as mud or sand stalactites, flowstone draperies, columns etc. In most of the situations calcareous material cements together the sand grains (Hill & Forti, 1997).

The formations in the sediments of Zesta Nera cave are earthpyramids created by erosion but in a different way that allows their development to be repeated. In contrast to the other sand and mud formations in caves the earthpyramids of Zesta Nera cave, have different morphology and they aren't cemented.

Conclusions

The Zesta Nera cave is attributed to a "Travertine Bridge" and this landform is described for first time in Greece. It must be noted that the travertine bridges can be considered as rare landforms, with few references all over the world.

At the south entrance of the Zesta Nera cave, sand formations were observed and they have been described as earthpyramids. It is also the first time that these erosional formations are referred into a cave of Greece, in contrast to the typical earthpyramids that are described always as a formation outside of the caves.

The earthpyramids of the Zesta Nera cave are temporal and they can be characterized by a procedure with a repeating character. This character is due to the alternation of a) the deposition that is realized during overflow events, which have continuous succession and b) the meanwhiles of the erosion of the sediments by the dripwater.

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P-7

Megalon Eptamilon cave (Serres, Macedonia, Greece) Speleogenesis and development

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Abstract

In the present study the Megalon Eptamilon cave is described and geological observations in relation to its speleogenesis and development are discussed. It is located at the foothills of the Menikio Mountain, in the county of Serres (Macedonia, Greece). The region belongs to the Pangeon unit of the Rila - Rhodope massif. The Megalon Eptamilon Cave is a system of karstic tubes and the development follows the main tectonic structure of the region. It has two (2) different directions of development, perpendicular between them. One has NE-SW and the other NW-SE direction. The corridors of the cave have two different shapes, according to their bearing. The NE-SW corridors are low and wide, while the NW-SE ones are high and narrow.

Introduction

The Megalon Eptamilon Cave (MEC) is located at the foothills of



Figure 1. Map showing where Megalon Eptamilon cave is located.

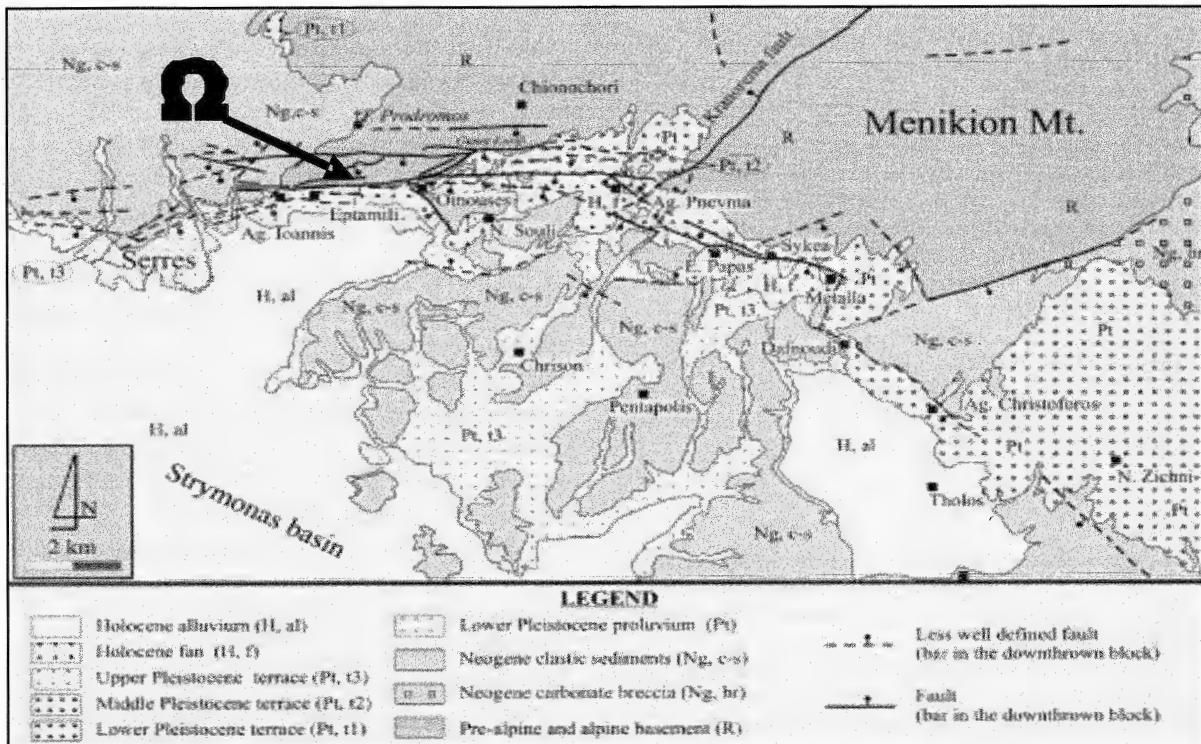


Figure 2. Geological map of the region of Serres (Tranos & Mountrakis 2004) with the Megalon Eptamilon cave (Ω) depicted.

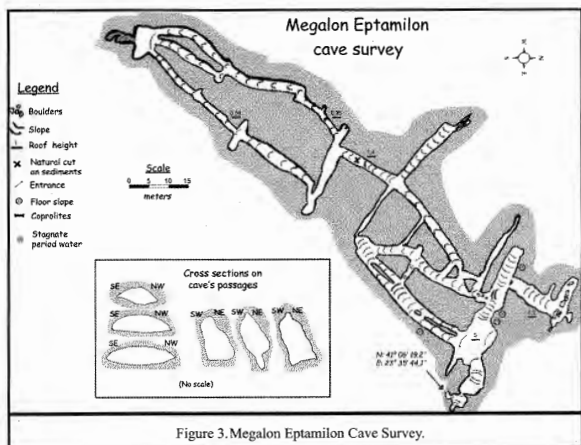


Figure 3. Megalon Eptamilon Cave Survey.

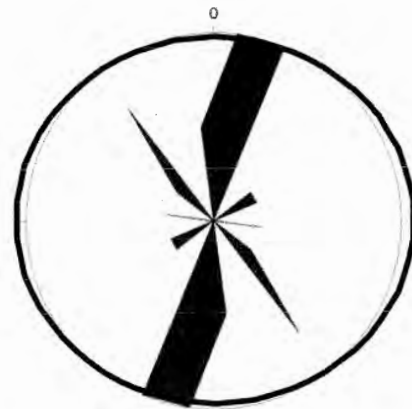


Figure 4. Joints plane from the outside area of the Megalon Eptamilon cave

Menikio Mt., close to Eptamili village, 3Km from Serres, Prefecture of Serres (Macedonia, N. Greece) (fig. 1). The cave was discovered in 1965 during the works at an old marble quarry. In the same year, the first exploration took place by members of the Hellenic Speleological Society (H.S.S.), the head of which was the speleologist †I. Ioannou.

Geological settings

The cave has been formed in Paleozoic marbles that belong to the Pantheon Unit of the Rhodope massif (Kilias & Mountrakis 1990). At the region acts a 10-km-fault segment of the Serres Fault Zone, which consists of sub-parallel E-W striking faults that dip at high to very high angles to

the S controlling the deposition of the Quaternary sediments up to the Late Pleistocene-Holocene fan deposits (Tranos & Mountrakis 2004) (fig. 2).

Geomorphological setting

At Menikio Mt. there were recognized four (4) uplifting movements by Vavliakis (1981), which developed equal Pediments and Glacis. These landforms have been formed between Middle Miocene to Middle Pliocene (Psilovikos, 1986). MEC has been formed on a Glacis surface, because of the action of Quaternary (Pleistocene) faults that acted at the region (Papaphilippou – Pennou, 2004).

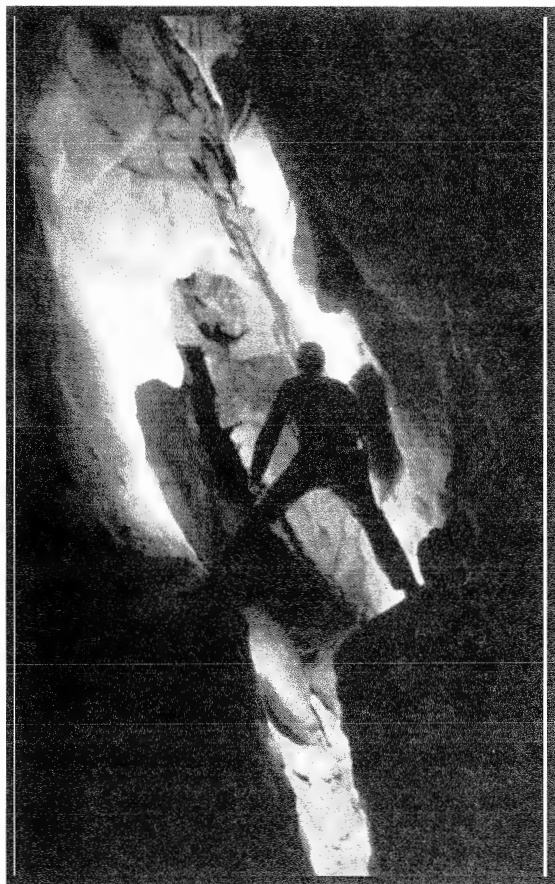
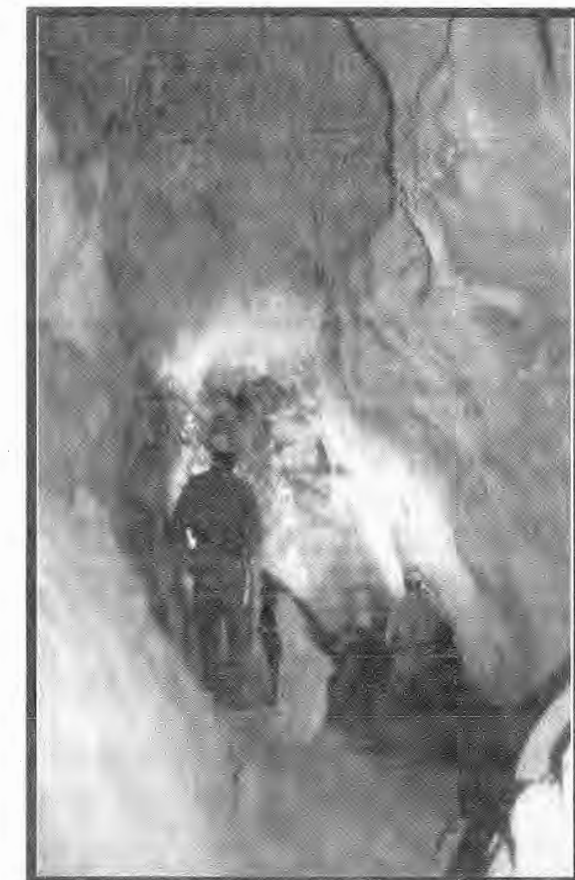


Figure 5. Megalon Eptamilon Cave: Passages of NE-SW direction.

Megalon Eptamilon Cave

Megalon Eptamilon Cave (MEC) is a system of karstic tubes of NE-SW direction that communicate with NW-SE passages. The total length of the passages of the cave is about 700m (fig. 3) (Pennos, unpubl. data).

In the cave there are various speleothemes such as stalactites, stalagmites, draperies and flowstones. During the research in the cave, few coprolites of a large carnivore were found. The size and shape, in compari-



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son with those found in the Agios Georgios Cave, allow them to be attributed to the spotted cave hyaena [*Crocota crocuta spelaea* (GO-LD-FUSS 1832), Tsoukala, pers. com.]. *Crocota crocuta spelaea* lived in Europe during the Late Pleistocene, so it can be concluded that at those period the cave may probably have a different entrance from the present one that was opened during the works at the quarry.

Speleogenesis and Development

Megalon Eptamilon Cave is a system of karstic tubes developed at

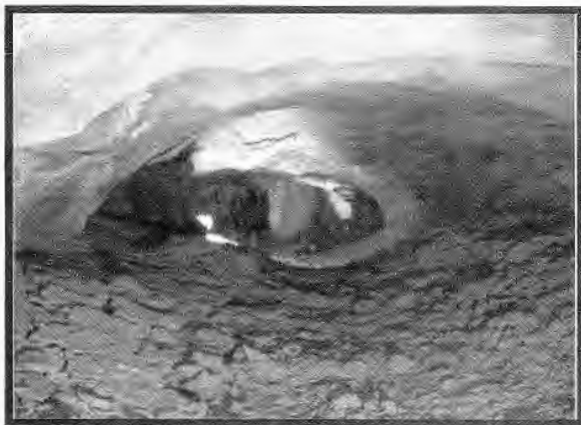
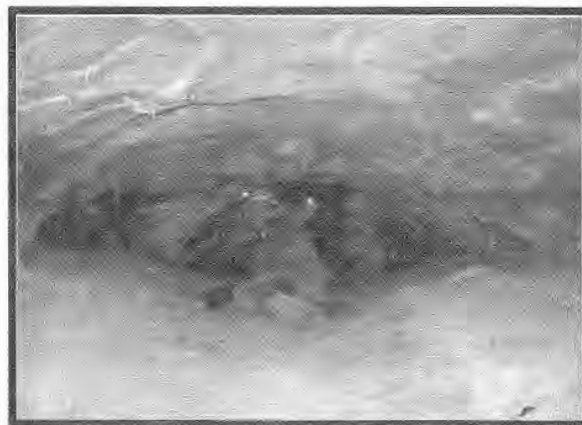


Figure 6. Megalon Eptamilon Cave: Passages of NW-SE direction.



the phreatic stage. In the present day the cave system is dry in the vadose zone. During the speleogenesis at the phreatic stage, two main groups of passages, perpendicular between them, are formed along NE-SW and NW-SE directions. The shape of the passages depends upon the directions they follow. The passages which have NE-SW direction are low and wide (fig. 5), in contrast with the others that follow NW-SE directions and they are high and narrow (fig. 6). In the former case the passages follow the crossing between the bending and the NE-SW joints. In the latter case passages are developed along the other group of joints of NW-SE striking. The water is flowed to the local basic level mainly through the NW-SE passages.

Afterwards, the cave passes to the vadose zone, when the local basic level had changed. The hypothetical shape of a phreatic passage along an almost vertical joint as these with the NW-SE striking, it can't compare with the shapes observed in these passages. This is due to the condensation inside the cave and, mainly, to the continuous collapses when the cave passed to the vadose zone. The speleothemes of the cave has been also formed during this stage.

The geometry of the discontinuities of the marbles is responsible for these collapses. The inclination of the marbles and the joints of NW-SE striking are the main discontinuities. The passages are becoming wider and higher because of the collapsed blocks from the SW sidewalls (fig. 7 & 8). These blocks are deposited at the floor of these passages as an ellouval cone of debris.

Conclusions

- The Megalon Eptamilon cave has been developed at a Glacis during the Pleistocene age.
- The cave has also been developed at the phreatic phase and then passed at the vadose zone.
- The NE-SW striking passages were developed during the phreatic phase along the crossing between the discontinuities, which derive from the bending and from one of the joint systems, giving them a circular shape.
- The NW-SE striking passages created at the phreatic stage along almost vertical joints, but their present shape was developed in the vadose zone by condensation and collapses.
- The bending and the joints of the marbles lead the collapses. The low angle of the bending, as well as the high dip joints in respect to

their striking contribute to the collapse process.

Acknowledgements

The authors would like to thank the speleologists of the Department of Northern Greece of the Hellenic Speleological Society, V. Makridis, I. Partsiou, G. Sotiriadis, S. Zachariadis, K. Polydoropoulos, H. Garlaouni, and S. Pappa for their help during the numerous visits at Megalon Eptamilon Cave. We would also like to thank Assist. Prof. E. Tsoukala for her help, and N. Tsiakmakis for his linguistic advice.

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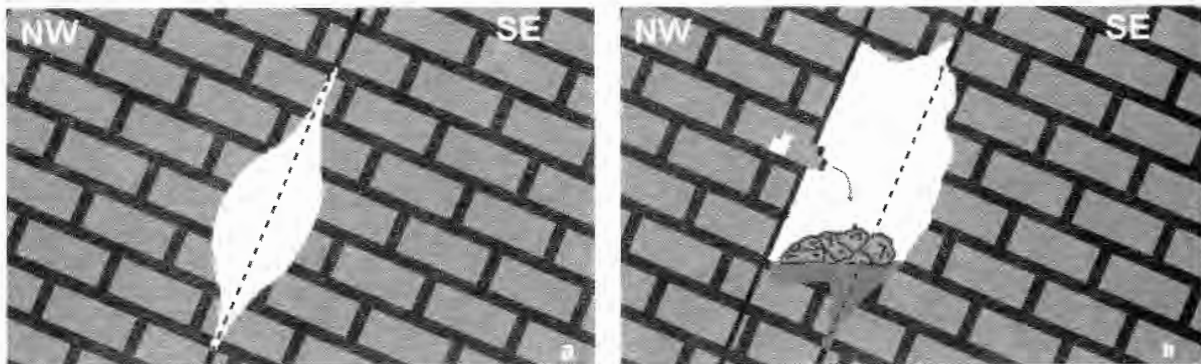


Figure 7. Megalon Eptamilon Cave: Development of passages of NW-SE direction.

a) Their shape at phreatic phase, b) their shape at vadose zone. Collapses mainly result in the morphology of the NW sidewalls. In contrast, the SE sidewalls are formed mainly by condensation.

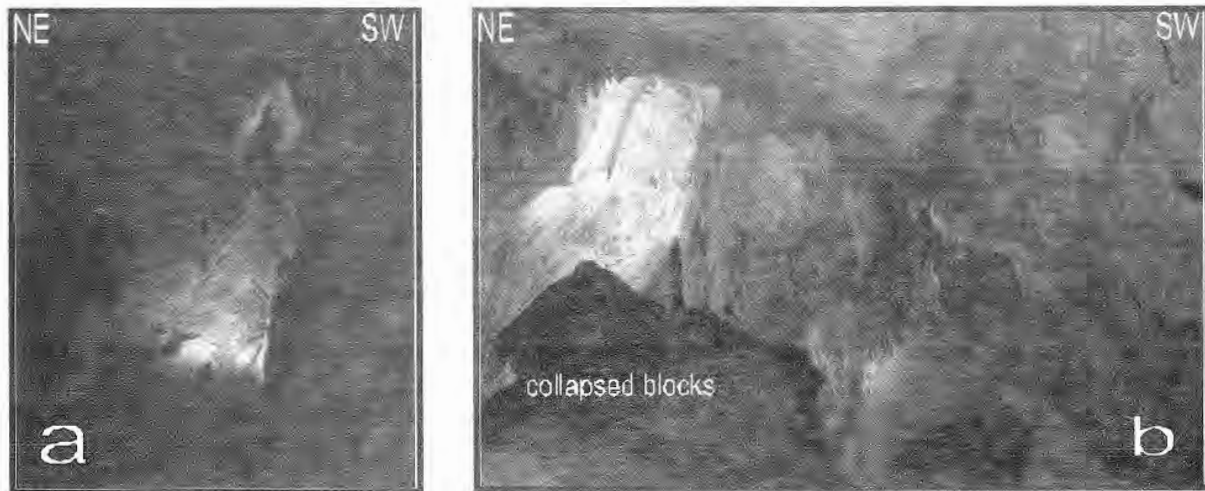


Figure 8. Megalon Eptamilon Cave: Passages of NW-SE direction of early (a) and older (b) stage.

P-8

The cenotes (anchialine caves) from Cozumel Island, Quintana Roo, Mexico.

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Abstract

The Cozumel Island is a Caribbean insular landscape that have karst as main component of soil. In this place the caves formed are the sinkholes (cenotes) and almost are considerate anchialine caves for their sea connections. The cenotes register was made in the Cozumel, in order to obtain it,

the aerial photography was analysed, and we made a visit to each cenote identified for corroborated the geographical localization at same time we measured the diameter and initial depth that showed the enter. This work show a checklist of cenotes from this island, location maps and we identify the regions in the distribution of this natural caves in the island.

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P-9

Geological and structural setting of Ermakia cave, northern Greece

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Ermakia cave is located in northern Greece, NE of Ptolemais town, between Spilia and Ermakia villages. It is a small cave (its total length is 50 m) which is formed by two interconnecting chambers. It is placed entirely in the Lower Cretaceous limestone rocks of Vermion nappe. In the cave area the nappe consists of gray - bluish medium bedded limestone, dipping at an average of 35 degrees towards the East. The nappe at the site has a maximum thickness of ca. 90 m, while the limestone appears strongly sheared near its base. Shearing sense indicates a W-SW sense of movement, which is compatible with observations in other sites near the nappe's roots. Younger deposits consist of erosion cover and local thin deposits of flysch and limestone colluviums, as well as terra rossa deposits in small cavities throughout the host hill, as well as in the form of soil cover. Both chambers of Ermakia cave are aligned in an almost N-S direction. This direction is similar to the general brittle structure of the area, as documented by the strike of one of the two dominant joint systems (D1), as well as by a normal fault that is visible at the connecting corridor between the two chambers, which has a S10E strike and dips towards the NNW. The second dominant joint system (D2) in the cave area is of

NW - SE direction, and is considered to be the conjugate one of D1. It is quite clear that the cave was formed along the pre-existing main fault line, while its development was facilitated by the mechanical discontinuities of D1 system and bedding surfaces of the same strike. The cave is currently not developing, due to its shallow depth and thin limestone cover; there are however some indications that it was affected by an earthquake, which has broken and displaced a large stalactite in the main chamber. The stalactite was subsequently healed by flowing water and speleothems. Based on geological and structural data of the cave and adjacent areas, although there are not enough stratigraphical information from the cave, it seems that the cave was formed along the visible N-S trending normal fault, which was probably formed during the Pliocene extensional stage. Since the completion of its development, the cave entered the period of maturity, which caused the fall of large blocks of overlying limestone along the pre-existing discontinuities. These conditions are not unique for this cave, i.e. they may apply to the broader area, it therefore is very likely that there are other "blind" cavities of the same characteristics in the area or adjacent hills that are covered by Vermion nappe limestone.

P-10

Sedimentation cycles in eastern Brazilian caves: origin and palaeoclimatic significanceAugusto S. Auler¹, Xianfeng Wang², Peter L. Smart³, R. Lawrence Edwards², Hai Cheng², Daniel Corrêa¹, Poliany Figueiredo¹¹ CPMTC - Instituto de Geociências, Universidade Federal de Minas Gerais, Av. Antonio Carlos, 6627, Belo Horizonte, MG, 31270-901, Brazil. aauler@terra.com.br² Department of Geology and Geophysics, University of Minnesota, MN 55455, USA.³ School of Geographical Sciences, University of Bristol, Bristol, BS8 1SS, England.**Abstract**

Caves in eastern Brazil commonly display extensive clastic sedimentation intercalated with calcite layers. Clastic sediments have often been totally or partially removed, leaving hanging calcite layers and fragmentary sediment sequences. These three different processes, i.e. sediment input, sediment removal and chemical precipitation, have been linked to distinct palaeoclimate/hydrological conditions. Sediment input is interpreted as being due to drier conditions in which scarce vegetation and unprotected soil favours high soil erosion rates in slopes leading to the caves during occasional rainfall events. Sediment removal, on the other hand, is probably related to somewhat wetter conditions in which sediment-free concentrated runoff (through ravines) in otherwise vegetated slopes is able to erode and transport sediment. Calcite deposition is unequivocally due to wetter past climatic conditions.

Calcite layers, besides indicating wetter intervals, may bracket the age of overlying and underlying clastic sedimentation. Ongoing mass spectrometric ²³⁰Th analyses, have allowed a better understanding of the timing and palaeoclimatic significance of these sequences. The presence of several generations of clastic sediments is favoured by slow uplift rates, which allow the caves to stay under the influence of cyclic climatic events for a prolonged period.

This situation was observed to occur in Clearwater Cave, Sarawak (Farrant et al., 1995). There are, however, non-climate related causes of sediment accumulation/removal in caves. These include passage constrictions (due for instance to ceiling collapse) causing sediment accumulation upstream from the blockage. Conversely, plugging of entrance can restrict sediment influx into the cave, leading to a period of non-deposition preceded by normal sedimentation. Autogenic sedimentation, which includes insoluble residues of the carbonate and biogenic materials such as guano can also be independent (or not directly related) of climate changes.

Caves are subjected to the same palaeoclimate-controlled cycles of clastic sedimentation and erosion as surface terrains, but they also show palaeoclimate related per descensum chemical precipitation that does not have an analogue on the surface. Chemical precipitation represents meteoric water that percolates through the soil and bedrock before reaching the cave, and thus is independent of type of entrance or base level control, although in order to precipitate, it requires a substrate where water flow, sedimentation and erosion are absent. This study, performed in two karst areas under distinct present climate (semiarid northeastern Brazil and subhumid southeastern Brazil) will analyse palaeoclimate conditions responsible for chemical precipitation, clastic sediment deposition and clastic sediment removal.

1. Introduction

Many caves in eastern Brazil show unmistakable evidence of past phases of sediment input and erosion. In many cases, the input phases include not only clastic sedimentation but also chemical precipitation represented by speleothem layers within clastic material. Although sediment infill can occur in the phreatic zone as discrete inputs through the roof in flooded passages, as autogenic sedimentation derived from insoluble residues in the bedrock, or as major inputs that lead to filling of most of the passage causing development through paragensis, we will discuss the palaeoclimate related sedimentation phases that take place after the cave passage has reached the vadose zone.

Cave clastic sedimentation can be controlled by a number of factors. Foremost among them is the type of entrance configuration. Many cave entrances lie in the bottom of dolines, and thus are subject to runoff from the doline slope. These dolines may have developed synchronously with the cave, and thus may have behaved as a sediment source throughout the life history of the passage, or may represent a random (and later) feature that brings sediment to a cave passage where allogenic sedimentation was otherwise largely absent. Many caves represent swallet systems, and receive substantial fluvial sedimentation from the river basin. The source area of sediment in this case is much larger than in the doline situation, and may include several tributaries and extensive areas of valley slope. Furthermore, the vertical amplitude of water level rises in caves can be several times higher than on the surface (Gillieson, 1996) due to the "closed" nature of the passage. The fluvial setting is thus likely to represent a much more complex system due to its large extension and combination of slope and river channel settings. These two situations occur in the cratonic area of eastern Brazil and will be further discussed.

Climate changes can also control sedimentation through variations in base level. A water level rise, or aggradation of the base level stream will lead to a decrease in channel gradient inside the cave, causing aggrada-

2. Sedimentation cycles in caves in stable cratonic settings

Caves in low relief, tectonically stable areas such as the cratonic area of eastern Brazil, will tend to remain within the range of palaeo water table variations for a more prolonged period than caves in tectonically active areas. This is because of the low rates of base level lowering compared to the recurrent interval of climatic changes, which means that short-term cyclic climatic events may affect caves at a given elevation for over several cycles before the site becomes inactive (Fig. 1). If one considers the rates of denudation in the São Francisco Craton reported by Harman et al. (1998) of 30 ± 10 m/Ma, and the water table variation obtained for the last glacial cycle at the Campo Formoso area, northeastern Brazil, of 13 ± 1 m (Auler and Smart, 2001), any given fluvial cave passage once above the water table will be affected by at least 3 glacial/interglacial cycles, before being decoupled from direct water input. In tectonically active areas, many fluvial cave passages are drained too quickly to be affected by more than one palaeoclimate cycle. In caves fed by dolines, the situation appears to be more complex because doline deepening (or aggradation) can depend on local factors, and a given sector in a cave can be under the influence of runoff for a more prolonged period.

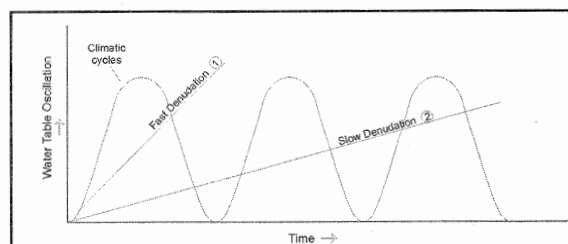


Figure 1. Schematic representation of the influence of palaeoclimate related water table oscillations in caves. Caves in areas with rapid denudation (1) will be affected by less climatic cycles than caves in stable cratonic settings (2).

3. Palaeoclimatic significance

3.1. Semiarid Northeastern Brazil

Speleothem deposition phases in northeastern Brazil have been summarised by Wang et al. (2004). These short periods of increased humidity were interspersed with drier intervals. The present semiarid climate has developed since 11,300 yr ago (Auler et al., 2004) as indicated by ^{230}Th dating of the youngest phase of calcite deposition in travertines. Present climatic conditions favours aggradation of (mostly dry) streambeds due to soil erosion in vegetation-free slopes during occasional rainstorms. These conditions also favours sediment input into caves, especially in doline associated cave entrances. In fluvial systems however, enough water is needed to transport into caves the fine-grained material eroded towards valley bottoms. Such conditions are not met during present semiarid climatic conditions since rainfall events do not provide enough energy to transport or erode sediment sequences. Observations in one of the caves demonstrate that not only speleothem deposition but also clastic sediment input and removal are associated with wetter than present conditions (Auler, 1999).

3.2. Subhumid Southeastern Brazil

Caves in subhumid southeastern Brazil are mostly of the doline-fed type and contain abundant chemical and clastic sedimentation. Speleothem deposition is largely absent at present, being restricted to limited drip water speleothems in a few caves. Although extensive deforestation has occurred since European settlement, the natural hydrological regime of the area under the present climate appears to have involved little or no sediment transport over doline slopes. The sediments in doline fed caves are at present undergoing erosion. The markedly seasonal climate (wet during austral summer and dry during winter) enables significant runoff to occur during the wet months, but because of the well-developed vegetation (enhanced during summer), no soil entrainment occurs.

The timing of speleothem deposition in the area is still being determined through systematic mass spectrometric ^{230}Th dating of calcite speleothems. Speleothem deposition unequivocally indicates wetter than present climate since there is no widespread speleothem deposition at present. An important feature of the subhumid southeastern Brazil karst area is that it provides a modern analogue of the phase of sediment erosion in caves. The present climate and vegetation are not associated with either speleothem, or clastic sediment deposition but active sediment removal from the caves is occurring. If this pattern is assumed as typical of present climatic conditions in the area, sediment deposited during drier periods could then be removed during the following moister phase. This is supported by the observation that speleothems are being exposed by sediment erosion, indicating that a phase of speleothem deposition was followed by sediment input. The data is, however, too fragmentary to allow more detailed interpretation. A more extensive sampling and morphological reconstruction of the speleothem layers and associated sediments are needed to refine the interpretation of any palaeoclimatic phases in this area.

4. Conclusions

Study of cycles of sediment removal and input in two areas of contrasting present day climate in eastern Brazil has enabled a preliminary assessment of the palaeoclimate control of these events. Speleothem deposition occurs under wet conditions, but sediment input can be assigned to any climatic phase, depending on local factors. In slope settings, sediment deposition tends to occur during dry periods, as suggested by data from northeastern Brazil. However, in fluvial settings, enough energy (and therefore water) is needed to transport sediment and deposit them inside caves. In Gruta do Convento, a fluvial cave in northeastern Brazil, both speleothem deposition and sediment input appear to occur simultaneously. The ubiquitous occurrence of speleothems with significant amounts of terrigenous material throughout the area confirms that at least some sediment input occurs during such phases.

The phase of sediment erosion remains the least known part of the sedimentation cycle in caves. Brain (1995), Brook and Nickmann (1996) and Brook et al. (1997) have correlated this phase to a wet period in which the vegetation would not allow soil entrainment. Brook et al. (1997) further add that such an event would require a climate wetter than required for speleothem growth because speleothem erosion was also observed to occur. Observations at the subhumid southeastern Brazil karst show this not to be the case because the present climate is clearly drier than required for extensive speleothem formation. It seems that sediment erosion could in fact occur in the transitions between the wet periods suitable for speleothem growth and the dry phases conducive to soil erosion, although very wet periods could possibly cause both erosion and speleothem deposition in slope setting caves. An alternative explanation for cave sediment erosion phases involves exhaustion of the sediment source. This is not the case in the Lagoa Santa area southeastern Brazil, because the soil originates from pedogenesis of phyllite layers which used to overlie the limestone (Piló, 1998). Any soil erosion would result in bare doline slopes which would not again be covered by soil. Barren limestone is rare in the area and thus complete removal of soil has not occurred. The processes of sediment input and erosion and their relationship with climatic patterns appear to be complex and local variables are likely to be of importance at any specific site.

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P-11

Unique features of fissure quartzite caves of the Inficionado Peak, central Brazil

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Abstract

Remarkable quartzite caves occur on the top of the Inficionado Peak, state of Minas Gerais, central Brazil. A series of fissures and canyons characterise the small (0.9 km²) but highly irregular surface of the upper portion of the peak. The two major caves, Centenario and Bocaina, are among the longest (respectively 3,800 m and 3,200 m) and deepest (-484 m and -404 m) caves known in quartzite. These caves develop as a network of very deep and narrow parallel crevasses linked by shorter and smaller passages. Only two other areas appear to display similar caves, the tepuy area of southern Venezuela and possibly the Chimanimani Mountains in Zimbabwe. Some of the underground forms of the Inficionado caves appear to be very rare or even unique, regardless of rock type: (i). Breakdown levels. Entire levels, some with perennial streams, are formed by the wedging of quartzite blocks into the fissures. The process starts

with blocks larger than the fissure width, then smaller blocks and eventually sand filling in the voids, resulting in a floor perched high up in the fissure. (ii). Ceilingless passages. Some of the passages have no ceiling proper. The undulating profile of the fissures creates a dark environment but some of the main passages are better described as very deep and narrow canyons. (iii). Lateral passage evolution by flaking of quartzite. Intergranular space in quartzite becomes water filled and eventually slabs, some up to 0.8 m wide, detach from the walls. This process accounts for the enlargement of the fissures. (iv). Short passages with rounded cross section. This type of passage are suggestive of phreatic flow. However they are closed on both ends. Parallel passages are sometimes joined by short passages (or windows) that cannot be ascribed to phreatic flow since they have no continuity and no input/output routes. These passages are possibly formed by slow disaggregation of quartzite.

P-12

The Svarthamar cave research project, Fauske, north Norway

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Abstract

The Svarthamar project was launched in 2003, aiming at a complete survey and speleogenetic analysis of caves within the 'Mefjell massif'. One of the caves, Svarthamarhola, is an anomalously huge cave room, the biggest in Scandinavia, containing a large ice mass which was formed since 1200 AD. Three MSc. projects (2005) were initiated in order to study cave microclimate, ice stratigraphy and speleothem stratigraphy. So far, accurate mapping of Svarthamarhola has revealed that the cave formed around a dipping anticline and that the cave has a complex history, probably originating from a set of dip tubes developed in a sheared bedding/foliation plane. The big rooms are most probably formed by a large river in the past, either as an ice-marginal overflow or maybe as a pre-glacial fluvial system. Our data logger measurements confirm very strong thermal winds through the cave and an expected dynamic behaviour in relation to external temperatures. We have also cored the upper 5 m of ice for environmental tracer analysis, which are in progress as well as a detailed study of a MIS 7 speleothem from the cave.

all standards the largest natural cave room in Scandinavia. It is also a dynamic ice-cave with stratified ice dating back to about 1200 AD. The huge rooms contain loose sediments and collapse blocks in all stages of weathering, ventifacts, fossils, ice and fragile mineral deposits. We gather that subaerial weathering of marble blocks might have acted for as much as 30 kyr without major disturbance, leaving many blocks in a very fragile state. This unique and extremely fragile system is heavily over-used by both organized and casual tourism, which has led to severe degradation of the cave's untouched atmosphere, as well as direct destruction by trampling, bonfires and vandalism. It was decided to document and study the system while it is still in a recognizable stage. First a thorough surveying of the main cave and adjacent caves were commenced, combined with photographic documentation. The main goal is to work out the speleogenesis of this anomalous room, secondly to understand the environmental information preserved in the cave. Part of this is done as MSc. Theses: Aspects of cave ventilation (L. Baastad), Ice stratigraphy and environmental tracers (J. Engelién) and MIS 7 speleothem chronostratigraphy (E. Fedje).

Introduction

Svarthamarhola in the Mefjell massif at Fauske, north Norway, is by

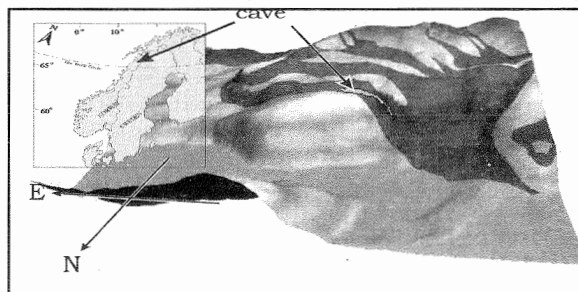


Figure 1 (left). Location of the cave in Scandinavia and in the local topography in the southern wall of the Fauske fjord. This massif is named 'Mefjell'.

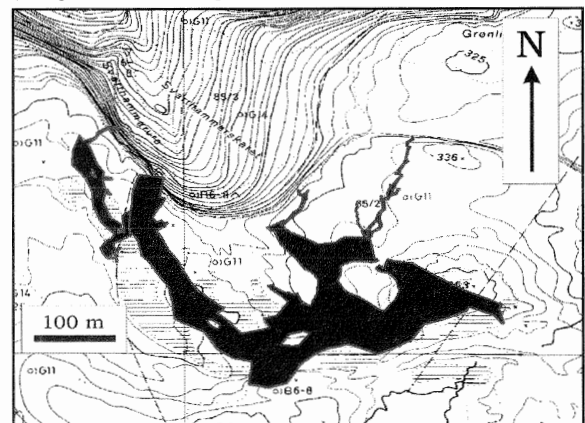


Figure 2 (right). Outline map of Svarthamarhola inserted into the local topography.

Geographic and geologic setting

The Meffjell massif is situated at the southern side of the Fauske fjord, Figure 1, with marble bands belonging to the Rognan Formation within the Fauske nappe. Carbonates are of probable Cambro-Silurian age and were metamorphosed during the Caledonian orogeny. The caves are situated on the shoulder of the main valley (fjord) where it is constricted. Just distally of this is a pre-boreal moraine, it is believed that the pre-boreal stage and this constriction are linked. The pre-Boreal events are often regarded as a result of dynamic reorganization of the ice surface, which became unstable after rapid calving inwards in the fjords. This re-organization created a push-up moraine, often located at fjord constrictions where calving would be halted.

Svarthamarhola

The cave was first reported in the late 1960'es and was surveyed shortly after (Heap 1970). Since the original map lacked vertical information, the cave was re-surveyed using photographic tripods, Suntoo instruments and a laser rangefinder. The large rooms allowed a modified triangulation technique to be used. In order to obtain accurate data from the huge cross-sections, a profile scanner was constructed from a laser rangefinder and a clinometer. In this way, an accurate survey of ceiling, walls and floor could be made. Survey data were processed on the cave survey program Grottoff (Lauritzen 2003), from which the centreline polygon could be exported to Corel Draw for adding walls and details.

Cave architecture

The laser scans clearly indicate that arced profiles, which by inspection in the cave and on photographs appear relatively smooth and rounded, are indeed irregular, reflecting geological structure, Figure 3. Cross-sections are up to 1100 m², and spalling has created dome structures in the ceiling. The cave is situated within a relatively thick marble pack, dipping south. The marble and schist pack forms a major anticline with axis dipping ca 20° S. Rotation of the centreline survey to maximum overlap yields a projection axis that is almost identical to the fold axis taken from geological maps. Hence, the southward bend in the cave outline (Figure 2) is actually a relatively horizontal stretch of passage bending around the

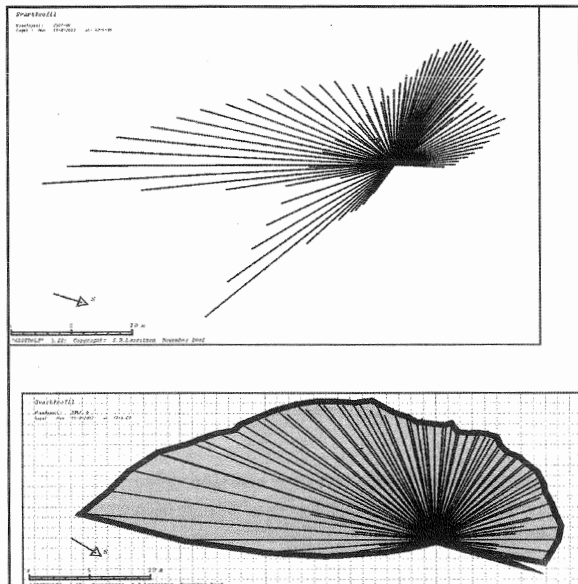


Figure 3. Cross-section made by laser scans. Two oblique planes. When rotated to overlap, the projection is parallel with the passage.

core of a fold, Figure 4.

Other caves

Several smaller caves are known in the area, and being situated within the same karst stripe, they serve to complete the speleogenetic picture of the Meffjell massif. These caves are Moengrotta (a streamsink), Svarthamargrotta and Kvithola (both fossil phreatic tubes) and tens of smaller tube fragments and unexplored entrances (Heap 1970, Lauritzen 1983, 1986).

Speleogenesis

Numerous small phreatic tubes with vadose invasion trenches penetrate from the southern hillside into the cave. Numerous small openings, either too tight to be penetrated, or choked with sediment, occur at a particular horizon in the marble. This horizon display evidence of shear movement, and was probably the target for cave initialization, or 'inception horizon'. Since the large rooms actually have a low gradient around the fold structure, it is likely that these voids were created by vadose erosion by a sizeable river. The cave's location closely beneath the paleic surface allude to a pre-glacial or tertiary development (i.e. Lauritzen 1990), although this hydrological requirement was fulfilled in almost every glaciation during the quaternary. Situated on the upper shoulder in the glacial fjord-valley, perched on a mica schist core in an anticline, one scenario would be ice-marginal overflow along a valley glacier at about the extent of the pre-Boreal or Younger Dryas stage, the latter is actually the 'average' extent during the whole Quaternary (e.g. Porter, 1989). Another, but less likely possibility is that these 'dip tubes' may be phreatic and vadose invasion features that targeted towards the pre-existing (large) void.

Balch-ventilation of the ice cave

Having two spacious entrances at an elevation difference of 45 m, the cave supports strong Balch-ventilation, which is most probably the reason for the great ice mass that is situated at the lower entrance, Figure 5. The ice mass is ablated from the underside by (presumably) geothermal heat,

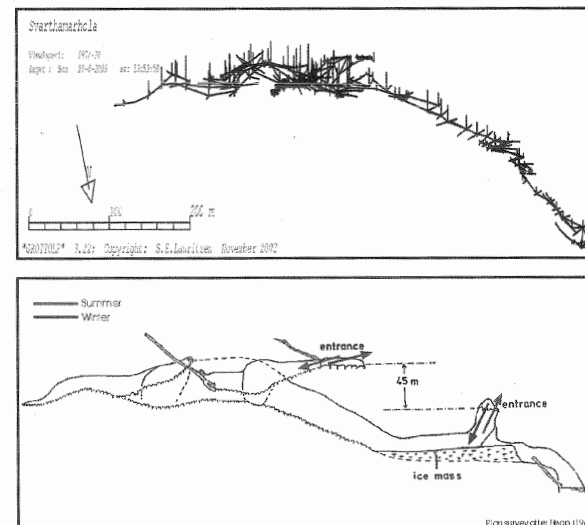


Figure 4 (top). Centerline map rotated until maximum overlap. In this case, the axis of projection is parallel with the general fold axis in the rock mass, demonstrating that the cave is indeed controlled by a major fold structure.

Figure 5 (bottom). Vertical projection of the cave, showing the two entrances with Balch-ventilation effects.



Figure 6 (left). Data Logger Station In The Upper Entrance, Logging Wind Speed, Direction, Temperature And Humidity. Photo: S.E. Lauritzen

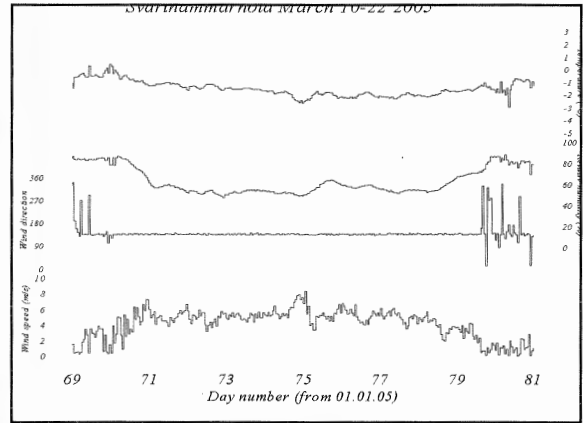


Figure 7 (right). Breathing episode in March 200. Curves from top: air temperature (°C), relative humidity (%), wind direction (°) and wind speed (m/sec).

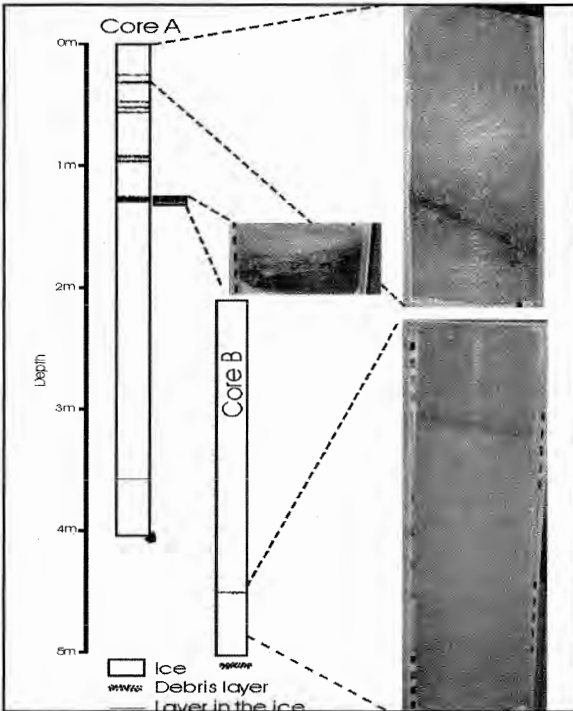


Figure 8. The 5 m deep ice core, showing dirt bands and layering.



Figure 9. Drilling the ice core. Photo: S.E. Lauritzen

creating a large ice wall at its deepest point and an ablation tunnel. Also, we think that the heat and air movements that are initiated from numerous visitors may affect the ice, which has notably shrunk during the last 30 years. This hypothesis will be tested through our monitoring program..

Cave and surface microclimate (L. Baastad)

In order to quantify air flux and enthalpy dynamics in the cave, two GSM driven, multichannel data logger stations were installed (Figure 6), together with 25 smaller loggers for humidity, air pressure and temperature at various places in the cave and on the surface. Particularly in cold periods, when surface temperature drops below the cave temperature, very strong, effluent winds are generated. Figure 7 shows one such breathing event, when surface dropped below freezing in march 2005. Assessment of volume and surface of the cave and of the ice mass, together with these

physical measurements will be used in our enthalpy model of the cave.

Ice stratigraphy (J. Bjørlien)

The ice mass is close to 20 m thick at its maximum, of which the lower 13 m is exposed in the lower ice wall and in the thermal ablation tunnel. AMS ¹⁴C dating of plant fragments suggests that the ice mass was formed after 1 200 AD and it grew first as a huge flowstone, which, - when it completely obstructed the cave- was transformed into an ice lake that froze in sequences. At least two periods of ablation occurred since it was first formed.

The upper ~ 10 m of the ice is not accessible for sampling and was cored from the top surface in march 2005, using equipment and expertise from Stockholms University. We were able to extract a 5 m continuous core before the drill hit a rock. A thermistor string was inserted into

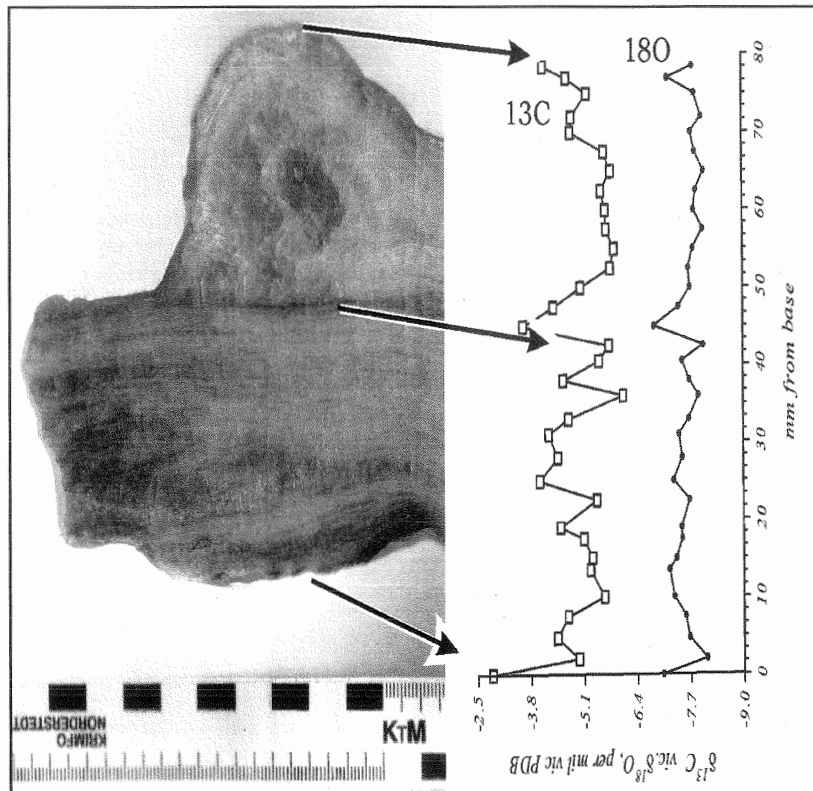


Figure 10. MIS7 speleothem with preliminary isotope record. The sample consists of a flowstone base, a dirty hiatus, and a stalagmite ongrowth. The dirty hiatus is visible isotopically in the sequence.

the hole before it was refilled with snow and ice fragments. The ice core contain one organic horizon and the sequence, which covers the recent history, will be used for environmental tracers, of which bomb ^{14}C , ^3H and commencement of copper smelting in the area might yield a time horizon.

Speleothem stratigraphy, MIS7? (E. Fedje)

Calcareous concretions (Höhlenkrappen) and frost-shattered speleothems were collected for dating. In addition to previous dates from MIS 5 (Lauritzen 1996), a new specimen dated by alpha counting to 170- 200 kyr (MIS 7?) and is now subject to detailed TIMS dating and isotope stratigraphy, Figure 10. This work is in progress, and further details will be presented in the poster.

Further work

Exploration for new caves and extensions are in progress in the massif around Svarthamarhola, as well as a microgravimetric survey, searching for other sizeable voids in the vicinity. We aim at a complete isotopic and trace element profile of the ice mass of which the commencement of copper smelting in the area is an interesting target. Another target of interest is to test the connection between surface climate and ice ablation/accumulation and to test if the heavy tourist trafficking may affect the ice mass.

Acknowledgements

Dr. Trond Ellingsen (cave owner) thanked for giving access to the cave and Fauske Municipality Administration for permitting snowscooter

transport of the ice-coring equipment etc. in March 2005. Department of Earth Science, Bergen University and The Bjerknes Centre for Climate Research are thanked for support. Stockholms Universitet provided ice-coring equipment and cryo-lab facilities. Financial support from Statoil (to Department of Earth Science, UiB) and from The Norwegian Research Council (NFR) through two projects, (NORPAST2; 155971/720) and ('Porosity development in marble stripe karst', 160232/V30).

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P-13

The karst in the Besapara heights, the Rhodopes mountain (Bulgaria)

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The studied region includes the northernmost parts of the Rhodopes Mountain. It is built by Paleozoic marbles, which take part in the North Rhodopes nappe. This nappe of block type is overthrusting various by age and lithology pre-Neogene complexes. Its integrity is disturbed also by tectonic movements and at Neogene-Quaternary boundary the Ispirikh graben is formed. The surface karst processes fade away under the 80-m thick Quaternary sediments due to the negative tectonic movements. In the Besapara heights the karstification is spread over 140 sq. km and it reaches down to 200 m depth. The surface karst is poorly developed due to the big dips of slope planes. The karst is presented mainly with groove lapiaz in the north and northeastern parts of Besapara heights and in the

rest parts - with uvalas and blind valleys. With boreholes are fixed several karstified zones at: 5-6 m; 20 m; 20-30 m; 123-125 m; 138 m and 185 m from the recent surface. The hydrological and the hydrogeological relations of the karst water formed are very complicated as a result of the intensive Quaternary tectonic. Within the studied region part of them are drained into the karst source "Tri voditzi" with flow rate of 850 liters per second. One of the biggest clastic karst caves in fluvial fans in Bulgaria is discovered in the region of rail station Ognyanovo, in the northern foot of Besapara heights at: 3.5 m; 6.5 m; 19.5-21.5 m and 24.0-28.8 m above the recent level of Maritza River. The karst relief is disturbed by paleo- and recent earthquakes, as well as by the up to date performed marble quarry mining.

P-14

Speleogenesis and landscape evolution in Tromsdalen karst, Verdal, Norway.

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*¹Department of Earth Science, Bergen University,**Allegaten 41, N-5007 Bergen, Norway***Abstract**

Pronounced fluvial landscape elements of Tromsdal north of Trondheim, Norway allude to that these elements may be preglacial and little altered by Quaternary ice erosion. The occurrence of karst caves with relatively clear morphology that points at adjustment to former base-levels makes it interesting to test of landforms and cave development can be linked. This is done through cave surveying and speleogenetic analysis, formulated as two MSc. Projects.

superb invasion morphology in relation to glacial quarrying and infilling. It is therefore tempting to test if these cave levels may display clustering and/ or correlate with benches and shoulders elsewhere in the valley and surrounding landscape.

Introduction

Verdal municipality is situated north of Trondheim in mid-Norway, Figure 1. Extensive marble outcrops are quarried in Tromsdalen, a tributary to Verdal proper. About 20 separate karst caves are known within the marbles, and the potential of the area is far from exhausted (Rian, 2002, 2003 and references therein). We have done preliminary assessment of the karst (Lauritzen 1999), and found that the topographic situation and cave morphology is sufficiently interesting to deserve a closer speleogenetic and geomorphological study. It was therefore decided to make two MSc projects for a closer study of two significant caves in the valley. These projects have just commenced, and we hope to present more material in the poster.

Problems

As can be seen in Figure 1, the topographic basin containing the marbles and caves display few glacial characteristics. First, as a tributary to the main E-W draining Verdal valley, it drains towards the East, opposite of regional ice streams during the Quaternary. The basin contain several ravine-shaped bedrock valleys that also show little glacial modification. Thick deposits of glacial sediments within the basin also allude to that the landform might have been filled with sediments and stagnant ice during long periods of time. Caves are distributed between 200 and 300 m a.s.l. Several of them display good morphological evidence of vadose/phreatic transitions (e.g. Lauritzen & Lundberg 2000). One cave display

Preliminary results*Benkeberg Cave*

This cave contain a relict, undulating phreatic tube with vadose incision. The diameter of this trunk passage is between 2 and 4 m. Upstream it is choked by glacial boulders and sumps downstream. This tube is invaded by a minor stream from the surface through a superbly meandering vadose canyon, forming a complete invasion system of quite rare morphological completeness. The upstream parts of the canyon cave is unroofed by glacial quarrying. A qualitative tracer test with Photin CU and cotton detectors was performed by T.Rian and S.E. Lauritzen in 2004, demonstrating direct hydrological connections to a major spring at the nearby river. Further work (by A. Øystese) will complete cave mapping, spelethem dating, etc. and we will also search for possible continuation of the phreatic trunk conduit. We believe that the relict phreatic tube is a sub-glacial or perhaps a pre-glacial feature which was much more extensive in the past. There is good chance to find continuation of this system in the form of fragments in the adjacent hillsides.

Ramsåsgrottene

This is a series of several extensive stream caves. They are all well-developed vadose caves with deep canyons, roof level oxbows and at least one distinct transition from vadose to phreatic morphology. Further work by F. Johannesen will hopefully provide a complete survey of the system.

Acknowledgements

We are indebted to Trond Rian and The Forestry Office in Verdal for enthusiastic support and accomodation.

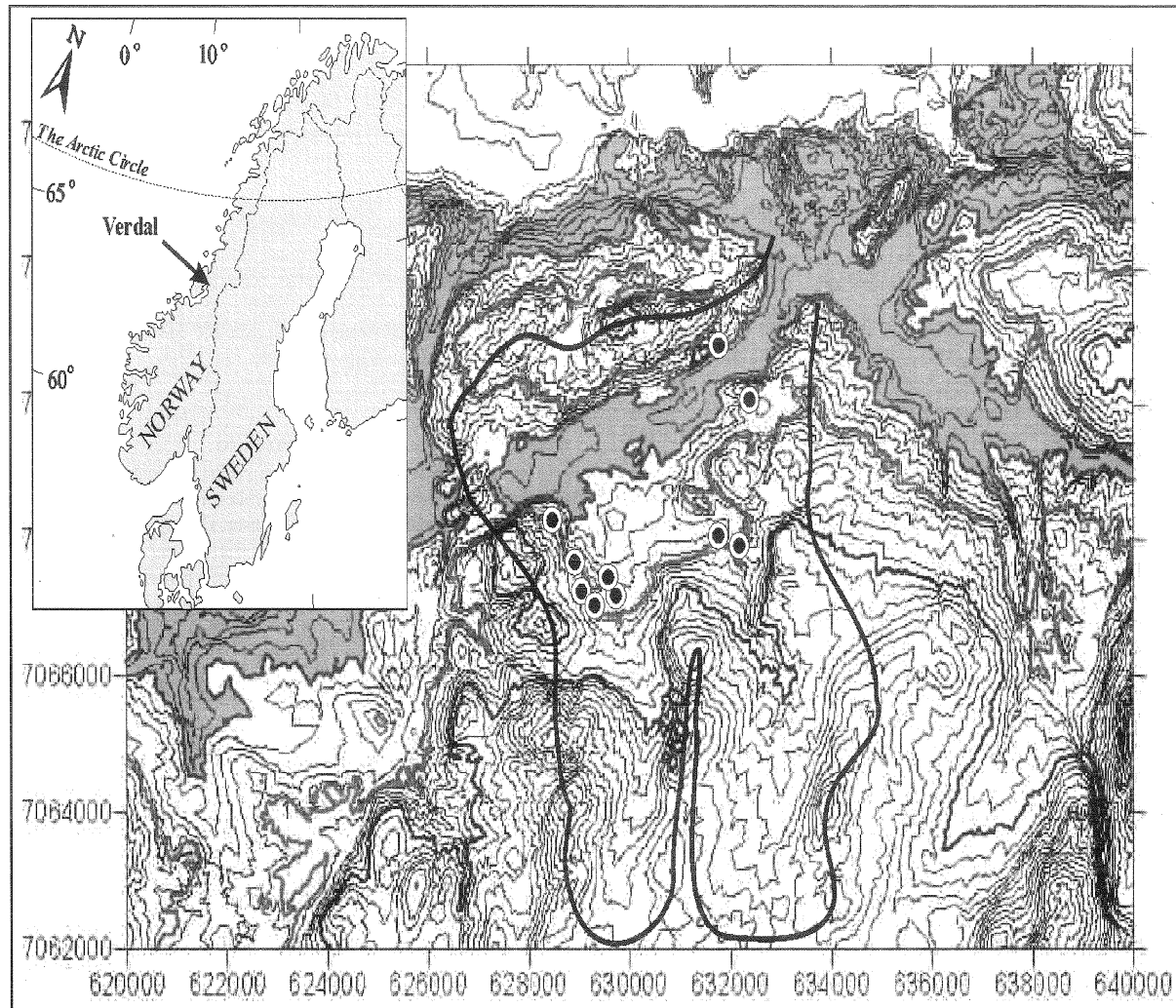


Figure 1. a) Key map to Verdal and Tromsdalen. b) Contour map of Tromsdalen with enhanced contour levels at 200 and 300 m a.s.l. Areas between 100 and 200 m a.s.l. shaded. Black dots: approximate position of known caves. The thick black line depicts approximate drainage area of Tromsdal river. This basin drains eastwards, against the regional ice direction and is a relict, paleic fluvial system with little modification from glacial ice.

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P-15

Groundwater Basin Catchment Delineation and Generalized Flow Routes Through the Karst Aquifer Beneath Bowling Green, Kentucky, USA

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Abstract

The major groundwater basin catchment areas and the generalized groundwater flow routes through the karst aquifer in the vicinity of Bowling Green, Kentucky, USA were determined using the following techniques: 1) dye tracing, 2) water table measurements, 3) cave mapping, and 4) cave location by microgravity and electrical resistivity. The research was directed by Nicholas Crawford and performed by the faculty, professional staff and students of the Center for Cave and Karst Studies (CCKS) from 1976 to the present.

Bowling Green is located entirely upon a low-relief sinkhole plain with large, shallow sinkholes with large catchment areas. Since these large sinkhole basins are almost flat, many homes and buildings have been constructed within these sinkhole basins. Sinkhole flooding is, therefore, a major problem for the city, and it has responded by requiring delineation of sinkhole flood plains and the construction of storm water detention basins. Although storm water sinks directly into the karst aquifer at numerous open-throat sinkholes and cave entrances, the city has drilled or constructed over 1,000 storm water drainage wells. The U.S. Environmental Protection Agency (USEPA) classifies these storm water drainage wells as Class V Storm Water Injection Wells. Until recently, the city has not made any serious attempts to improve the water quality of the storm water runoff sinking into the karst aquifer. USEPA now requires all towns with populations above 10,000 to comply with its Phase II Storm Water Management Plan Requirements. This has resulted in Bowling Green passing a tax increase and hiring five employees to deal with storm water quality. In an attempt to assist the city to meet the new EPA requirements, the CCKS has compiled much of its data collected over the years into a GIS map showing the major springs, caves, karst windows, sinking streams and other karst features. The map shows the numerous dye traces as red lines with arrows and the water table elevation contours as blue lines. They were estimated from measurements taken from open borehole water wells and storm water drainage wells that extend below the water table, cave streams, springs, and perennial surface streams. The approximate groundwater basin catchment boundaries, based upon dye traces and water table elevations, are shown as dashed green lines. The map identifies the approximate groundwater flow routes and groundwater basin catchment areas for the six major springs that drain the karst aquifer beneath Bowling Green.

Dye Tracing

Over 100 dye tracer tests have been performed using as many as 13 different dyes. However, most of the traces were performed using: Sodium Fluorescein (C.I. Acid Yellow 73), Eosin (C.I. Acid Red 87), Sulphorhodamine B (C.I. Acid Red 52), and Tinopal CBS-X: Fluorescent Brightening Agent 351. Most of the dye traces were qualitative, using activated coconut charcoal dye receptors, but other traces were quantitative, using up to five ISCO automatic water samplers. The dye analysis was performed at the CCKS Dye Tracer Laboratory on a Shimadzu spectrofluorophotometer. Dye traces and water table contours northeast of the Barren River performed by the late James Quinlan and Joe Ray (1981, revised 1989) were included in the GIS map.

Water Table Elevation

Water table elevations were measured at springs, cave streams, karst windows, and perennial streams and in over 100 open borehole drainage wells that extended below the water table.

Groundwater Basin Catchment Boundaries

The approximate groundwater basin catchment boundaries were established for the karst watershed for the following major springs: 1) Lost River Rise, 2) Graham Springs, 3) Hobson Grove Springs, 4) Double Springs, 5) Mt. Ayr Blue Hole and Bluff Springs, and 6) Harris Spring. Figure 1 is a black and white representation of a portion of the GIS color map. Topographic contour lines and cultural features have been omitted to reduce confusion of graphics on the black and white copy.

Cave Mapping

Accessible caves were mapped and corrected using magnetic induction transmissions (cave radio) at selected locations. The caves were plotted on the GIS map. Other caves without entrances were located using a combination of microgravity and electrical resistivity traverses perpendicular to cave trends established by dye tracing and water table measurements. Both LaCoste and Romberg Model D and a Scintrex CG-3M microgravity meters were used to locate low-gravity anomalies (Crawford and others, 1999). A Sting/Swift electrical resistivity meter was used to locate high-resistivity anomalies. The low-gravity, high-resistivity anomalies were explored by borings, both into the anomalies and on both sides to confirm the location of caves (Figure 2). Dye traces were then performed to identify the cave stream flowing past the well drilled into the cave. Once a cave stream was confirmed, its route was established by taking additional microgravity and electrical resistivity traverses in a "leap-frog" fashion (Figure 3).

Intended Use of Map

The GIS map identifies the approximate groundwater flow routes within the karst aquifer in the vicinity of Bowling Green. Since almost all surface runoff sinks rapidly through sinkholes, sinking streams, storm water drainage wells or the relatively thin and permeable soils into the karst aquifer, the map should assist the Bowling Green Fire Department, Bowling Green Department of Public Works, Bowling Green Municipal Utilities, Kentucky Environmental Response Team, Kentucky Division of Water, Kentucky Division of Waste Management and other agencies concerned with spills and leaks of hazardous materials. The map is intended to aid the Bowling Green-Warren County Planning and Zoning Commission and the Bowling Green Public Works Department with landuse management decisions and sinkhole flooding problems as well as assisting the Warren County Health Department with decisions concerning on-site waste disposal systems (septic tanks). It provides useful information that will help Bowling Green and Warren County to meet the U.S. Environmental Protection Agency Phase II Storm Water Management Plan Re-

quirements. It should also assist Bowling Green Municipal Utilities in protecting the water quality upstream from its water intake on the Barren River (Figure 1). Although the map may assist commercial and industrial businesses with groundwater flow direction, the map clearly indicates that monitoring wells are not appropriate in most of the Bowling Green area unless they are drilled directly into the karst conduit that drains the facility and then confirmed by a dye trace.

Hopefully, the map will serve to educate the public by illustrating that surface runoff, spills and leaks of hazardous liquids, septic tank effluent,

herbicides, pesticides, fertilizers, soil erosion, animal waste and other potential contaminants sink directly into the ground and then flow rapidly through cave conduits beneath the city to springs and surface streams. In the past, spills and leaks of hazardous chemicals, such as, gasoline, into the karst aquifer have resulted in dangerous vapors rising into homes and buildings (Crawford 1989 and 2001). Bowling Green and other cities built upon karst must, therefore, be extremely careful to protect groundwater and caves from contamination. The map clearly indicates that contaminants that sink into the karst aquifer not only threaten groundwater,

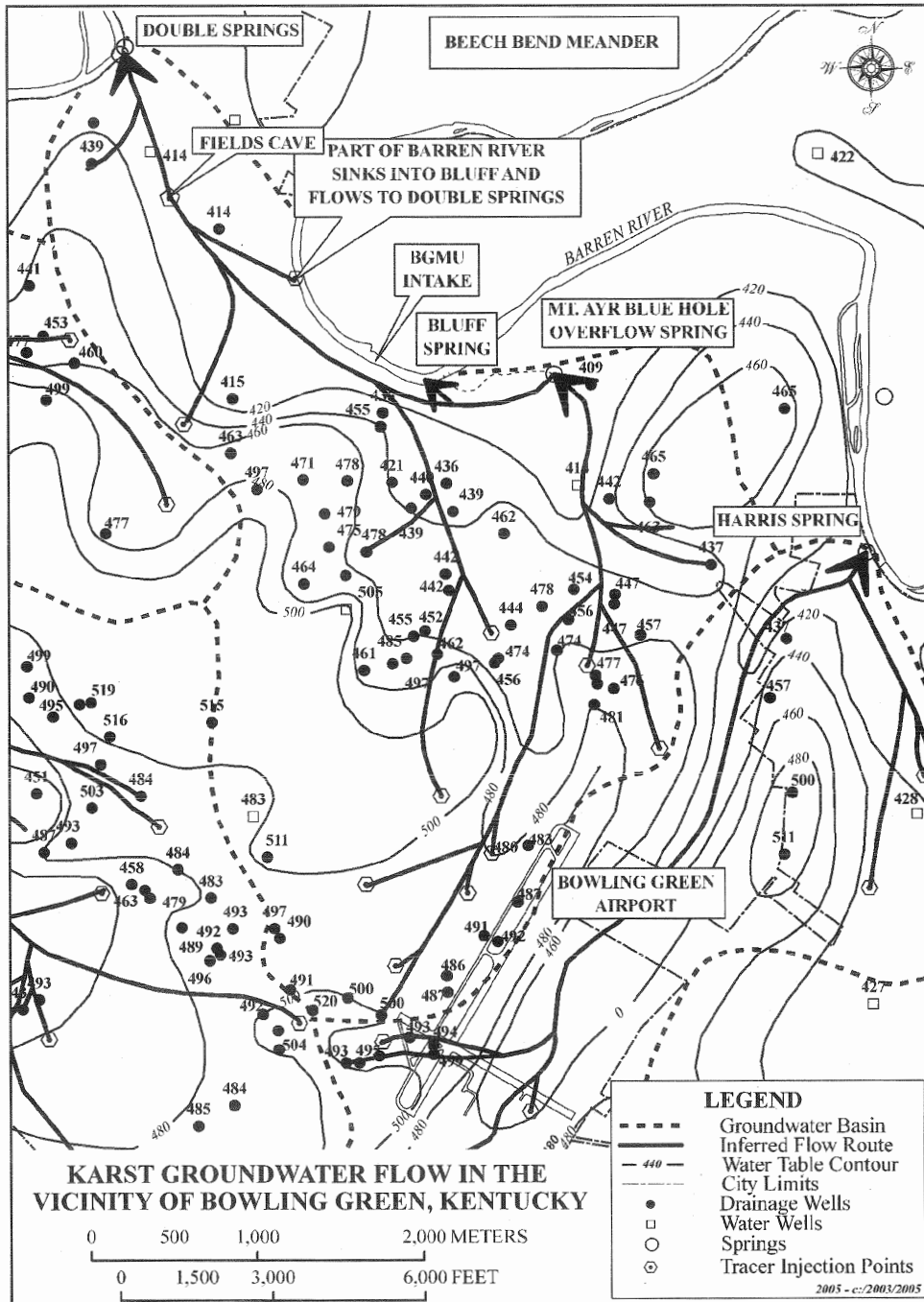


Figure 1. A black and white representation of a portion of the GIS color map.

caves, and rare and exotic cave life, they also endanger the people who live above the karst aquifer. The CCKS intends to periodically update the GIS map. Hopefully, it will assist in the protection of groundwater quality in the karst aquifer beneath Bowling Green and the surrounding area.

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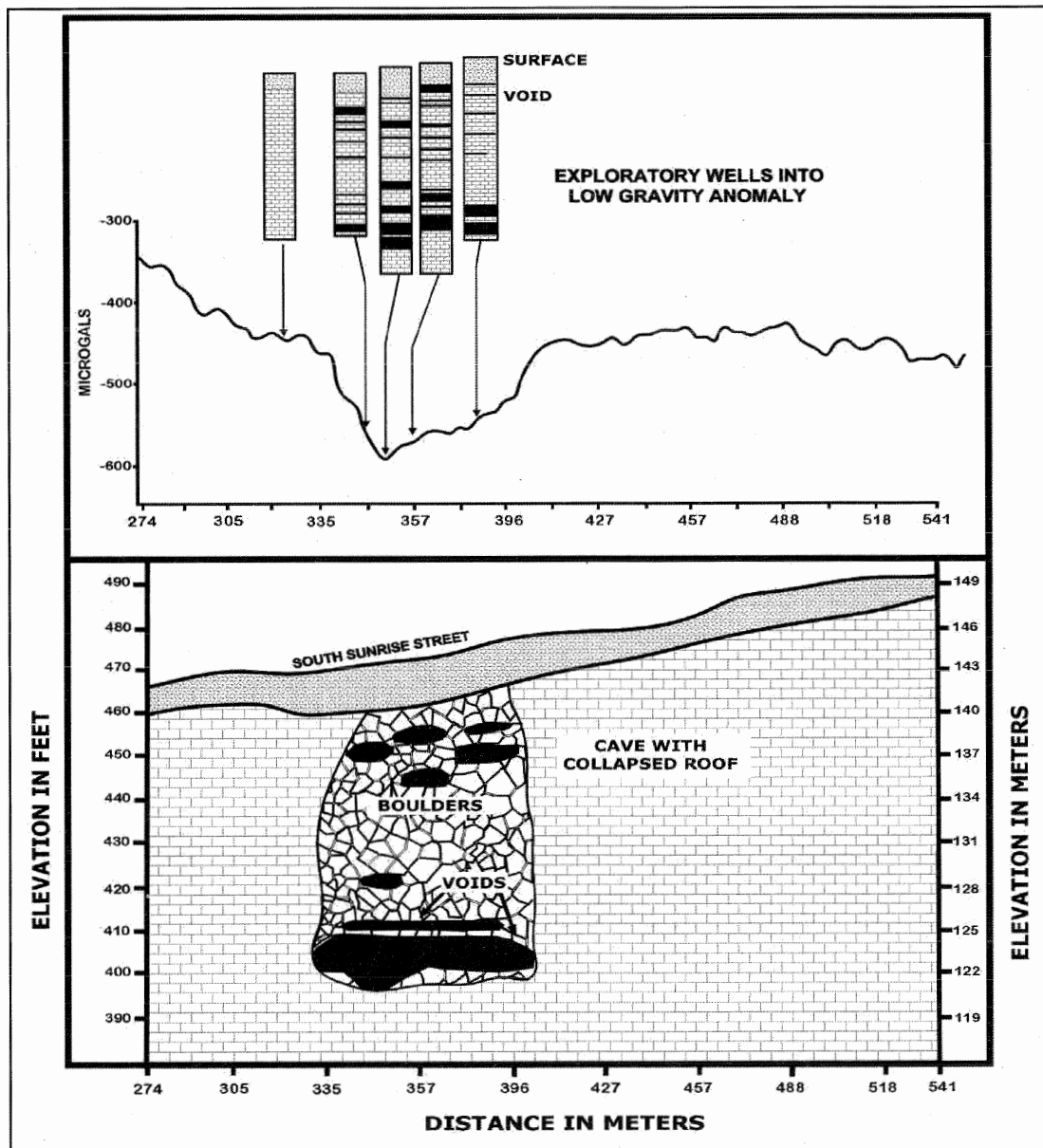


Figure 2. Four borings into this large low-gravity anomaly along South Sunrise Street in Bowling Green intersected numerous voids and boulders indicative of a collapsed bedrock cave. There is no surface expression that might reveal the presence of the collapsed cave. Other borings along the traverse did not intersect voids.

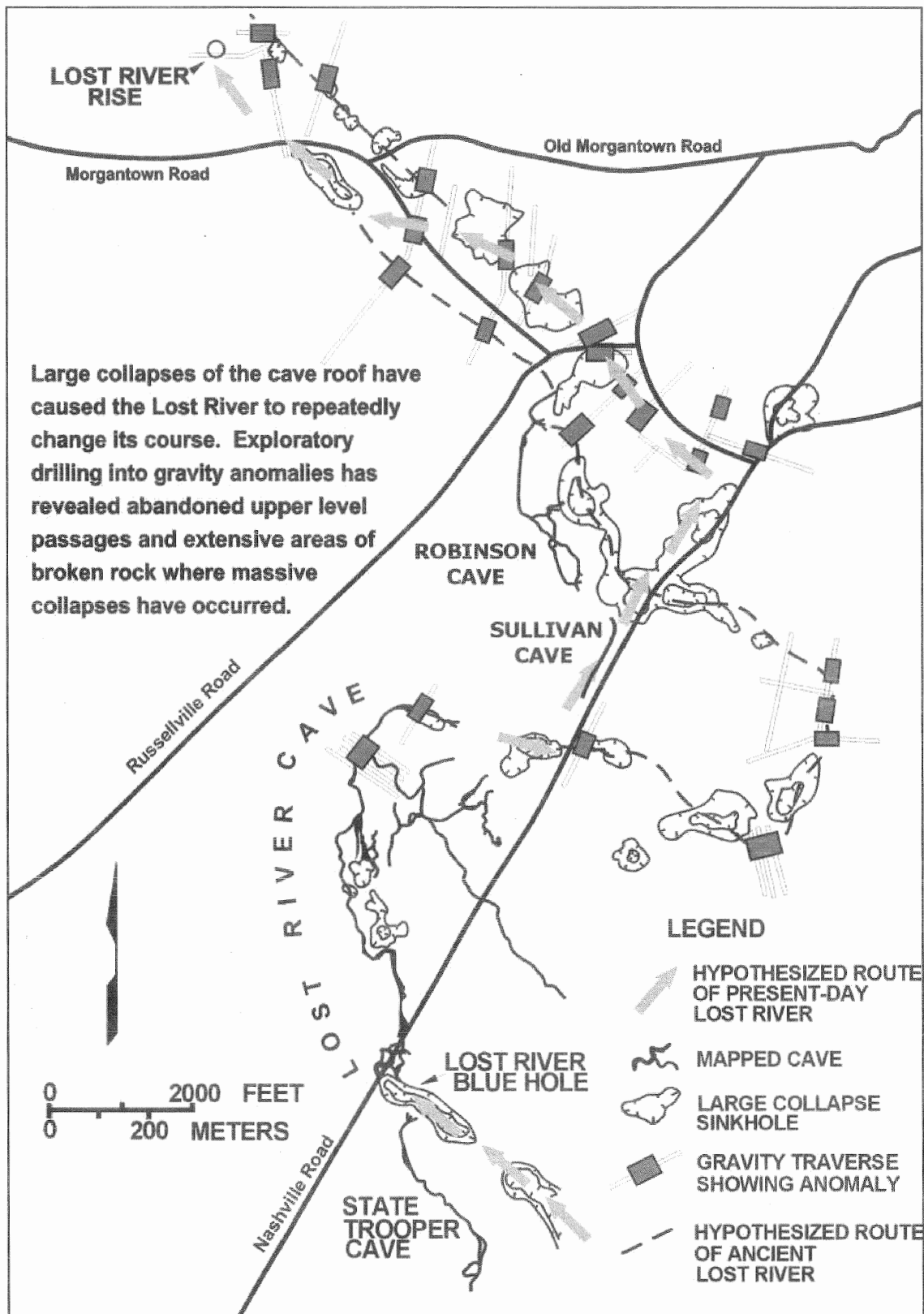


Figure 3. Mapped portions of Lost River Cave and hypothesized present-day and ancient routes as determined by microgravity. Source modified from Crawford and others (1999)

P-16

Sub-daily cycles and hydrological behaviour of Bus de la Spia - Acquasanta karst system (Brenta Dolomites, NE Italy)

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*Museo Tridentino di Scienze Naturali, Trento, Italy***Abstract**

Bus de la Spia cave - Acquasanta spring are an important karst system which developed at the foothill of the Brenta Dolomites (Long. 11°02'00" E; Lat.: 46°13'30") in the Trento Province, NE Italy. Acquasanta spring (elevation 477 m a.s.l., mean discharge 800 L/s) is characterized by cyclical discharge fluctuations with periods which vary between 2.5 to 12 hours depending by the aquifer condition. Bus de la Spia cave (entrance elevation 477 m a.s.l.), located 1.1 km NW from Acquasanta spring, consists in a single downdipping gallery that terminates at a depth of 58 m in a siphon. A two years continuous temperature, electrical conductivity, and

level/discharge monitoring allow to investigate the complex hydrology of the system. The level of Bus de la Spia siphon oscillates with the same periodicity of Acquasanta spring, but it anticipated the spring hydrograph by about 40 minutes. The sub-daily discharge/level cycles are typically asymmetrical, with a rising limb lasting 40 minutes followed by an exponential decrease. The sub-daily cycles characterize most of the hydrological year, and are substituted by near-sinusoidal daily cycles during high-discharge periods, like the snowmelt. The Acquasanta spring sub-daily discharge fluctuations are also coupled with more damped temperature and electrical conductivity fluctuations.

P-17

Characterization of a karstic-pseudokarstic Alpine aquifer by means of field fluorometer tracing tests (Tovel Valley, NE Italy)

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*Museo Tridentino di Scienze Naturali, Via Calepina 14, I-38100 Trento, Italy***Abstract**

Tovel valley, located in the northern part of the Brenta Dolomites (Trento Province, NE Italy) is a 17 km long karstic valley developed in upper Triassic and lower Jurassic dolomites and limestones. The central part of the valley is occupied by complex landslide and glacial deposits, several tens of meters thick, that dammed the valley and create Lake Tovel (surface 0.382 km²). The karstic-pseudokarstic hydrology of Lake Tovel drained basin (around 20 km²) was investigated within the SALTO project by means of discharge monitoring and tracing tests. We utilized several uranine and Tinopal CBS-X injection coupled with field fluorometer monitoring to reconstruct the karstic pathways in the upper part of the basin, as well as the complex hydrology within the pseudokarstic porous aquifer that surround the lake. In fact, the major inflow to lake Tovel occurred via underground pathway and it is fed by the S. Maria Flavona stream which partially drained the upper part of Tovel valley and sinks within the landslide deposits approximately 1 km upstream of the lake.

Tracing tests made under different flow regimes confirmed the hydrological connection between the S. Maria Flavona sinking stream and several perialcual springs and allow to calculate the hydraulic properties of the aquifer. In particular, the maximum velocity of the tracer varied between 0.75 m/h and 5 m/h with breakthrough curves that last between 20 days and two months. Simultaneously, the S. Maria Flavona stream catchment was investigated by tracing different sinkholes and sinking streams in the upper part of the valley that is characterized by typical glaciokarstic morphology and developed between 1500 and 2900 m a.s.l. Only two of these injections were detected at the S. Maria Flavona stream spring, with a calculated maximum velocity of 500 m/h. Other three tracing tests carried out in the upper part of the valley were detected neither along the S. Maria Flavona stream neither at the Tovel perialcual springs suggesting that in this part of the valley the karstic drainage is directed outside the lake Tovel hydrogeological basin.

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P-18

Cave development in se Spain during upper pleistocene under periglacial conditionsGonzález-Ramón⁽¹⁾, A.; Andreo, B⁽²⁾, Ruiz-Bustos, A.⁽³⁾ and Richards, D. A. ⁽⁴⁾*(1) Instituto Geológico y Minero de España. Urb. Alcázar del Genil, 4. Edif. Zulema bajo, Granada, Spain. E-mail: antonio.gonzález@igme.es**(2) Departamento de Geología. Facultad de Ciencias. Universidad de Málaga, Spain. E-mail: andreo@uma.es**(3) Instituto Andaluz de Ciencias de la Tierra (CSIC). Facultad de Ciencias. Universidad de Granada, Spain. E-mail: aruizb@ugr.es**(4) School of Geographical Sciences, University of Bristol, Bristol, BS8 1SS, UK (david.richards@bristol.ac.uk)***Abstract**

Cucú Cave is a small cavity, 30 m long, 1600 m above sea level in the southern slope of Sierra de María (N Almería province, Spain), an area where the present precipitation occurs partially as snow. A sedimentary sequence 9 m thick, including fossils, fills the cave. The sediment characteristics allow us to consider the prevailing climatic conditions, and also the age and evolution of the genesis of the cavity. The lithological sequence is dominated by clast supported detrital sediments without evidence of alluvial transport. These sediments were formed by gelifraction under periglacial conditions. The micromammal fossil species are of Upper Pleistocene age and the mammal bioenogram also indicates that cold conditions prevailed at the time of deposition, between 140 and 70

ka. Sedimentological and biostratigraphical evidence within the cave indicates, during the Upper Pleistocene, increasing dimensions of the karst cavity previously created by solution. The detrital sequence is covered by a flowstone which evolved during a period of warmer, wetter conditions and provides a minimum U-Th isochron age of 40 ± 7 ka for the timing of periglacial action.

Introduction

Climatic change has been much debated in the scientific world in recent decades. Many studies of climatic and hydrological variations have

been made using carbonate deposits, particularly speleothems, because they are less affected by postdepositional processes than are superficial sediments. Speleothems can be dated precisely by means of the U/Th decay series and consequently they can contribute to our knowledge of paleoclimatic and paleohydrologic events in continental areas (Schwarcz, 1986). Geochemical studies can be performed with a very high time resolution from stable isotopes such as $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$, which respectively may reflect paleotemperature and vegetation (Gascoyne, 1992), and trace elements like Mg and Sr, which are indicators of paleohydrology (Fairchild et al., 2001). Nevertheless, the analysis of paleontological remains and the detrital sediments filling the cavities can also be used for paleoclimatic investigations (Ruiz Bustos, 1995, 1996, 1999).

The main aim of this work is to show the interest and the complementarity of geological, paleontological and geochronological methods to find out more about paleoclimatic conditions, taking into account the preliminary results obtained in El Cucú cave. This cave is located in SE Spain, in the northern part of Almería province, in the region of Andalusia. The cave is situated within the Natural Park known as Sierra de María-Los Vélez, in the southern slopes of El Cabezo mountain (which rises to 1948 m a.s.l.), at an altitude of 1600 m a.s.l. (Fig. 1).

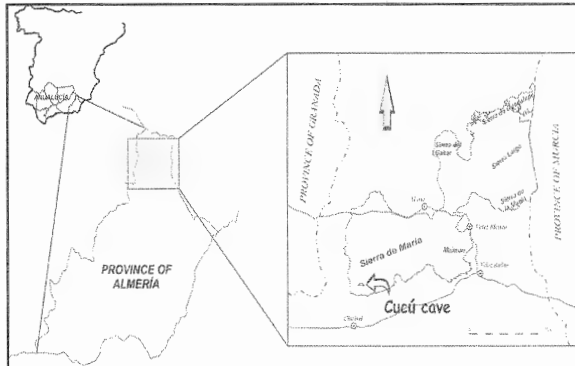


Figure 1. Geographic situation of El Cucú cave. Extension of the Sierra María-Los Vélez Natural Park shown in grey.

From the geological standpoint, the cave evolved in Jurassic limestones in the Inner Subbetic domain of the External Zone of the Betic Cordillera (Andreo, 1990). These limestones are severely deformed by fold structures that were subsequently affected by faulting.

The cavity is some 30 m long, has a very large mouth and a principal chamber that has frequently been used as a shelter for cattle (Fig. 2). At the far end of the cave is a second, smaller chamber, where a group of

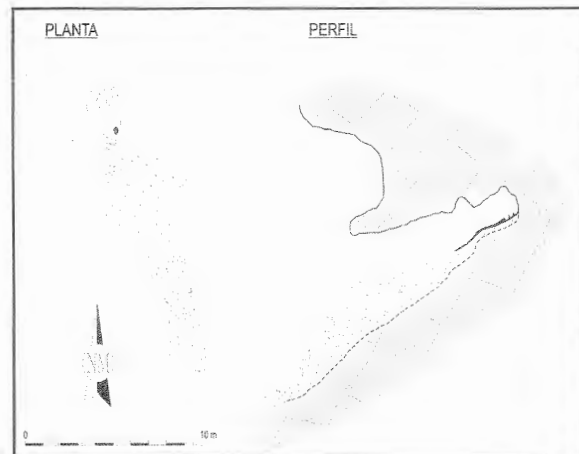


Figure 2. Topographic sketch of El Cucú cave (after Velez Association Speleologists).

gours have evolved, thanks to the existence of a small spring that only drains water during particularly wet winters. The cave was explored and mapped in 2001 by the Velez Association of Speleologists (González-Ramón, 2002; González-Ramón, et al. 2002).

Description of the sedimentary filling

The photograph in Figure 3 illustrates the study area, together with an explicatory sketch showing the points that were sampled for the paleontological study.

At the cave entrance there is a filling some 9 m thick, the stratigraphic column of which is shown in Fig. 4. The filling is basically made up of angular, unrounded clasts, with dimensions ranging from sand-grain size to large blocks several metres across. The sediments are mainly clast supported, because the matrix is scarce and of a silty nature. Although no clear stratification can be observed, it is possible to distinguish levels with coarsely-ordered granulometries, and even coarse upward sequences. There is a calcite flowstone above the latter sediments.

The cave developed following one of the faults created by the escarpments of Sierra del Cabezo. This fracture presents as fault rock the remains of Cretaceous marls, several metres thick, which constitute a discontinuity in the permeability of the Jurassic limestones and favour the presence of the perched drainage at the rear of the cave. The existence of this flow, during periods of cold climate, must have favoured the cryoclastic action which gradually caused the fissure to widen. This widening led to instabilities that provoked rockfalls from the roof and enlarged the cave.

Dating of the cave filling

The remains of micromammal species found in some of these levels must have been seized and carried there by birds of prey nesting within the cave. The following inventory has been made of the fauna contained in samples obtained from the sedimentary infilling: *Apodemus sylvaticus*; *Microtus nivalis*; *Microtus arvalis arvalis*; *Miomys (Villanyia) savini*; *Neomys* sp. *Crocidura* ?; *Oricyolagus* sp.; *Lepus* sp.; *Capra pirenaica*; *Aves*; *Lacerta* sp.; *Bufo* sp.; *Salmo* sp. From the evidence of this fauna content, the filling of El Cucú cave dates from the upper Pleistocene, biozone Mp-20, intrazone SI-20-3 (Ruiz Bustos, 1995, 1996, 1999) with an age of 140-70 ka.

The flowstone covering the detric filling was dated at the Laboratory of Geochronology of the University of Bristol, and a U-Th isochron age of 40 ± 7 ka was estimated.

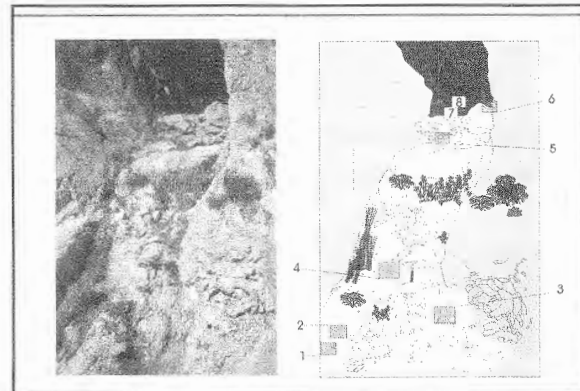


Figure 3. Photograph of the study area and explicatory sketch showing the location of the points sampled.

Paleoclimatic considerations

According to the above-mentioned results, the cave was partially created by the solution or karstification of Jurassic limestone, probably during the middle Pleistocene. The features of the detrital filling (supported clast and angular shapes of the heterometric pebbles) are in agreement with a periglacial origin. Thus the cavity created by solution was subsequently enlarged by gelifraction and by occasional rockfalls from the cave roof.

The fauna encountered in the sequence is also indicative of very cold conditions in southern Spain. The filling of El Cucú cave occurred at a moment of intense cold in the region, as is evidenced in other karstic cavities in Andalusia (Ruiz Bustos, 1995, 1996, 1999). Taking into account that the sedimentation coincided with the moment of lowest temperatures in the region, the most probable age of a large proportion of the sedimentary register is 80 ± 5 ka.

Since about 40 ± 7 ka, periglacial climatic conditions have become less significant, as shown by the fact that it was during this period that the flowstone covering the whole of the detrital filling was deposited, and because since then there has been no deposition of detrital fillings similar to those described above.

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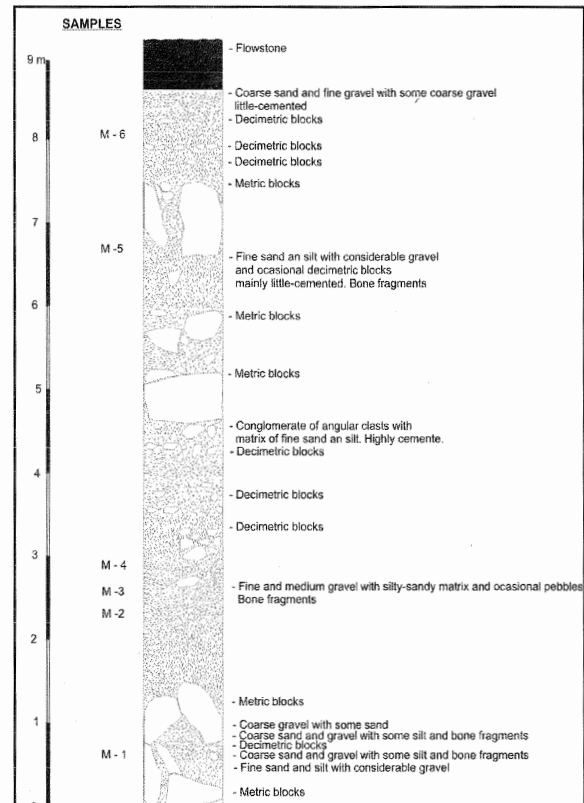


Figure 4. Stratigraphic column of the filling at El Cucú cave.

P-19

Lateral planation and notched forms of cave Georelief: morphology, typology and developmental features

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Abstract

The basic characterization of morphology and typology of lateral planation and notched forms of cave georelief (flat roofs, terraced flat roofs, flat floors, terraced flat floors, horizontal notches deepened into cave rock walls) are presented in this paper. These geomorphic forms originated by lateral corrosion/erosion (denudation flat roof and floors, wall notches) or accumulation of fluvial/lacustrine sediments (erosion-accumulation and accumulation flat floors) are important indicators of the hydrographical and geomorphic development of caves. The formation of these forms corresponds to a certain developmental phase of surface terrain planation (if ones are formed in the framework of the development of cave level) or is conditioned by local hydrogeological barrier with an elevated water table.

Key words: karst geomorphology, cave georelief, planation forms, flat roof, flat floor, cave river terrace, wall notch

Introduction

The character of cave georelief and sedimentary formations reflect former or recent natural conditions and processes of cave genesis. From the point of view of the reconstruction of hydrographical development of caves in solution rocks (limestone, gypsum, salt) flat roofs, flat floors, cave river terraces and various wall notches belong to the most remarkable geomorphic forms of cave georelief. They refer to the phases of underground water lateral corrosion/erosion or planation in consequence of the long-lasting stable erosion base on the terrain surface (outflow levelled cave passage leads to karst spring), long-lasting and repeated floods of cavities (at the foot of karst towers in a plain or alluvial land) or the long-lasting increase of water table caused by hydrogeological (bedrock or sedimentary) barrier. These lateral planation and notched forms are characterized and classified by morphological and genetic features.

Cave flat roofs and floors

From the genetic point of view cave solution flat roofs are observed in several hydrogeological and hydrographical conditions: (1) in the hanging

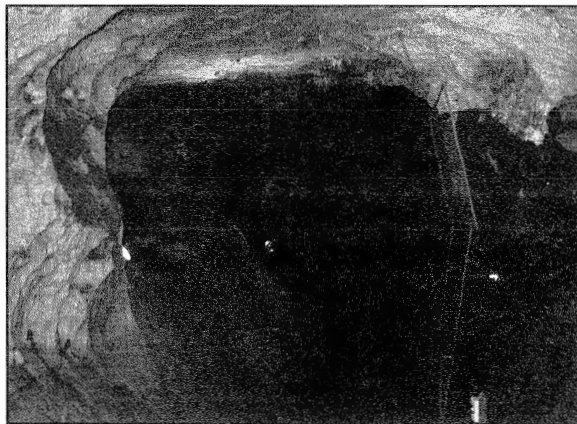


Fig. 1. Solution flat roof and planes of repose. Ochtina Aragonite Cave, Slovakia. Photo: P. Bella

position above the local erosion base on the terrain surface: (a) in the isolated island position of karst hydrogeological structures with cave lakes fed by seeping precipitation waters or episodic runnels flowing from an adjacent non-karstic area, e. g. Ochtina Aragonite Cave (Slovakia) and Na Spicaku Cave (Czech Republic); (b) in connection to the hydrogeological barrier of impermeable rocks determining the level of elevated water table of slowly running or almost stagnant underground water in the partial hydrogeological structure fed mostly by runnels and streams flowing from an adjacent non-karstic area, e. g. Mejiro-do Cave, Hirotani-no-ana Cave and Seiryu-kutsu Cave (Japan); (c) in connection with the locally elevated water table in consequence of the barrier of agglomerate breakdown or fluvial sediments in the fluviokarst cave passage determining the lake-like increase of water table with the marked reduction of water flow (Valea Lesului Cave and Vent Cave, Romania);

(2) in connection with the local erosion base on the surface terrain: (a) in the side valley position or basin position of the lateral ponor branch of surface stream, e. g. Dobsina Ice Cave and Stratena Cave (Slovakia) or in the range of repeated floods permeated from a surface stream, e. g. near-valley gypsum caves in the Pre-Ural Region (Russia); (c) in the non-side valley position of underground stream, in the flow-spring position or only in the spring position of underground stream between water inputs and outputs, e. g. Kagekiyo-do Cave (Japan); Gargas Cave and Betharram Cave (France); several caves in the salt karst of the Zagros Mts. (Iran); (d) at the foot of karst towers originated along a water table during repeated floods of surrounding plain or alluvial land, e. g. Fung Kui Water Cave (China); (e) in the shallow phreatic zone near under a water table that vertically corresponds to the place of water spring on the surface or into the surface river bed (invisible very slow outflow of water to a neighbour karst hydrogeologic recipient, cave lakes have not a direct hydrogeological connection with a hanging surface stream), e. g. the developmental level in the lowest part of the Jasov Cave (Slovakia).

Several morphogenetic types of solution flat roofs are known (Bella 2003):

(1) Flat roofs formed by natural water convection (Laugdecken) in the shallow phreatic zone near under the locally elevated water table (in passages with a typical trigonally cross-section, inclined walls called Facetten or facets) in several gypsum caves in Germany, salt caves in Israel or

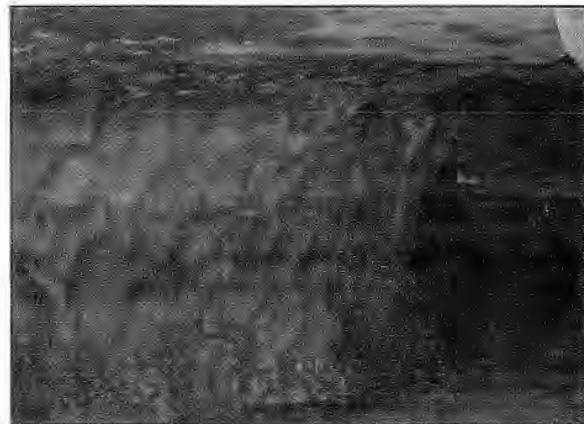


Fig. 2. Solution flat roof, Kagekiyo-do Cave, Japan. Photo: P. Bella

limestone caves, e. g. Ochtina Aragonite Cave (Slovakia) and Na Spicaku Cave (Czech Republic).

(2) Flat roofs formed by epiphreatic remodelling and enlargement of permanently or repeatedly flooded cavities (water-level planes), e. g. Mejiro-do Cave and the Hirotani-no-ana Cave (Japan), Jasov Cave (Slovakia), Gargas Cave (France).

(3) Flat roofs formed by phreatic remodelling of cave roofs after the paragenetic developmental phases of fluviokarstic passages in the conditions of slowly flowing or stagnant water between floor sediments and a rock roof, e. g. Stratena Cave and Dobsina Ice Cave (Slovakia).

(4) Flat roofs formed by epiphreatic lateral corrosion and erosion of meandering underground stream without the relevant morphological features of paragenetic development, e. g. Cave of Tri Nahacu (Iran), Kagekiyo-do Cave, Seiryu-kutsu Cave and Hirotani-no-ana Cave (Japan), Demanova Cave of Peace (Slovakia). Undercut meander is enlarged in the rock wall on the cut-bank of cave river bed, fluvial sediments are accumulated on the opposite side of river bed. The lateral morphogenetic effect of meandering underground stream is given by enlargement of meanders oscillating along the main axis of underground stream and their migration in the direction of stream flow or by lateral displacement of river bed.

In many caves with solution flat roofs, the active phreatic or epiphreatic phase of cave rock georelief development finish up by roof planation. Flat roofs in several fluviokarst caves were remodelled and dissected during the younger paragenetic phase of their development, e. g. Stratena Cave and Dobsina Ice Cave (Slovakia), Betharram Cave (France). Terraced flat roofs present lateral flat roofs under the step of inverse terraces or last non-paragenetic passages.

Larger floor planation forms are originated in the connection with the development of cave levels of river bed type. Their origin is connected with the development of cave river terraces (Huang 1993). From the genetic point of view erosion-denudation, erosion-accumulation and accumulation flat floors are known in caves. From the morphological point of view flat floors and terraced flat floors (cave river terraces) are distinguished.

The origin of cave solution flat roofs and floors in connection with the surface long-lasting stable erosion base can be correlated with the development phases of terrain surface in the surrounding area during the phases of tectonic stability and lateral planation of georelief. Fluviokarst cave passages with solution flat roofs or floors in the side valley position and in the spring position of underground stream present cave levels of river



Fig. 3. Solution flat roof and meandering channel, Seiryu-kutsu Cave, Japan. Photo: P. Bella

bed type. In many cases, if solution flat roofs or floors occur in the spring part also in the ponor part of caves, there is the border karst of horizontal contact with the influx of allogenic water and shallow piezometric level. Another cave solution flat roofs or floors correspond to cave levels of water table type, ones are formed along a water table, in many cases in the hydrographical position below surface sinking streams in the catchment area. Their roofs or floors are remodelled and enlarged by planation of slowly running or stagnant water in relation to the stable erosion base. Horizontal flat roofs and floors are formed in ideal water table caves or caves with mixture of phreatic and water table levelled components (after Ford 1988, Ford & Ewers 1978).

Cave horizontal wall notches

Various morphological and genetic types of wall notches are described by Bretz (1942), Lange (1962, 1963), Serban & Domsa (1985), Ford (1988), Slabe (1995) and others. The complex characterization of notches is given by Lauritzen and Lundberg (2000). They distinguish these various genetic types of notches: corrosion horizontal waterline notches in vadose standing water with an open air surface, inclined vadose and paragenetic wall notches formed by alluviated streams cutting laterally into passage walls, corrosion notches related to the Laugdecke and Laughöhle profiles as standing phreatic water features formed by slowly moving cells of density-driven currents.

Main emphasis is focused to the differentiation of various morphological or morphogenetic types of lateral notches and their significance from the point of view of the hydrographical reconstruction of cave genesis. According to the morphology, spatial configuration and variations of notches Bella (2004) distinguishes simple (one-phased) notches formed during one developmental phase, composite (more-phased) notches formed during several developmental phases, series of simple uniform or different notches, series of composite uniform or different notches, also combined series of simple and composite notches.

According to the morphology of cross-section and ground plan, several types of simple and composite notches are distinguished. There are various types of simple notches with a mainly horizontal developmental dimension deepened into cave rock walls: lateral meandering channels (frequently scalloped or fluted), lateral one-sided or double-sided longitudinal oval channels (frequently scalloped or fluted), lateral upward enlarged paragenetic channels, lateral downward enlarged channels, lateral

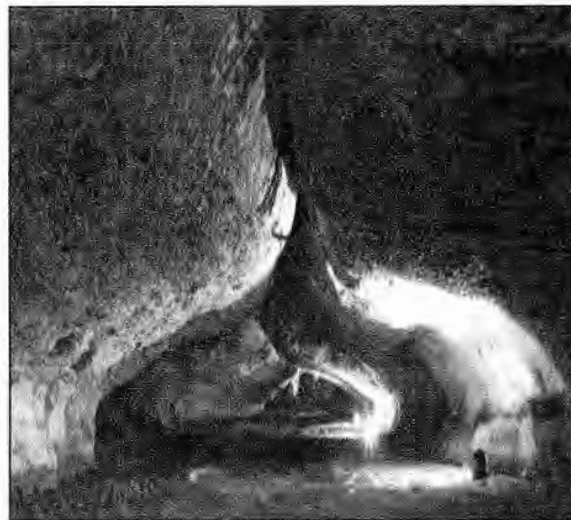


Fig. 4. Accumulation flat floor, Grotte de Lombrives Cave, France. Reproduction

one-sided oval runnels (frequently scalloped), small or larger half-cylindrical notches without or with small between-ribbed or irregular hollows (trough-shaped notches modelled by waves of water), nick water-level notches (water-level lines formed by more intense dissolution caused by absorption of CO_2 from cave air), slotted water-level notches, symmetrical wedge-shaped notches, strictly one-sided downward asymmetrical wedge-shaped notches or half-heart-shaped notches (Laugdecken type), strictly one-sided upward asymmetrical wedge-shaped notches, partially downward or upward asymmetrical wedge-shaped notches, symmetrical or asymmetrical wedge-shaped notches with a rounded vertex (frequently with small between-ribbed or irregular hollows), one-stepped notches (type of above-sediment corner), overhanging one-stepped notches (type of water-level corner), quasi-prismatic notches (rectangular higher and less or more deep slotted notches between lower and overhanging upper corrosion corner), deeper quasi-prismatic notches ended by lateral channel or wedge-shaped notch, and other similar types. Composite notches present

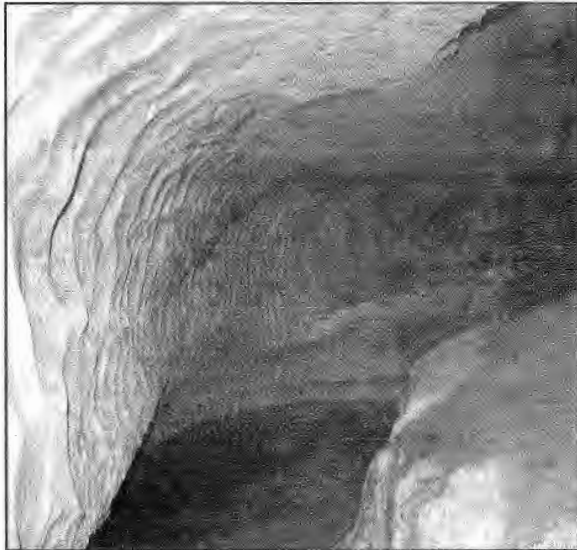


Fig. 5. Lateral meandering channel, Seiryu-kutsu Cave, Japan. Photo: P. Bella

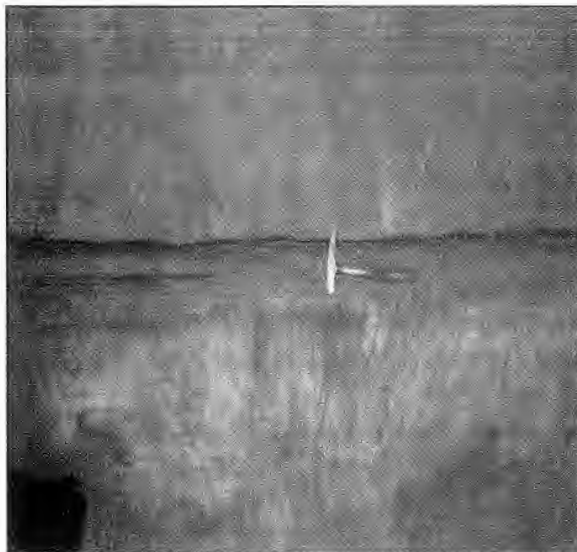


Fig. 7. Lateral rounded runnel in a hanging position, Stratena Cave, Slovakia. Photo: P. Bella

more-phased equivalent united notches, more-phased floor stepped notches, more-phased overhanging stepped notches, combined more-phased floor and overhanging stepped notches, also other combined types.

Neighbouring lateral notches are united into monoform series (with morphogenetically homogenous and dimensionally quasi-equal notches), dimensionally polyform series (with morphogenetically homogenous and dimensionally different notches), morphogenetically polyform series (with morphogenetically different and dimensionally quasi-equal notches) or morphogenetically and dimensionally polyform series (with morphogenetically and dimensionally different notches). From the morphological point of view, polyform series of notches are differentiated into gradational and irregular series. Lateral notches occurred on adjacent or opposite sides of cave passages or halls are symmetrical or asymmetrical (Bella 2004).

If lateral water table or meandering notches deepened into cave rock



Fig. 6. Small overhanging stepped water-line notches, Mejiro-do Cave, Japan. Photo: P. Bella

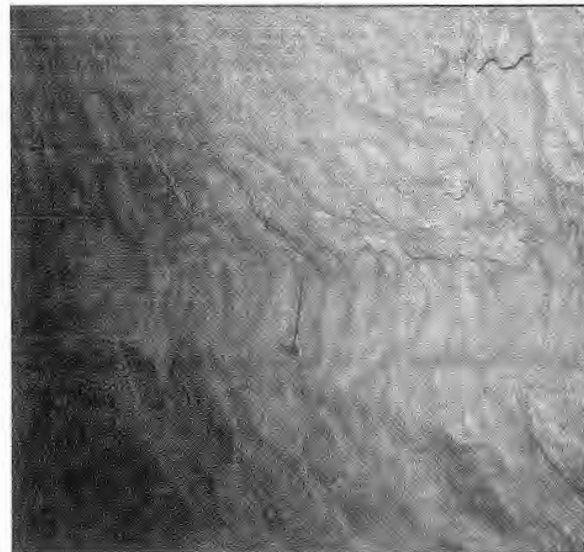


Fig. 8. Small trough-shaped notch with transversal between-ribbed hollows, Dead Bats Cave, Slovakia. Photo: P. Bella

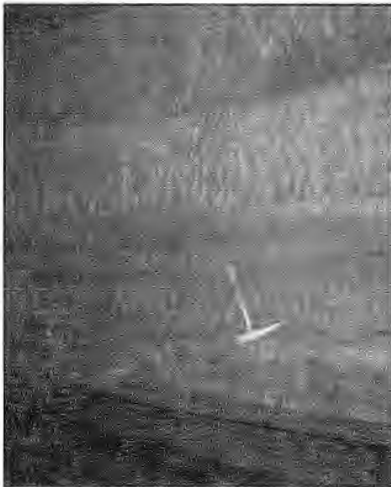


Fig. 9. Shallow channels with scallops, Domica Cave, Slovakia. Photo: P. Bella



Fig. 10. Lateral notches and flat ceiling channel, Domica Cave, Slovakia. Photo: P. Bella

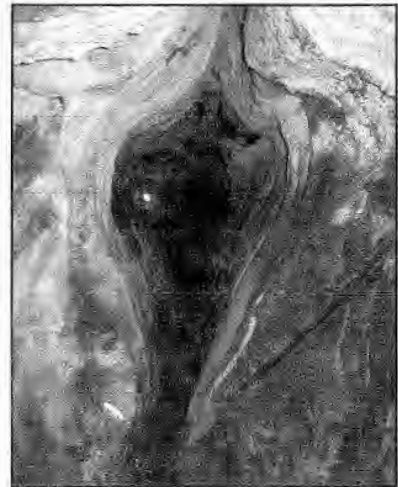


Fig. 11. Half-heart-shaped notches (Laugdecken type), Na Spicaku Cave, Czech Republic. Photo: P. Bella

walls belong to geomorphic forms of cave levels, their development is correlated in connection with the stable erosion base. In other cases, these lateral notches are originated by local lateral corrosion/erosion in individual cave parts.

Acknowledgement: I am very grateful to Dr. Kensaku Urata for the assistance of my cave field observations in Japan throughout two study trips of Slovak speleologists in 2002 and 2003 supported by the Japan International Cooperation Agency (JICA).

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P-20

Caracterización geomorfológica e hidrogeológica preliminar de la zona cársica del tercio inferior de la cuenca del río guanabo, en el occidente de Cuba

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Entre las funciones y servicios ambientales del curso se distinguen la formación de acuíferos, la recarga del manto freático y la construcción de formaciones espeleológicas (cuevas, nichos, casimbas, etc.) que le imprimen un valor ambiental y económico a éste tipo de litología, por la explotación turística y de sus recursos hídricos entre otros. La cuenca del

río Guanabo esta ubicada en la región geomorfológica de las Alturas del Norte de La Habana - Matanzas, el curso de esta región se desarrolla en un relieve de llanura costera por lo que los problemas ambientales están relacionados con la influencia del mar. El presente trabajo, ofrece una breve caracterización geomorfológica e hidrogeológica de la zona cársica del tercio inferior de la cuenca del río Guanabo y algunos de los principales problemas ambientales detectados.

P-21

A simple growth model for allogenic pedestals in glaciated karst.

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*Department of Earth Science, University of Bergen, Allegaten 41, N-5007 bergen Norway, Stein.lauritzen@geo.uib.no***Abstract**

Limestone pedestals (Karrentische) are believed to develop by differential corrosion beneath and around a protecting boulder. Here, we develop mathematical models for the size of limestone pedestals as a function of time and the properties of the perched boulder. These properties are the shortest horizontal axis of the boulder, its shape factor and the rate of condensation corrosion beneath it. Because the shielding effect will decrease with increasing pedestal height, pedestals will, over time, attain a finite, steady-state height. The time needed to acquire the steady-state height is considerable, and probably longer than the Holocene (10,000 years) for most sites. The present-day height of pedestals in a given site is dependent on up to 3 different parameters that are likely to vary within a pedestal population. Hence, the model also explains the variability observed in pedestal heights within a site. A method for estimating the total denudation by means of measurable pedestal properties was developed and tested with favorable outcome on pedestal populations at the Svartisen karst, north Norway and in north-west Spitzbergen.

piece of the local limestone (autogenic). The formation of a pedestal is due to differential corrosion between the area beneath the boulder and the surrounding area, Figure 1a. The corrosion rate beneath the boulder is lower than elsewhere because the boulder acts like an umbrella and protects the limestone surface below from the action of corrosive precipitation. Pedestals are mostly found in glaciokarst settings, where the growth process was zeroed by glacial erosion when the erratics were laid down.

In the karst geomorphological literature, much attention has been given to the height of pedestals, and to their significance as measures of total denudation in bare and alpine karst settings (Ford & Williams 1989, Bögli 1961, Peterson 1982, White 1988). The average or maximum height of pedestals have been taken as equivalent to the total denudation; this is rarely the case. Here, we develop a simple mathematical model for pedestal growth, which aims at determining the total denudation of the area outside the pedestal (Lauritzen 1997). This growth model also explains the variability observed in pedestal heights.

Limestone Pedestals.

Limestone pedestals (Karrentische, Bögli 1960) develop underneath boulders. The perched block can either be an allogenic, non-karstic rock type (for instance, a glacial erratic in alpine karst) or it can be an in situ

Qualitative properties of pedestals

The following observations are based on alpine sites in Norway and Spitsbergen. Within the same area, pedestal heights reveal a rough positive correlation with the size of the perched boulder, although there is a considerable spread and linear models do not work (e.g. Finnesand 2002,

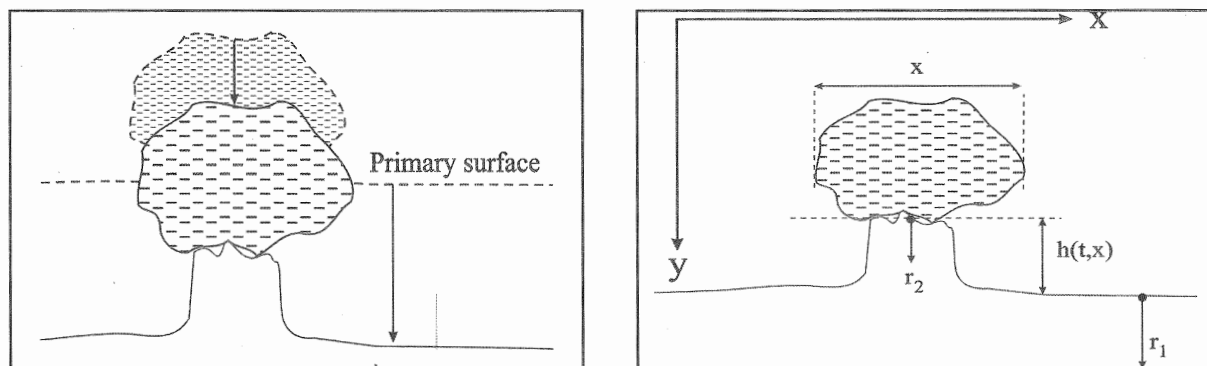


Figure 1. Left: The height of an allogenic pedestal is a function of differential corrosion beneath and around the perched block. The height of any such pedestal is only a minimum measure of the total denudation at the site. Right: Coordinate system and variables used in the growth model.

2003). There appears to be a lower threshold for pedestal growth, because pedestals are absent beneath small boulders.

The top surface of the pedestal, beneath the boulder, is always rugged and pitted, indicating that corrosion is going on even under the largest boulders. (The largest boulder observed by the author was more than 4 m across). This corrosion mechanism may be ascribed to condensation (ϵ , see below). A block resting on the ground will not only shelter against direct rainfall, but is also a locus of long-lasting, low levels of moisture. Therefore, even the highest pedestals are only a minimum measure of the total denudation around them.

Supporting evidence for various condensation and evaporation-related processes beneath the boulders is the existence of botryoidal precipitates on minor protrusions and edges, due to seasonal evaporation. This is also a common phenomenon on many other karst surfaces, like the sharp edges of rillenkarren.

It must also be kept in mind that there is some difference between the authogenic karrentische (described by Bögli 1961) and allogenic pedestals carrying a non-carbonate, glacial erratic. Only allogenic pedestals have uniquely defined initial conditions, i.e. resetting of the process at $t=0$. The commencement of growth is not well defined for authogenic blocks resting on its actual bedding plane parting, thus the height of the pedestal is not necessarily a precise measure of the post-glacial denudation of the site. In this case, the pedestal is the exhumed, or 'Hoodoo type' (Lauritzen 2005).

The observed evaporational precipitates and the attenuated corrosion deduced for authogenic blocks add complexity to the problem. A growth model which include all these effects will inevitably become extremely complicated and have little but theoretical interest. A simplistic, approximate model which in some way summarize these effects is preferable. A growth model should, as a minimum, accommodate the following criteria:

1. There is a minimum, or threshold size, x_{min} , for a boulder to produce a pedestal. The function describing pedestal height with respect to boulder size must not pass through the origin.
2. The function must include the condensation corrosion that occurs beneath all boulders, regardless of their size.
3. In order to be practically applicable, the model should be as simple as possible.

The model

The observed pedestal height is a result of two independent corrosion rates acting on the karst surface, the rate outside the boulder (r_1), and the rate underneath the boulder (r_2). r_1 , is acting everywhere on the surrounding rock surface, and is identical to the surface denudation rate of the loca-

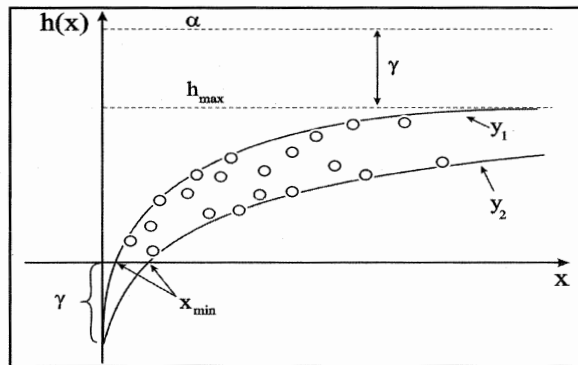


Figure 2. Pedestal growth model, eqn(3). Pedestal height as a function of boulder 'size' is represented by a family of functions, sharing the same α and γ , but with different β . (y_1) and lower (y_2) boundary is shown.

tion, Figure 1. It is independent of the properties of the boulder, or even the existence of it. Beneath the erratic boulder, the surface is shielded, depending on various properties of both the boulder itself and of its surroundings.

As a first approximation we assume shielding is caused entirely by a shape effect (β), i.e. shielding increases with the 'size' of the block. This effect is controlled by the boulder's ability to keep the underlying rock surface dry from snow and rain. Hence, the shortest horizontal axis of the boulder should be a better measure of shielding than for instance, the shadow-equivalent area. We have :

$$\frac{dr_2}{dx} = -\beta r_1 \quad \text{with} \quad \begin{cases} r_2 = r_1 + \epsilon & x = 0 \\ r_2 = \epsilon & x \rightarrow \infty \end{cases} \quad (1)$$

with solution: $r_2 = r_1 e^{-\beta x} + \epsilon$ (2). The differential rate, $r_1 - r_2$ is integrated with respect to time, and simplified to:

$$h(x) = \begin{cases} 0 & ; x \leq x_{min} \\ \alpha(1 - e^{-\beta x}) & ; x > x_{min} \end{cases} \quad (3)$$

where $h(x)$ is the height of a given pedestal beneath a boulder with size x , α is the total denudation far away from the pedestal, β the shielding efficiency, or 'umbrella factor', and finally, γ the amount of condensation corrosion acting on all surfaces, also beneath the boulder. The smallest boulder that can support a pedestal then becomes:

$$x_{min} = -\frac{1}{\beta} \ln \left[\frac{\alpha - \gamma}{\alpha} \right] \quad (4)$$

The scatter of pedestal heights as a function of boulder size (e.g. shortest horizontal axis) can then be explained with a family of functions (eqn 3), all sharing the same α (i.e. total denudation), but having different β and γ , Figure 2.

Estimating the total denudation (α).

Given a large number of pedestals one may fit curved functions to the data set to accommodate a common α , but with various β and γ values. This may be done by trial and error on a spreadsheet or by designing proper computer algorithms. The model (eqn. 3) may be linearized to:

$$\ln[(\alpha - \gamma) - h(x)] = -\beta x + \ln \alpha \quad (5)$$

Realizing that $(\alpha - \gamma) = h_{max}$, i.e. the maximum, asymptotic pedestal height, $\ln(\alpha)$ may be determined by the y-intercept of straight lines (for various β) fitted to a plot of $\ln[h_{max} - h(x)]$ versus $\ln(x)$, Figure 3. h_{max} , and

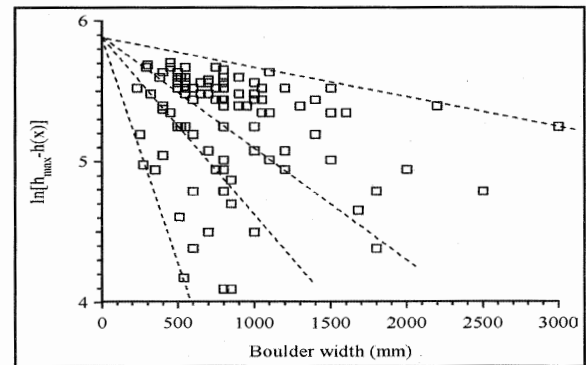


Figure 3. Pedestal data linearized according to eqn (5). The slope of each line is equal to the umbrella factor (β), so that this can be determined for each individual.

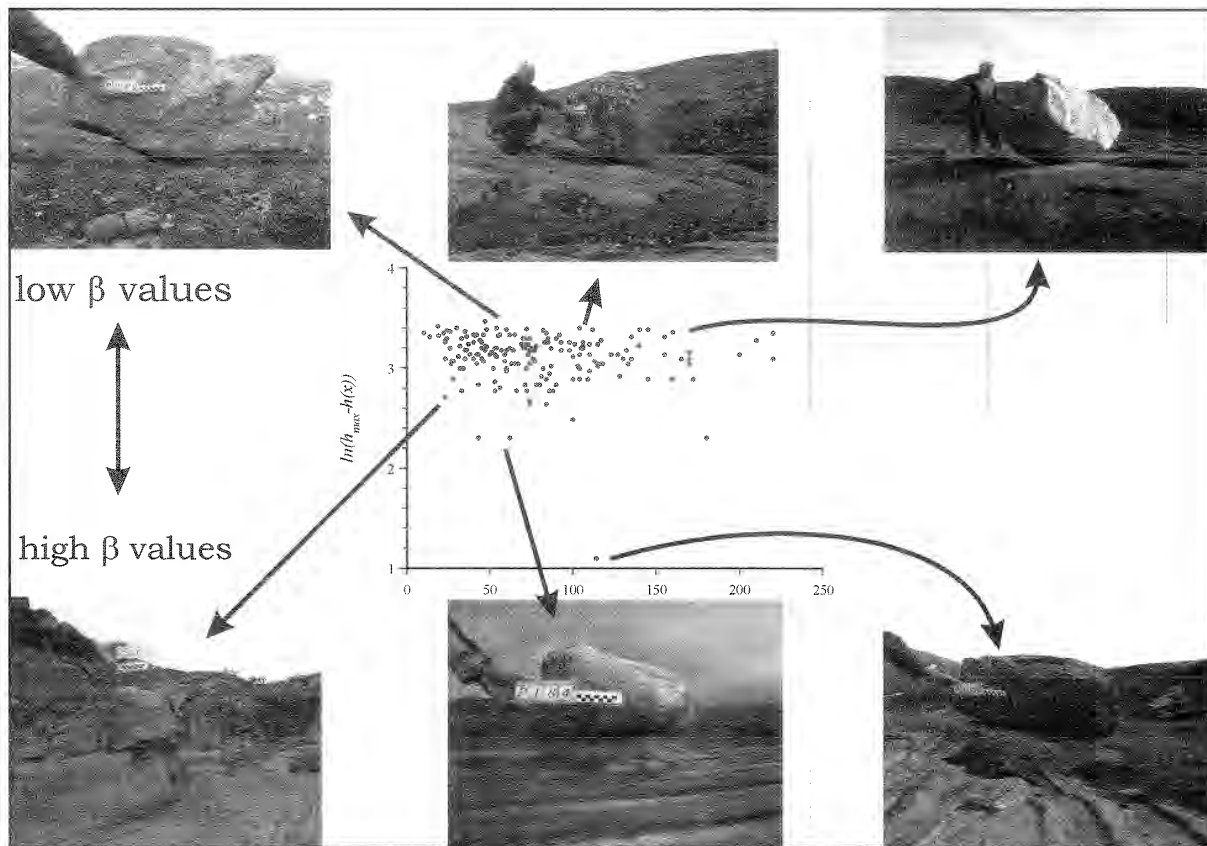


Figure 4. Identifying boulders with various β value in a linearized plot. High β blocks display pronounced drip edges or flat undersides, low β blocks have generally sloping or convex undersides, according to the concept of an 'umbrella effect'. Data set of 185 pedestals at Glomfjell, Svartisen, north Norway

thereby the common y-intercept ($\ln(\alpha)$) for upper and lower boundary functions (Figure 2) may be determined by iteration. This was done for 4 different pedestal populations, 3 at Svartisen (at The Arctic Circle in North Norway, 67°N) and one at Blomstrand, Svalbard (78°N).

The results are shown in Table 1. Total denudation (α) is 25 - 80 % higher than the highest observed pedestal, but still in accord with independent assessment of the total post-glacial denudation for the sites. Such assessments are the maximum extent of protruding quartz veins, (extrapolated) micro-erosion meter readings, and hydrochemical denudation estimates, e.g. Lauritzen (1983, 1991). For example, for the Pikhaugene karst at Svartisen, we find that $\alpha = 200$ mm, 1.7 times the highest observed pedestal $h(x) = 120$ mm. However, the highest observed protruding quartz vein at 220 mm in the area is in good accordance with this higher value. We may assume solutional denudation of a quartz vein as negligible in this environment and timeframe. Assuming that post-glacial denudation time is some 10 ka, this corresponds to 0.020 mm/year, in good accordance with the micro-erosion meter rate (during 14 years) of 0.018 mm/year. Hydrochemical denudation (the autogenic component) is 0.033 mm/year (Lauritzen 1991) which incorporate both exo- and endokarst solution.

What controls the umbrella effect?

In a linearized scatterplot, we may identify families of pedestals sharing the same value of β . So far (august 2004), more than 200 pedestals have not only been measured, but also subjected to accurate photogrammetric shape analysis, GPS positioning, and evaluated in micro- and macroscale landscape context. Multivariate analysis of these data is in

progress and will hopefully reveal the factors that most effectively determine the 'umbrella effect'. This work will be presented later. However, just by evaluating photographs of pedestals that display extreme β values, it is very suggestible (or obvious) that boulders with flat or concave underside and distinct drip-edges tend to have high β values, whilst boulders with convex undersides and no drip-edges have the lowest β values of them all, Figure 4.

Large pedestals.

As the pedestal grows taller, the sides of the pedestal and the underside of the boulder becomes more exposed, and we should expect the shielding effect to decrease with the acquired height of the pedestal. Given sufficient time, the ultimate fate of a pedestal is extinction, as the top surface of the pedestal may get sufficiently rounded to let the block fall off, and even a new cycle may commence. We may also conceive a steady-state condition, where $r_1 = r_2$. A time-dependent model for pedestal growth is:

$$h(t, x) = \frac{r_1(1 - e^{-\beta x}) - \varepsilon}{\delta} (1 - e^{-\delta t}) \quad (6)$$

where x , β and ε are as before, and the additional parameter δ describes the inhibition of growth rate as a function of acquired height. A cartoon of a pedestal's life cycle is depicted in Figure.5. Except for very small boulders, it is unlikely that any of the pedestals in the four study areas have attained their maximum height, suggesting that a timespan much longer than the postglacial (> 10 kyr) is needed to see this effect.

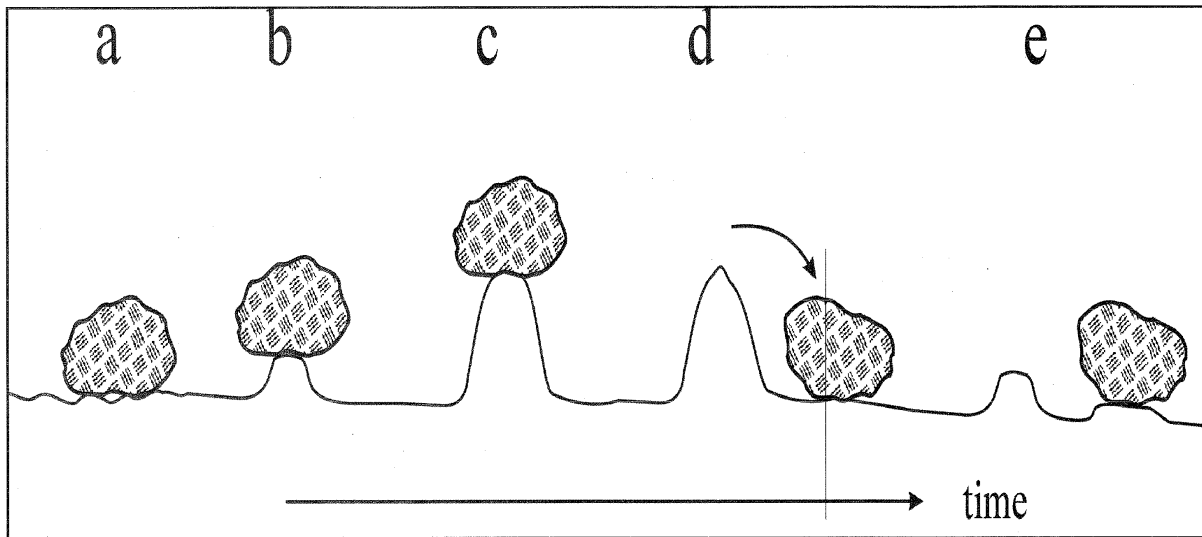


Figure 5. The life cycle of a pedestal. a) commencement of growth, the block is left on a glacially smoothed surface ($t=0$). b) Shielding (β) is optimal and the pedestal grows fast. c) The pedestal becomes so high that the sides are attacked, and it may reach a steady-state constant height. d) most likely, the pedestal will become rounded and the block will fall off before stage c) is reached. e) a new cycle begins while the old pedestal becomes degraded.

Table 1
Pedestal parameters for various sites (All lengths in mm.)

Location	α	Hmax	Factor ¹	γ_1	γ_2	β_1	β_2
Central Glomfjell	330	260	1.26	70	160	0.0033	0.0009
Fiskvatn	260	160	1.62	90	140	0.0035	0.002
Pikhaug	200	120	1.66	60	60	0.003	0.00075
Blomstrand	65	36	1.80	25	45	0.07	0.05

¹ "Factor" is α/h_{\max} .

Conclusions.

A mathematically simple growth model for allogenic pedestals has been developed. The model has three adjustable parameters, the total denudation of the site, outside the pedestal (α), its umbrella factor (β), and the condensation corrosion acting on all surfaces (γ). This allows us to determine the total, post-glacial denudation of the site from measurable properties of a pedestal population. Estimated total denudation is then some 25- 80% higher than the maximum observed pedestal height.

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P-22

The Grønli-Seter cave research project, Rana, North Norway

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Abstract

The Grønli-Seter Cave Research Project (2001- 2005) is a multidisciplinary study of one of the longest caves in the country and also the most used tourist caves. The project was launched to accommodate the need for a proper survey and thorough knowledge of the system. The work was divided into three MSc. Theses, covering structural speleology, cave sedimentology and karst hydrology. The Grønli- Seter system, consisting of several separate caves now have an aggregate surveyed length of 8.2 km. This has led to detailed knowledge on cave morphology, structural and stratigraphic control, paleohydrology, stratigraphy and sedimentological facies as well as details on aquifer behaviour, volume and present-day dissolution rate in the system. This makes the caves to the best surveyed and most thoroughly investigated caves in the country.

Introduction: the project

Grønligrotta at Mo i Rana, North Norway is one of the oldest known caves in the country. The first professional account of the cave was in 1875, and the first survey published in 1914 (StPierre, 2003). This cave is also the oldest tourist cave in the country and also the only existing commercial cave with electric light and footpaths, attracting about 8,000 visitors per year. Later, the nearby cave Setergrotta was surveyed by Horn (1947) and later Langgrotta-Isgrotta was added to the company (Grønlie 1980). Cave sediments of Grønligrotta were investigated by StPierre (1988) and Løvlie et al. (1988). On this background, the project was launched as a 'total survey enterprise', shared between the authors, the maps served as an accurate basis for detailed studies of structural speleology (Skutlaberg 2003), hydrology (Øvrevik 2002) and cave sedimentology (Hestangen 2005).

Location and setting

The caves are all located in the wall and shoulder of Rødvassdalen at

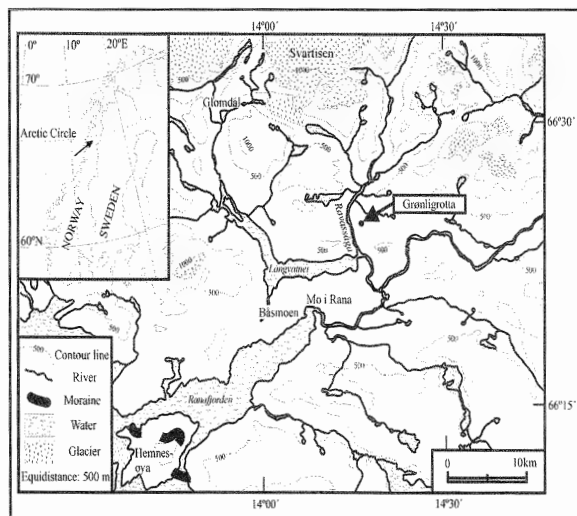


Figure 1 (above). Location and topographic setting of the Grønli caves in Rødvassdalen at Mo i Rana, N. Norway

Mo i Rana, north Norway, a Glacial through that leads directly out from the Svartisen ice cap, Figure 1. The caves are located in bands of calcite and dolomitic marble belonging to the Rødingefjell nappe complex (Søvegjarto et al. 1989). The caves are located near the mica schist contact in the upper limb of a recumbent fold, Figure 2. Thus the caves are confined under a dipping (19°NE) mica schist contact and are of Morphotype B ('Low dip phreatic network or maze') in the stripe karst cave classification of Lauritzen (2001).

Cave surveying

The caves were surveyed to BCRA grade 5C by the use of compass, clinometer, tape and laser rangefinder, using photographic tripods as stations. Passage dimensions were measured at each station and detailed cross sections drawn, recording geologic structures like foliation and fractures. Occasionally, the polygon survey was linked to fixed points on the cave walls which were marked semi-permanently by means of a steel awl. Survey data were processed on the cave survey program Grottoff (Lauritzen 2003). The projected centerline survey was exported as a HPGL file (*.plt) and imported to Corel Draw for addition of passage details, Figure 3. Speleometric results are listed in Table 1. In addition to the surveying done by the authors, additional explorational pushing and digging towards a connection of all caves has been done: Nedre Isgrotta (Solbakk, Lauritzen unpublished 2002) and new, upstream extensions of Setergrotta ('Det Forjettede Land', Lauritzen and others unpublished 2003).

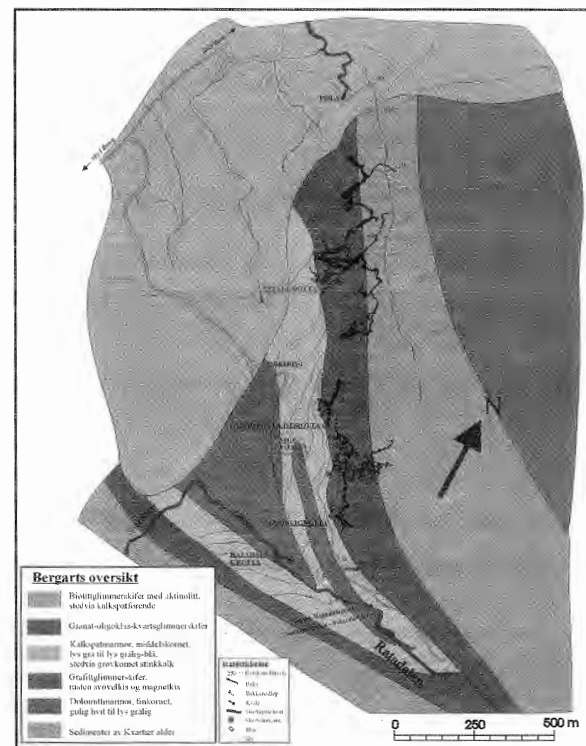


Figure 2 (right). Simplified geological map of the recumbent fold containing the caves. See text for further discussion.

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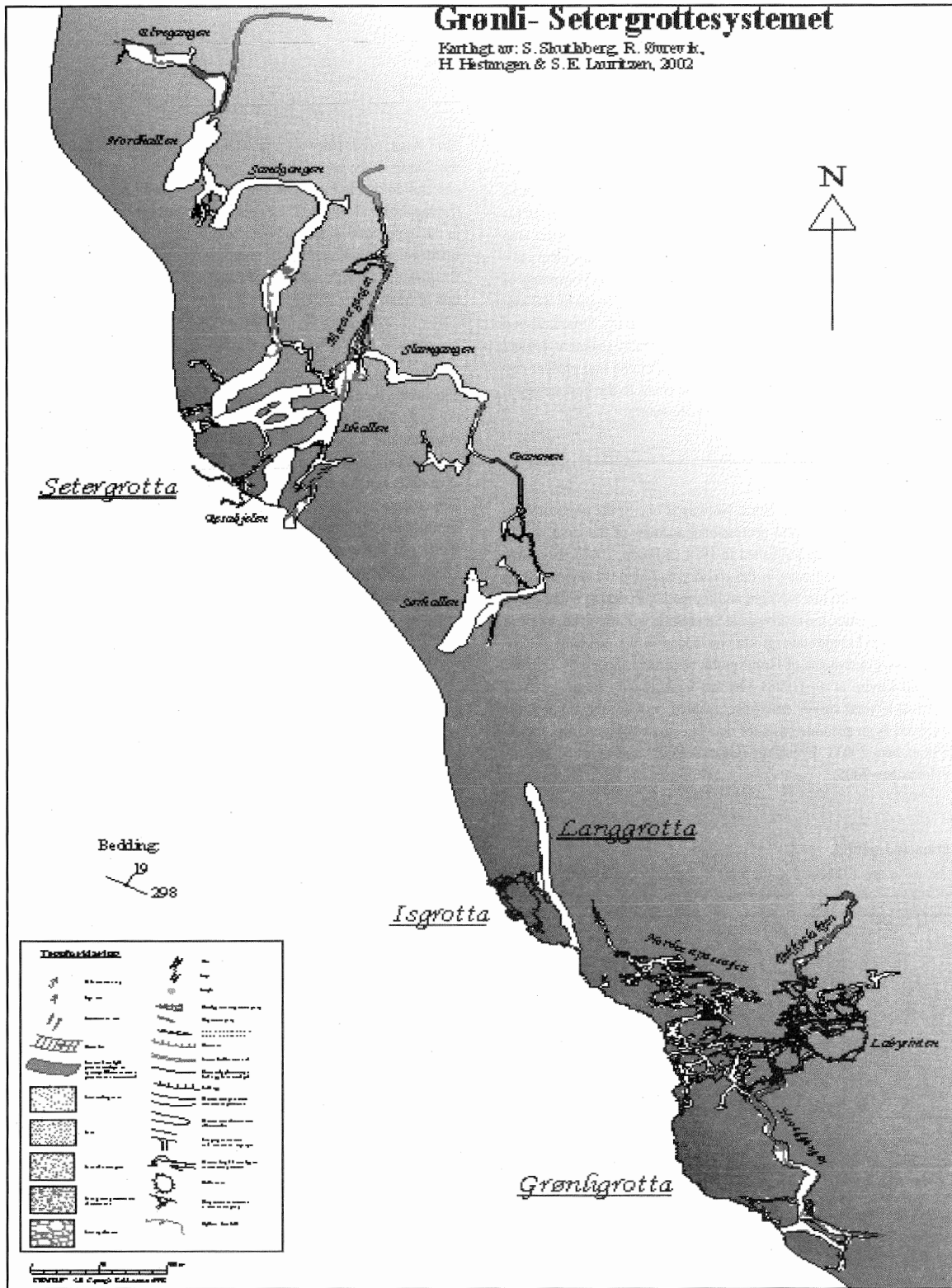


Figure 3. All Caves In The Grønli-Seter System, except extensions in Setergrotta done in 2003, i.e. 'Det Forfjettede Land', which reduces the horizontal distance between Langgrotta and Setergrotta to about 40 m.

Proper reference to this map is: Skutlberg, S.M.; Øvrevik, R.; Hestengen, H. & Lauritzen, S.E. 2002: "Grønli- Setergrotte systemet Cave map".

Table 1
Speleometric data for the Grønli-Seter system

Cave	Length (m)	Depth (m)	Volume (m ³) ^a	comment
Grønligrotta	4,100	110	12,290	Complete 2002
Langgrotta-Isgrotta	440		3,540	Connected by survey, complete 2002
Nedre Isgrotta	268	25	-	Situated below isgrotta, 2002-2003
Setergrotta	3,430	81	46,130	Survey by 2003, including extension
Total	8,238	234		

^a Volume calculated from passage dimensions at each survey station, assuming rectangular cross-sections.

Structural speleology and paleohydrology (Skutlaberg 2003)

Structural geology

The present-day metasediments were folded and metamorphosed in the late Silurian, Caledonian orogeny with regional compression NW-SE. The stress direction was deviated around large granite bodies in East and South so that the marbles were folded around them and in Grønli the compression was basically N-S creating the large recumbent fold structure which hosts the caves. A later E-W compression depressed the fold axis, so that the structure plunges to the SE (Figure 2). Some brittle-ductile shear planes seen in the caves are probably from this period. Later penetration of tonalitic magmatic dykes also penetrated the carbonate mass. A variable composition suggests different injection episodes, and they have been displaced by later shear movements. As aquicludes, these dykes display a pronounced influence on speleogenesis where they occur. Later fracturing in the brittle regime produced strong E-W and NW-SE striking, steeply dipping fault and shear planes. Neotectonic movements (NS) imply that some of the NE-SW shearplanes might have been activated as Riedel shears. Subsequent fracture systems developed as erosional unloading occurred and during the last, Tertiary uplift. Glacio-isostatic loading/unloading also opened fractures, basically by sheeting mechanisms closer to the surface.

Speleogenesis

Initial speleogenesis commenced along a pyrite-impregnated horizon at the upper marble-schist contact, and we propose pyrite oxidation and sulphuric acid corrosion as the first speleogenetic process, which is quite common in Norway (Lauritzen 2001). Such marble-mica schist contacts



Figure 4. Hjökullaup fascies in setergrotta. Rounded boulders imbricated uphill indicate enormous discharges out of the system. Photo S.E. Lauritzen.

are often sheared, providing a primary void for attack by the oxidising fluids. The timing of cave initialization is difficult to set, but the oxidation demand a meteoric environment rather than hypogean, hydrothermal conditions. Paleocurrent directions based on scallop morphometry clearly demonstrate that all caves were in general effluent with phreatic flow towards S. Consequently, flow was uphill and can only be explained by subglacial hydraulic gradients (Lauritzen 1984), probably at stages when local ice-streams filled the adjacent valley. Speleothem dating in other caves in the region put subglacial scalloping back beyond 30 kyr (Lauritzen unpublished). Maze- and labyrinth morphology (Grønligrotta, Isgrotta and parts of Setergrotta) advocate epiphreatic pumping as the most probable speleogenetic regime (See Øvrevik & Lauritzen, this volume). The larger passages of Setergrotta and Langgrotta are developed along almost vertical, NNE-SSW fractures and in pattern they form a series of large phreatic loops in the inclined foliation contact (298°/19° NE), closely resembling the speleogenetic model for inclined bedding planes (Ewers 1982), see Figure 3. Late re-routing of drainage due to blockfall and sediment chokes can be demonstrated in some places, as well as gradual lowering of the watertable through schist and dyke barriers, creating epiphreatic conditions and flooding sumps. Later vadose clogging is evident along the present-day streamway which forms an invasion passage

Dissolution rate as a stratigraphic tool

In spite of an extensive marble pack, the caves are clustered at the upper schist contact. Apart from pyrite impregnation in the schist ceiling and the magmatic veins, the marble also contains dolomitic horizons, so that a more extensive chemical control of the stratigraphic position of the caves at horizons of high speleogenetic affinity cannot be ruled out from inspection alone. Therefore, the karst rocks were logged at great detail and investigated for chemical and mineralogical composition. In particular, we measured dissolution rates on rock tablets and powder in free-drift experiments at ambient, atmospheric P_{CO_2} in order to determine dissolution rates at various stages of saturation. We propose that loss of ignition at 800° (expelling CO_2), dissolution in dilute HCl (total Ca- and Mg-carbonates) and kinetic properties are the best measures of speleogenetic affinity. Over a stratigraphic distance of 150 m, of which the caves occupy the upper 30 m, initial dissolution rate and apparent time to saturation on powder runs show that the upper 75 m of the sequence has a higher speleogenetic affinity than the lower half. However, we did not find any preferential zone of neither purity nor dissolution rate that could explain the much closer clustering of passages (apart from the pyrite impregnation). We therefore suggest that the stratigraphic position of the caves is mainly a hydraulic effect; the cave was created in the phreatic zone, confined beneath the mica schist ceiling rock.

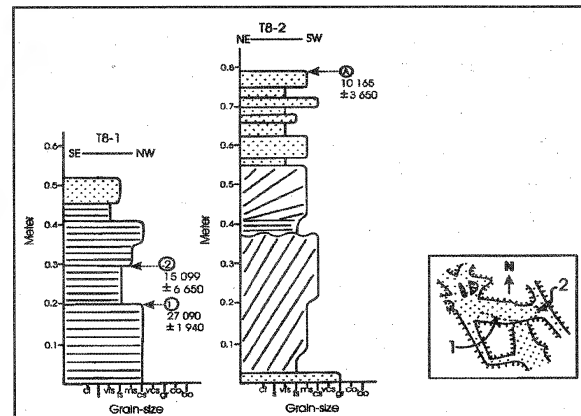


Figure 5. Sand sequence from Grønligrotta with calcite, u-series dated to 10, 15 and 27 kyr. From Hestangen (2005).

Stratigraphy and sedimentological fascies (Hestangen 2005)

Sedimentological fascies found in the caves

Except for the active streamways and some phreatic tubes, most of the cave floor is covered with sediments. Grain sized cover all ranges, from glacial clays to blocks. Stagnant, glacialacustrine fascies have been detected in a few places, the best section is at a high level in Grønligrotta, where paleomagnetic dating suggests lacustrine conditions at 8.9 - 9.5 kyr, under ice-contact conditions (Løvlie et al. 1988). Fluvial sand and gravel is the most common fascies, such sections contain numerous cut-and-fill structures, making lithostratigraphic correlation difficult even over short distances. Flood and levee-type deposits are found in the large, downstream passages of Setergrotta, as well as the epiphreatic passages display parallel accretion of organic mud in the ceiling and walls. The most dramatic fascies found in the cave is the *hjøkullaup fascies*, represented by huge rounded boulder that are imbricated uphill in a sloping gallery. The blocks have median axes of about 3 m and equally large giant scallops or inverted potholes are eroded into the mica schist roof above the deposit, Figure 4. We ascribe these conditions to have occurred during deglaciations, when large amounts of water were available and ice-contact created phreatic conditions in the cave.

Uranium-series dating of flowstones covering sediments yielded mid-Holocene dates whilst several calcareous concretions (Höhlekrappen) yielded isochron ages of mid-Weichselian age (28- 32 kyr). One of them were in direct contact with a sand sequence, Figure 5.

Hydrogeology and dissolution rate (Øvrevik 2002)

Methods

Stage, water temperature and electric conductivity were automatically monitored with sensors and data loggers at two stations; the cave inlet (Grønligrotta) and the main spring. Discharge was estimated by standard salt dilution method and stage-discharge curves were established. A systematic program of quantitative fluorometric dye tracing experiments was carried out by standard procedures using Rhodamine WT. Water samples were collected manually by conventional procedure.

Hydrologic measurements

Spring discharge, during the hydrological year 2000/2001, averages 130 ± 50 l/s, and can exceed 2000 l/s during storm flow. The lowest discharges appear during winter. From April to mid-June, discharge is dominated snow-melt. The aquifer modifies the hydrograph to a minor extent. Flood response is rapid and accompanied by sharp changes in chemistry and temperature. The specific conductivity in the spring (mean about 32

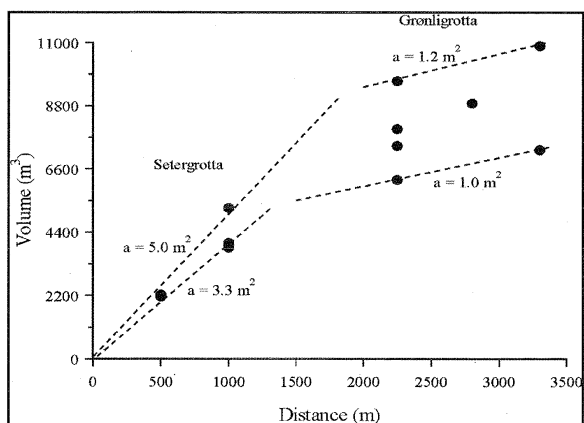


Figure 6. Aquifer volume shown as a function of distance from main spring. Volume estimates are based on mean tracer transit time.

$\mu\text{S}/\text{cm}$) is significantly higher than in the cave inlet (mean about $24 \mu\text{S}/\text{cm}$) due to dissolved CaCO_3 . Water temperature in the Grønli-Seter aquifer is bimodal due to the sub-arctic climate. During winter, spring water temperature approach 3°C in stable periods while it in summer stabilizes at about 10°C .

Fluorometric dye tracing

The Grønli-Seter aquifer has single peaked breakthrough curves, relatively high recovery and insignificant difference in water discharge between sink and spring, indicating an aquifer with a rather simple conduit system and little dispersion. Volume estimates based on mean tracer transit time, are plotted versus distance in figure 6. There is a distinct change in gradient in the curve which seems to take place a few hundred metres downstream of Grønligrotta. In accordance with observations and mapping, the downstream, mostly phreatic parts of the system display a relatively high specific volume, about $4 \text{ m}^3/\text{m}$, whilst the essentially vadose, upstream parts (i.e. Grønligrotta) display a much lower specific volume, about $1 \text{ m}^3/\text{m}$.

Water chemistry

pH is slightly alkaline as common for karst water, ranging from 6.8 to 8.3. Bicarbonate, HCO_3^- , and calcium, Ca^{2+} , are the most abundant ion components in the system. They are positively correlated and concentrations increase through the aquifer. The aquifer also contains lower concentrations of magnesium, Mg^{2+} . All three components are negatively correlated with discharge and positively correlated with specific conductivity. Other ions present are Na^+ , Cl^- , SO_4^{2-} and K^+ . All water samples are strongly under-saturated with respect to calcite (and dolomite) with saturation indexes ranging between -1.1 and -3.3. The saturation index of calcite is significantly higher in the spring than in the cave inlet at the same discharge (two-tailed, paired t-test, $p < 0.001$). Water in the aquifer never reaches saturation, because the contact time between water and marble is too short to exploit the whole dissolution potential of the water.

Chemical corrosion rate

To make an estimate of the chemical corrosion rate in the aquifer we simplify calculation by making some assumptions. According to Palmer (1991), the rate solutional wall retreat, S , in a passage segment of finite length (L) and essentially constant cross-section can be estimated by the following equation:

$$S = \frac{31.56Q(C - C_0)}{pL\rho_r} \quad (1)$$

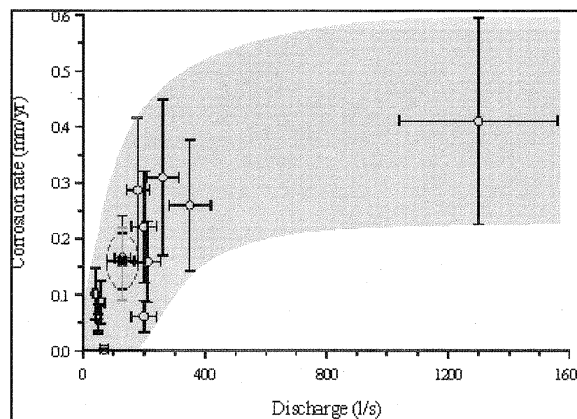


Figure 7. Instantaneous chemical corrosion rates are shown as a function of discharge. In addition, mean rates based on mean annual run-off (broken circle) and chemical state (grey line) are plotted into the diagram.

where Q = discharge, C_0 and C are solute concentrations at the upstream and downstream end of the segment, respectively, p = wet perimeter and ρ , is density of the carbonate rock (2.7 g/cm^3). The coefficient 31.56 converts seconds to years, grams to milligrams and litres to cm^3 . The numerator is the transport rate of calcite, T , out of the passage. Mean annual run-off in the spring is $130 \pm 50 \text{ l/s}$ which yield a total annual transport of calcite between 7.7 and 14.2 metric ton, with a best estimate of 11.1 metric ton. The length of the aquifer is 2800 m. The vadose and phreatic parts of the aquifer have quite different mean cross-sectional areas, about 1 m^2 and 4 m^2 , respectively. The phreatic part of the aquifer is about 1800 m long, while the vadose part is about 1000 m long. The wet perimeter of the phreatic part is estimated as a circle while the wet perimeter of the vadose part is estimated as three sides of a square. The perimeter of smooth cylinders turned out to underestimate the perimeter of irregular cross-sections by about 57%. According to this relation the wet perimeter of the phreatic conduits will be 11.5 m, and for the vadose conduits 5.1 m. The best estimate of wall area exposed to corrosion is then $25\,892 \text{ m}^2$. From equation (1) the chemical corrosion rate is calculated to range between 0.11 and 0.20 mm/yr, with a best estimate of 0.16 mm/yr. Instantaneous chemical corrosion rates have been estimated from total hardness in water samples and corresponding discharge measurements, Figure 7.

Acknowledgements

Logistic support, unlimited access to the caves and accommodation from Setergrotta A/S (P.G. Hjorthen) and from Grønligrotta (The Pedersen family) are gratefully acknowledged.

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P-23

Speleotheme dating from Svarthammerhola and MIS 7 oxygen isotope and uranium series study

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Abstract

Dating of a stalagmite found under ice cover in Svarthammerhola in northern Norway (give more geography) is being undertaken by means of uranium series analysis. It is believed that the development of this speleothem spans the time of marine isotope stage 7 (MIS7). Preliminary dating carried out by S.E.Lauritzen show that the speleothem is at least 200 000yr. This particular interval is of significant interest because, currently,

very few terrestrial deposits representing this time have been found in northern Norway. It is the intention of this study to localize growth in the speleothem which is attributed to interglacial 7 (Domnitz?) and identify the $^{13}\text{C}/^{18}\text{O}$ variability for use as a climate proxy. The final goal being to build a climate curve with correlated (absolute?) age which will describe conditions in northern Norway roughly 200 000yr ago.

P-24

Speleothem records older than 500 ka from Southern Siberia

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Abstract

Speleothems have proven to be generally well-preserved and widely distributed terrestrial tools for tracing palaeoclimatic history (Vaks et al. 2003, Hou et al. 2003, Burns et al. 2001, Gascoyne 1992). Furthermore, some speleothems (especially stalagmites) have proven to be datable with high precision, using U/Th decay schemes (Richards & Dorale 2003, Neff et al. 2001, Wang et al. 2001). Few speleothems have been dated with U/Pb series so far (Richards et al. 1998).

Here we present the U/Th and stable isotope results obtained from stalagmites retrieved from Southern Siberian caves documenting the climate variability of the interior of Central Eurasia. Furthermore we carried out ICP-MS and XRD measurements in order to screen selected elements and identify the mineralogy of the speleothems.

We report data from two caves (i) Botovskaya cave located in Ordovician limestone 670 km NE of Irkutsk and (ii) Polytechnika cave located in Rhipaean limestones NW of the vicinity of Lake Baikal. All stalagmites (with one exception) analyzed show $^{230}\text{Th}/^{238}\text{U} > 1$ and hence are in secular equilibrium and older than ~500ka (Edwards et al. 1986/87). Stalagmite Boti 881 (Botovskaya cave) consists of both, calcite and aragonite minerals. We have found high uranium concentrations of up to 73.6 ppm. Therefore this stalagmite seems suitable for U/Pb dating (Richards et al. 1998).

Stable oxygen isotope ratios range from -11.2 ‰ to -14.1 ‰ (VPDB standard). $\delta^{13}\text{C}$ values vary from +1.8 ‰ to -1.6 ‰. Stalagmite Poly 1 (Polytechnika cave) consists of pure calcite. Its uranium concentration reaches 0.95 ppm. Stable oxygen isotope ratios range from -11.7 ‰ to -14.2 ‰ (VPDB standard). $\delta^{13}\text{C}$ values vary between -3.9 ‰ and -7 ‰. These changes in the isotopic composition in the stalagmite's calcite are most probably climate-related.

Future work will be focused on U/Pb dating. This method can give speleothem ages well beyond the established U/Th dating method and therefore these potential data may be extremely interesting for Neogene palaeoclimate reconstruction.

Comparison of our data with results from the Baikal Drilling Project will help us to validate independently both records and to elucidate climatic history of this still under-represented continental region.

Introduction

Speleothems (secondary cave deposits) are widely distributed powerful archives of palaeoclimatic proxies (McDermott 2004). Advances in mass spectrometry enable us to analyse trace elements and stable isotopes, as well as radioactive elements with very high precision. Since stalagmites are very stable over long periods of time, and can be dated precisely with U/Th and U/Pb methods (Richards et al. 1998), they are most useful for paleoclimate research.

Here we present first stalagmite records from Southeast Siberia (see Fig. 1). Two cave locations have been sampled and three stalagmites analysed. Botovskaya cave is located near river Lena, about 670 km NE of Irkutsk. The plateau, in which the cave is developed, consists of Ordovician sediments (sandstone, siltstone and limestone). The cave is a horizontal maze labyrinth and is longer than 60 km (Göbel & Breitenbach 2003).

Polytechnika cave is a vertical cave located in the Pribaikalsk Mountain ridge, about 70 km E of Irkutsk. The host rock is Rhipaean limestone

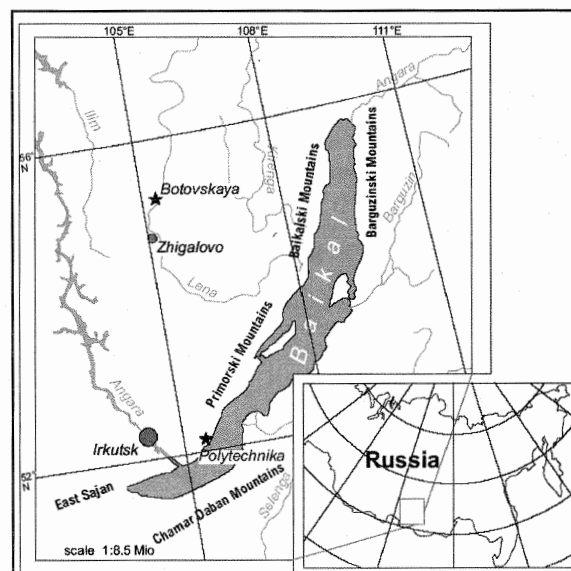


Fig. 1 Map of lake Baikal and surrounding region. Localities of Botovskaya and Polytechnika caves are shown as stars.

and the cave is a multi-level system, bound to tectonic faults. Lake Baikal is ca. 7 km to the SE (Breitenbach et al. 2004).

Both caves are situated in a region with strong continentality, and thus high annual temperature amplitude, though lake Baikal has a mitigating effect (Endlicher 2000, Breitenbach 2004).

Methods

Samples were prepared for petrologic and stratigraphic observations by cutting and polishing stalagmites from both caves. Thin slides were prepared for CL (cathodoluminescence) microscopy. We carried out X-Ray diffraction (XRD) measurements for mineralogy and ICP-MS analysis for elemental screening. To distinguish between calcite and aragonite, we used both, cathodoluminescence microscopic techniques and XRD (Breitenbach 2004). We used a ThermoFinnigan DELTA^{plus}XL mass spectrometer with coupled Gasbench II for stable isotope measurements ($\delta^{13}\text{C}$ and $\delta^{18}\text{O}$). To determine ages, U and Th isotopic ratios have been measured on a Finnigan Neptune multi collector inductively coupled mass spectrometer (MC ICP-MS). Although this method allows high precision age determination up to ~500,000 years, we found that the isotopic ratios in the analysed stalagmites are in secular equilibrium, showing that they have been precipitated beyond the limit of the U/Th method (Edwards et al. 1986/87). Therefore we concentrate on U/Pb techniques for dating. This method is well established for rock older than half a million years (Tera & Wasserburg 1972) and only recently for comparatively young carbonates (Richards et al. 1998).

Stable isotope samples ($2 \times 250 \pm 50 \mu\text{g}$ each) have been taken along the growth axis with a cleaned in 10% HCl stainless steel drill bit ($\varnothing 0.5 \text{ mm}$) and along individual growth layers for HENDY tests (Fig. 2 and 3).

After closure of the samples in glass vials under helium inert atmosphere at $72.0 \pm 0.1^\circ\text{C}$, phosphoric acid (concentrated H_3PO_4) was added and the CO_2 generated transferred through a GC column into the mass spectrometer (see Spötl & Vennemann 2003 for methodical details). The 2σ error for $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ is $<0.1\%$.

ICP-MS samples have been taken with a 1 mm drill bit for U concentration measurements. Samples for U/Th measurements for age calculations were taken using a 0.5 mm drill bit. Sample size ranges from 0.14 to 0.19 g (Botovskaya cave) and 0.1 to 1.04 g (Polytechnika cave). Analytical sample treatment is described in Edwards et al. 1986/87.

Tab. 1 U and Th samples taken from Boti 881 and Poly 1¹

Sample	^{238}U (ng/g)	^{232}Th (pg/g)	$\delta^{234}\text{U}_m^2$	$(^{230}\text{Th}/^{238}\text{U})_{\text{act}}^3$	$(^{230}\text{Th}/^{232}\text{Th})_{\text{act}}^3 \times 10^3$
Poly 1-1a	711.1 ± 0.1	$15,262 \pm 16$	4.9 ± 0.2	1.023 ± 0.004	145.6 ± 0.5
Poly 1-1b	710.5 ± 0.2	$19,084 \pm 42$	5.5 ± 0.3	1.017 ± 0.007	115.7 ± 0.8
Poly 1-1c	704.6 ± 0.1	$12,423 \pm 14$	3.7 ± 0.2	1.025 ± 0.004	177.7 ± 0.6
Poly 1-3	863.1 ± 0.3	230.0 ± 0.2	3.7 ± 0.3	1.030 ± 0.001	11.8 ± 3
Poly 1-4	$1,098.2 \pm 0.3$	158.8 ± 0.1	1.6 ± 0.2	1.031 ± 0.001	21.8 ± 8
Poly 1-5	780.3 ± 0.3	294.0 ± 0.2	-0.3 ± 0.3	1.030 ± 0.001	8.4 ± 1.6
Poly 1-6	740.5 ± 0.3	319.5 ± 0.2	0.3 ± 0.3	1.035 ± 0.001	7.3 ± 1.3
Poly 1-7	901.4 ± 0.3	187.7 ± 0.2	3.7 ± 0.3	1.031 ± 0.001	15.1 ± 4.7
Poly 1-8	$1,034.1 \pm 0.3$	103.5 ± 0.1	-221.1 ± 0.2	1.031 ± 0.001	31.5 ± 17.5
Boti 881-5	$33,474 \pm 19$	926.6 ± 15.7	13.80 ± 0.6	1.048 ± 0.008	115.7 ± 9
Boti 881-6	$45,879 \pm 18$	422.5 ± 6.7	13.61 ± 0.4	1.045 ± 0.006	347 ± 56
Boti 881-7	$73,632 \pm 20$	131.3 ± 2.2	15.52 ± 0.3	0.895 ± 0.004	$1,533 \pm 826$
Boti 881-8	$52,773 \pm 19$	149.1 ± 2.4	16.71 ± 0.4	1.050 ± 0.005	$1,136 \pm 530$
Boti 881-9	$45,069 \pm 19$	$1,441 \pm 24$	15.53 ± 0.4	1.087 ± 0.006	103.9 ± 5.2
Boti 881-10	$29,655 \pm 22$	$1,018 \pm 20$	15.44 ± 0.8	1.050 ± 0.010	93.3 ± 7.7

¹All errors are 2σ standard deviation.

² $\delta^{234}\text{U}_m = \left\{ \left(\frac{^{234}\text{U}/^{238}\text{U}}{^{234}\text{U}/^{238}\text{U}} \right) - 1 \right\} \times 10^3$ measured where $(^{234}\text{U}/^{238}\text{U})_{\text{eq}}$ is the atomic ratio at secular equilibrium; $\lambda_{234} = 2.8262 \times 10^{-6}$, $\lambda_{238} = 1.55125 \times 10^{-10}$, $\lambda_{230} = 9.158 \times 10^{-6}$ (Chen et al. 2000)

³Activity ratio calculated by dividing $^{230}\text{Th}/^{238}\text{U}$ by the $^{230}\text{Th}/^{238}\text{U}$ atomic ratio at secular equilibrium.

visible in Boti 881, which may be a palaeoclimate proxy (McDermott 2004).

Stalagmite Poly 1 from Polytechnika cave is 220 mm long, with a ~ 50 mm diameter. It is pristine calcite (two XRD samples), except for the lowermost part and the edge, where clay particles are incorporated. The crystals are in the form of radial columnar palisades. Both stalagmites are dense and finely laminated. Boti 881 is white and shows weathering at the edge, whereas Poly 1 shows a brown color and shows no secondary alteration.

Geochronology

From both stalagmites presented here, 6-8 samples for each stalagmite were taken for U/Th dating. The sample size required was calculated after determination of the ^{238}U concentration on 3-4 samples ($\sim 100\text{mg}$ each) on a Finnigan ELEMENT ICP-MS. To control the samples for detrital thorium 230, the activity ratio $^{230}\text{Th}/^{232}\text{Th}$ is used. If this ratio is bigger than 100, the detrital thorium fraction is assumed to be negligible. As it turned out, the entire material discussed here is older than $\sim 500,000$ years. This is based on the $^{230}\text{Th}/^{238}\text{U}$ activity ratio found to be >1 (tab. 1), which represents secular equilibrium of the parent and daughter isotopes and hence the

Results

Petrography

Stalagmite Boti 881 from Botovskaya cave is a 162 mm long cone with a maximum diameter of 75 mm. The samples show a dense palisade crystal structure, with laminae in sub millimetre scale. The crystal growth is radial. The top of this stalagmite shows a broken remnant of a stalactite. Sample Boti 881 consists of both, aragonite and calcite (three XRD samples). Layered Mn and Mg enrichment are vaguely

limit of the U and Th method (Edwards et al. 1986/87). The smaller errors found for the activities for samples Poly 1-3 to Poly 1-8 reflect the fact that we use a larger sample mass and also we improved the blank value. We are not able to explain the 3%-excess above the secular equilibrium number with our internal or external precision. We are establishing U/Pb dating techniques using MC ICP-MS analysis, which hopefully will also help us to understand the activity values found. Fortunately, stalagmite Boti 881 shows very high ^{238}U concentrations (tab. 1, fig. 2). We use the ratios of stable lead isotopes to determine the age of the sample (Tera & Wasserburg 1972). So far, we are able to implement a column separation procedure to obtain lead and uranium fractions with minimal amount of calcium. This method will allow dating these surprisingly old stalagmite samples. The low ^{238}U concentration in Poly 1 (fig. 3) will probably not allow U/Pb age determination.

Further we found that the ^{238}U concentration trend in Boti 881 shows similarities to the $\delta^{18}\text{O}$ curve, although the number of samples is not sufficient for detailed comparison. Similar observations have been reported by Kuang et al. (2002) and were interpreted as related to organic matter in soil above the cave. Thus, the ^{238}U concentration may be another palaeo-vegetation indicator. We cannot clearly observe the same trend in Poly 1, probably because of a lack of more samples.

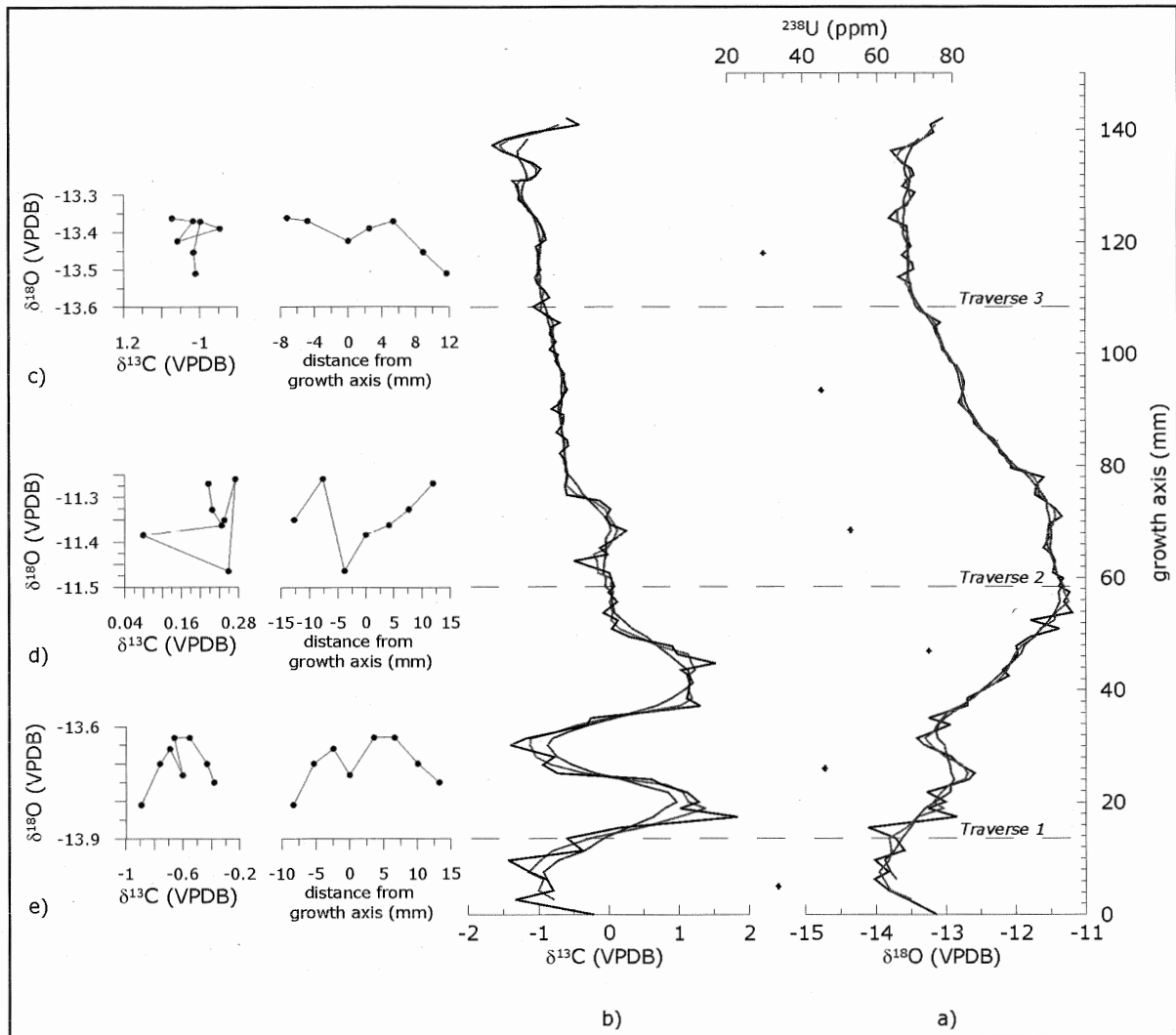


Fig. 2 Stable isotope ratios, Hendy-test plots and ^{238}U concentrations of stalagmite Boti 881 (Botovskaya cave). The 3-point running average is given in red, the 7-point running average in blue. The uranium concentration shows similarities with the $\delta^{18}\text{O}$ record.

Stable Isotopes

For stable isotope measurements, more than 550 sub-samples for Poly 1 and more than 280 sub-samples for Boti 881 were recovered. Multiple Hendy-tests were carried out to test for isotopic fractionation in individual growth layers (Hendy 1971). In fig. 2 and 3 the isotope ratios, $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$, against growth axis, as well as the Hendy-test plots are given. Stable oxygen isotope ratios range of Boti 881 from -11.2‰ to -14.1‰ (all isotope values are given against Vienna Pee Dee Belemnite (VPDB) standard). The uncertainty in the Hendy-tests has been considered to be negligible (with the variation in the calcite Δ

$\delta^{18}\text{O}_c = 0.2 < 2\sigma$ standard deviation ($= 0.2\text{‰} - 0.3\text{‰}$). Therefore, isotopic equilibrium during stalagmite growth is assumed (Linge et al. 2001, Breitenbach 2004).

The $\delta^{13}\text{C}$ values vary from $+1.8\text{‰}$ to -1.6‰ . Here the 2σ error for the measurements is $<0.2\text{‰}$. $\delta^{13}\text{C}$ values of this range are commonly associated with C3 vegetation (McDermott 2004, Baker et al. 1997). Nonetheless, since we find both, aragonite and calcite, in Boti 881, interpretation of isotopic signatures remains difficult because of possible fractionation between both phases (Breitenbach 2004).

The stable oxygen isotope ratios of Poly 1 range from -11.7‰ to -14.2‰ , with 2σ standard deviation of $<0.3\text{‰}$. Five Hendy-test traverses were taken, none of which shows significant correlation between $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$. $\Delta\delta^{18}\text{O}_c$ is as big as 0.77‰ , but is caused by sampling error (for details see Breitenbach 2004). A tolerance of 0.5‰ in $\Delta\delta^{18}\text{O}_c$ is assumed following Linge et al. 2003. Equilibrium conditions are likely for the time of precipitation of sampled growth layers.

The $\delta^{13}\text{C}$ values vary between -3.9‰ and -7‰ and $2\sigma = 0.16\text{‰}$. These values may be related to shifts in the vegetation above the cave between C3 (forest) and C4 (grasses) photosynthesis (McDermott 2004).

Conclusions

The petrography of both stalagmites supports palaeoclimatic analysis, because the samples consist of dense laminated and not secondary affected calcite and aragonite material. The use of the U/Pb dating method will allow us for the first time to determine palaeoclimate proxies older than 500,000 years from stalagmites from the continental Siberia. Furthermore, the high uranium concentrations in Boti 881 may be another proxy

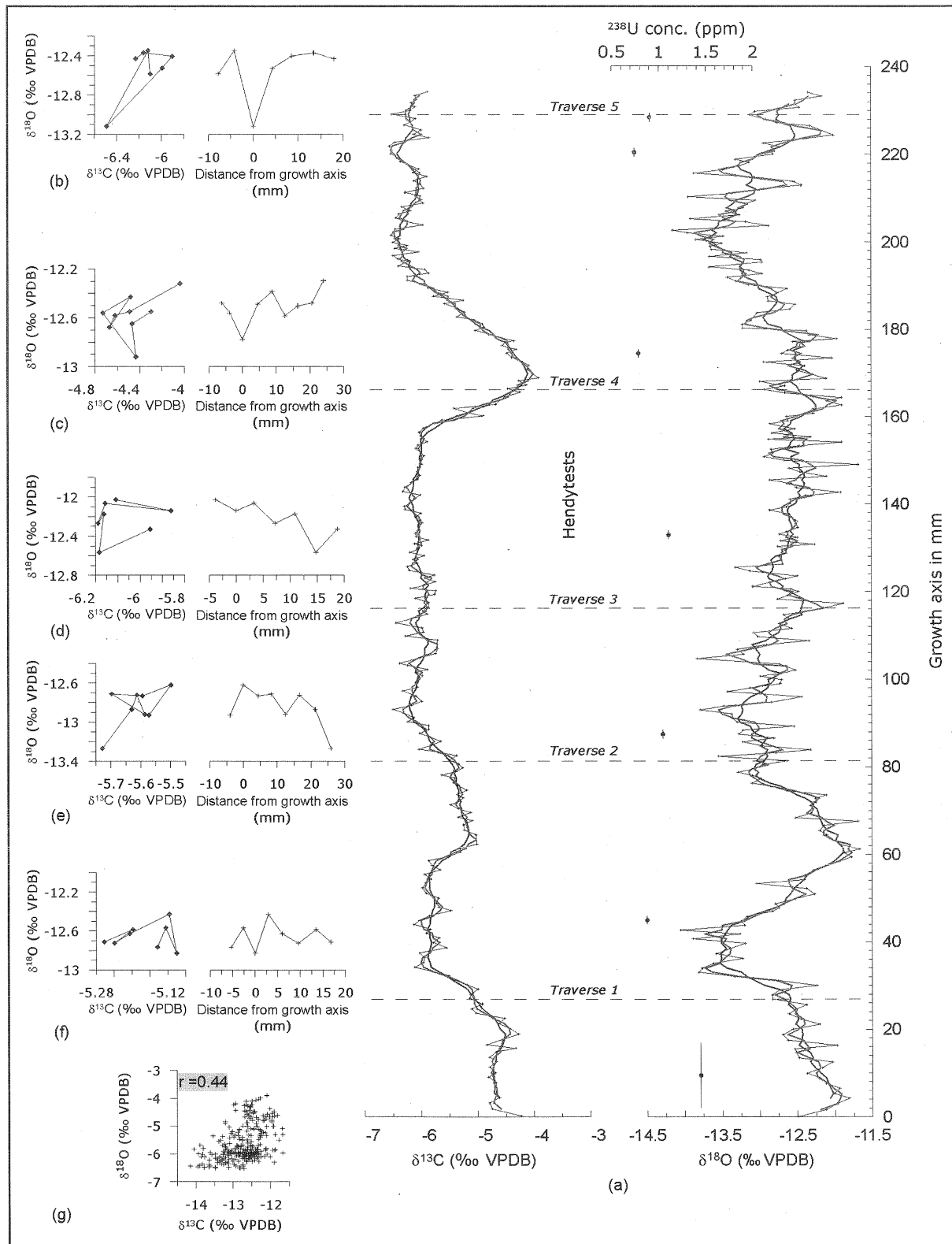


Fig. 3 Stable isotope ratios, Hendy-test plots and ^{238}U concentrations of stalagmite Poly 1 (Polytekhnika cave). Error-bars of the U samples show the range one sample integrates. In blue the 7-point running average, and in red a 3-point running average is presented.

itself for soil and/or vegetation cover on the surface (Kuang et al. 2002). The stable isotope signals in both stalagmites shows large variations and are therefore useful for climatic interpretation. Further investigation will show detailed analysis of various proxies of these extraordinary old records from a region not well explored yet. Comparison with records from lake Baikal will enable us to understand the climate of the past of this continental Asian region.

Acknowledgements

Palaeoclimatic research was funded on DFG travel support (grant: 436 RUS 18/3/03 H. Oberhaensli) and INTAS grant 03-51-4152. Logistic support came from Speleoclub ARABIKA, Irkutsk, RF. XRD analysis was kindly carried out by R. Naumann (GFZ Potsdam).

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P-25

Palaeomagnetic and palaeontological research in Raciska pecina Cave, SW Slovenia

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*Institute of Geology, Academy of Sciences of the Czech Republic, Rozvojova 135, 165 02 Praha 6, Czech Republic***Abstract**

Raciska pecina Cave (Matarsko podolje, SW Slovenia) at about 590 m a.s.l. consists of simple southwards dipping gallery, which is mostly over 10 wide and 5-10 m high and 304 m long. It was formed in paragenetic or epiphreatic conditions. The studied section was about 13 m long with composite thickness of sampled profile of 552 cm. The lower part (177 cm) is built of 3 sequences, individual growth stages of huge vaulted stalagmite. They consist of massive but porous speleothems with interbeds of red clays and unconformities. The second part consists of subhorizontal laminated, mostly porous flowstones, sometimes with gours, red clays and calcitised silts. Collapsed roof blocks cover clays with finds of fauna. The top part is built of huge stalagmites, which were not studied. Standard analytical procedure for detection of palaeomagnetic properties was used: thermal demagnetisation for 18 samples, and alternating-field demagnetisation for 111 samples. The obtained data have high-resolution character with distance of samples in centimetres. Samples of clays from principal clay accumulation were washed. Fossil remains were found in clay layer in the middle of the profile covered by collapsed blocks from roof. Rodents and rests of probably fresh-water crabs were found. Rodent (vole) rests represented poorly determinable assemblage of fragments of rooted teeth (molars). The character of mammal assemblage, especially rooted

form and internal texture of teeth excludes Quaternary age. Determined *Borsodia* (*Lagurini*) - *B. cf. hungarica*, *Miomys pitmyoides* groups and *Apodemus* (*Sylvaemus*) *cf. sylvaticus* indicate Pliocene biozone MN17 (Villanyian, cca 1.8 to 2.4 Ma). The character of speleothems, especially high porosity, can indicate rapid growth in warm and humid climate and syn- and postdepositional corrosion of speleothems. Clay intercalations represent result of floods with allochthonous load. Alternation of normal and reverse polarised magnetozones and palaeontological content enable to fix well our data with the GPTS. The bottom of Olduvai subchron (1.77 to 1.95 Ma) was detected within clay with fauna. Short normal chron just below detected Olduvai bottom is compared with Reunion subchron (2.14-2.15 Ma). The lower part of profile can be compared with dominantly normal polarised Gauss chron (from 2.581 Ma). According to arrangement of individual subchrons, studied profile terminates at about 3.2 Ma. The geometry of subchrons in profile is changed by numerous breaks in deposition. Obtained picture can estimate the duration of individual breaks up to 150-250 ka. This fact can also explain 36° difference in declination values in upper and lower parts indicating paleorotations of the respective tectonic block. Collapsed roof blocks in the clay with fauna indicate some tectonic unrest at about 1.9 Ma.

P-26

About Several Problems on Dating Stone-Door Tunnels and Caves

S. M. Shahinyan

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About Several Problems on Dating Stone-Door Tunnels and Caves Samvel M. Shaninyan Armenian Speleological Center Abstract The stone-door caves are underground engineering constructions, which were only built in the territory of historical Armenia. Similar caves come across in North-Western areas of Turkey, around the former Armenian capital Ani, near Bayazet and at the foot of Mountain Ararat. A report on these caves has been presented (UIS 1989, 10th congress II, p 440-442). These exquisite engineering constructions present significant theoretical, practical and

archeological interest. On the basis of analysis of the research material from the archeological constructions of Armenia both usage period and the construction date of these buildings were determined. As a result it appeared that: The art of stone-door caves got lost in XIX c Various details of stone-door caves come across both in medieval fort complexes (fortress of Amberd, Ilikia and Paravi) and in the cyclopean forts of Arbatta or Ararat kingdom (IX - VII BC) in Gegharkunik region. The application of stone doors in church-building has not been registered.

P-27

Origin of the gypsum flower in Okgye Cave, Kangwondo, Korea

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*Cave Research Institute of Korea, Kangwon National University, Chuncheon, Kangwondo, 200-701, Korea***Abstract**

Okgye Cave contains a variety of speleothems such as stalactite, soda straw, stalagmite, flowstone, cave coral, and draperies, etc. Most speleothems are composed of aragonite and/or calcite. Recently cave flower composed of gypsum was discovered. Okgye Cave has been developed by corrosion/erosion of groundwater along the joints and bedding planes of the Ordovician limestone (Seokbyeongsan Formation, Joseon Super-group). XRD analysis revealed that the cave flower is entirely composed of gypsum. This speleothem is present only in the small part of the dry passage. The speleothem occurs on the surface of fallen rock (or wall) as a crust, and sometimes it is included as a wedge within the rock, parallel to the bedding plane. The pH values of meteoric water, stream water, and

cave water ranges from 6.4 to 8.3, and the stream and cave water values tend to be higher (6.8 ~ 8.3). The $\delta^{34}\text{S}$ contents of the dissolved SO_4^{2-} in cave water and meteoric water range from 3.5 to 5.8 ‰ (CDT), whereas those in stream water show the narrower range (3.9 ~ 5.2 ‰). The $\delta^{34}\text{S}$ values of the pyrite in surrounding limestone range from -13.5 to -2.9 ‰. Therefore, the $\delta^{34}\text{S}$ compositions of the gypsum flower (2.6 ~ 4.5 ‰) are more depleted than those of meteoric water and cave water, but more enriched than that of the pyrite. A simple mass balance suggests that most sulfur of the gypsum flower was mostly supplied from meteoric water. Also the inverse relationship between dissolved sulfate and its $\delta^{34}\text{S}$ values confirms the sulfur source.

1. Introduction

Limestone caves in Korea are mostly developed in the Cambro-Ordovician carbonate rocks (Joseon Supergroup). The Seokbyeongsan Formation is distributed in Sangye-ri area in Gangneung City and more than 20 limestone caves including the Okgye Cave have been developed in this area. The Okgye Cave, nominated as the Kangwon Provincial Monument No. 37, is also called 'Cave Flower Cave' due to the abundance of anthodites, helictites, and moonmilk. The cave is about 950 m long (main passage=750 m, branches=200m), and developed north to south along the directions of the joints and bedding planes of the surrounding limestone. The passage is more or less horizontal (Woo, 1999; Choi et al., 2003). The cave was developed from the corrosion and erosion of groundwater which was supplied along the joints and bedding planes. In the cave, various minerals were reported including calcite, aragonite, halite, dolomite, and hydromagnesite (Woo, 1999). Gypsum speleothem is recently found, and this is the first report of the gypsum speleothem in Korea. Gypsum formation was reported in limestone caves that were developed by the dissolution by sulfuric acid which was formed by the oxidation of hydrogen sulfide. Gypsum can be also formed by the evaporation of sulfate-rich cave water. In addition, gypsum can be precipitated by the oxidation of pyrite or dissolution of anhydrite or gypsum and reprecipitation (George, 1977; Hill, 1979; Hill and Forti, 1986; Palmer, 1986; Pohl and Born, 1935; Pohl and White, 1965). Gypsum speleothem deposit, more than a few meters in thickness, can be formed when sulfur-rich groundwater circulates. But it is relatively rare in limestone caves elsewhere (Palmer and Palmer, 1995). The objectives of this paper are to delineate the origin of the gypsum cave flower based on textural and geochemical data.

2. Geologic setting

The Seokbyeongsan Formation which includes the Okgye Cave is mostly composed of limestone with a minor contribution of calcic dolomite and dolomite. The dolomite distribution is quite patchy and irregular. Strike direction of the bedding planes is N10~20°E, and that of the joints is EW and N75~89°W. No perennial stream is present near the cave.

3. Methods

Gypsum samples were collected for textural examination and geochemical analyses. Thin sections were examined to understand the texture, and the mineralogy was determined using X-ray diffractometer (XRD; Philips Bruker D5005). Cave water, rainwater, and stream water were collected from June to December, 2002. Elemental compositions of the waters were determined using ion chromatograph (IC; Dionex DX-320) and inductively coupled plasma spectrometer (ICP; Leeman PS950). Pyrite minerals were separated using magnetic barrier laboratory separator after the digestion with acid. Sulfur isotopic compositions were analyzed using stable isotope mass spectrometer (VG Isotech, Prism II) after the precipitation as BaSO₄ from dissolved sulfur (Kolthoff et al., 1969), and the data was obtained in Korea Basic Science Institute. Analytical error for the sulfur isotope is ±0.2 ‰, and NBS-127 ($\delta^{34}\text{S}_{\text{CDT}} = 20.32 \text{ ‰}$) was used as a standard. The sulfur isotope values are reported here relative to Canyon Diablo Troilite (CDT).

4. Results

4.1 Gypsum Speleothem

Cave flower in this study is entirely composed of gypsum (CaSO₄·2H₂O), and mostly occurs where rock-falls are present. Gypsum crystals are mostly acicular, but rosette-shaped gypsum flower is also present. They are white to transparent and the size of the crystals ranges from 0.5 to 6 cm. They usually occur in cracks such as joints or bedding

planes, and the growth of the gypsum crystals sometimes result in breaking limestone. This is why many rock-falls are present where the gypsum formation is present. The growth of some gypsum crystals break the rock into pieces or make bedding plane bend.

4.2 Chemical Composition of Cave Water, Stream Water, and Rainwater

Cave water has the pH values ranging from 7.7 to 8.0, and water temperature (= about 11.7 °C) is constant throughout the year. Steam water and rainwater have pH values of 7.7 to 7.8 and water temperature is 14.4~14.5 and 25.1~29 °C, respectively. Sulfur isotopic composition of the cave water ($\delta^{34}\text{S} = 3.5 \sim 5.8 \text{ ‰}$) shows similar range to those of stream water ($\delta^{34}\text{S} = 3.9 \sim 5.2 \text{ ‰}$) and rainwater ($\delta^{34}\text{S} = 5.4 \text{ ‰}$). Sulfur isotopic compositions of the gypsum flower is 2.6~4.5 ‰, which is more enriched than those of pyrite in surrounding limestone ($\delta^{34}\text{S} = -13.5 \sim -2.9 \text{ ‰}$). δD and $\delta^{18}\text{O}$ values of rainwater show wide ranges of -103~53.4 ‰ and -14~7.3 ‰. However, δD values of cave and stream waters have relatively narrower ranges of -80.3~57.2 and -73.7~64.4 ‰, and $\delta^{18}\text{O}$ values also show narrower ranges of -11.3~8.4 and -10.5~9.7 ‰, respectively. The δD and $\delta^{18}\text{O}$ values follow the Meteoric Water Line of Craig (1961). Chemical composition of rainwater is mostly controlled by water vapor, gas composition in atmosphere and anthropogenic pollutants (Faure, 1991). Cl⁻, NO₃⁻, and SO₄²⁻ compositions of rainwater is 2.2~3.6, 12.9~21.7, and 7.3~9.9 mg/l. Cave water has similar Cl⁻ composition (2.87~3.30 mg/l) to rainwater, however NO₃⁻ and SO₄²⁻ compositions (12.86~21.65, 7.33~9.88 mg/l) are higher. Stream water has Cl⁻, NO₃⁻, and SO₄²⁻ compositions of 2.9~4.3, 7.0~16.9, and 6.3~7.2 mg/l, and they are higher than rainwater, but lower than cave water.

5. Discussion

Plotting the elemental compositions in the Piper's diagram (Piper, 1944) cave water in Okgye Cave and stream water nearby is dominated by Ca-HCO₃ type (Fig. 1). The diagram suggests that Cl⁻ and SO₄²⁻ in rainwater could be derived from the fog on the sea. To determine the influence from seawater vs. anthropogenic pollutants, Cl⁻ compositions of cave water show the narrow and similar range to that of rain water, but stream water show the higher range. But NO₃⁻ and SO₄²⁻ compositions of rain water are the lowest and those of cave water is the highest, indicating that nitrate and sulfate compositions of rainwater were not affected

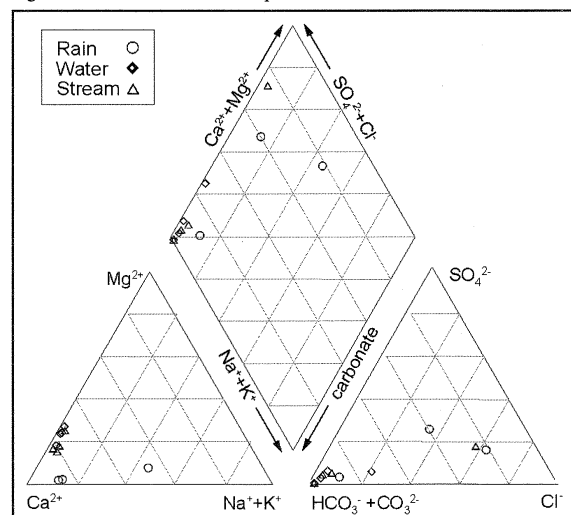


Fig. 1. Piper diagram (Piper, 1944), showing the chemical compositions of the water samples from the study area.

from anthropogenic pollutants. Using the equation of Mizutani and Rafter (1969) to calculate the percentage (A) of (sulfate from seawater)/(total sulfate in rainwater), 14–41 % of sulfate in rain water was derived from seawater sulfate, and 4.7–5.5% and 3.7–9.7% of the sulfate in cave water and stream water were from seawater sulfate. For the case of rain water in which A is more than 10%, sulfate ions were mostly derived from seawater, which affected stream water and cave water. However, because sulfate ions in cave water and stream water are less than 10% from June to August, most sulfate ions were derived from other sources such as surrounding limestone or anthropogenic pollutants. Rain water collected during this period has much lower SO_4^{2-} and NO_3^- compositions than cave water, which suggests that surrounding limestone is more likely the source than pollutants. Also, sulfate contents may be related to the amount of precipitation. That is, during the period of low precipitation (about 150–250 mm/month), groundwater is more buffered with surrounding limestone and cave water has higher sulfate content as a result. However, if the supply rate of cave water increases, the buffering time will decrease and cave water will have lower sulfate content. Oxygen and deuterium isotope values follow global Meteoric Water Line, indicating that cave water was not buffered enough with overlying limestone and reflect rain water and stream water to some extent.

Sulfur isotopic compositions of gypsum flower has the similar range those of cave water, even though it is a little lower (Fig. 2). A mass balance equation shows that about 63 to 88% of the sulfate in the gypsum flower was from cave water and only 12 to 37 % was from the pyrite in surrounding limestone. Also, sulfur isotopic compositions of waters increase with the decrease in sulfate content, suggesting that sulfur isotopic composition of gypsum flower is mostly controlled by rain water (Fig. 3)

6. Conclusions

The cave flower in the Okgye Cave is entirely composed of gypsum. Sulfur isotopic compositions of cave water, rain water, and stream water show similar ranges, but more enriched relative to those of pyrite in surrounding limestone. The sulfur isotope values of the gypsum flower in the Okgye Cave are more depleted than those of rain water and cave water, but much more enriched than those of the pyrite in surrounding limestone. Therefore, the sulfur in gypsum flower was supplied more by rain water than by pyrite.

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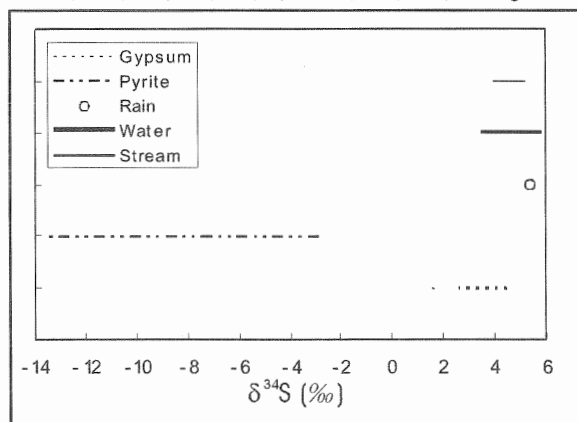


Fig. 2. Sulfur isotope composition from the study area. The relationship of gypsum speleothem, pyrite in the bedrock and different water samples for sulfur isotope composition.

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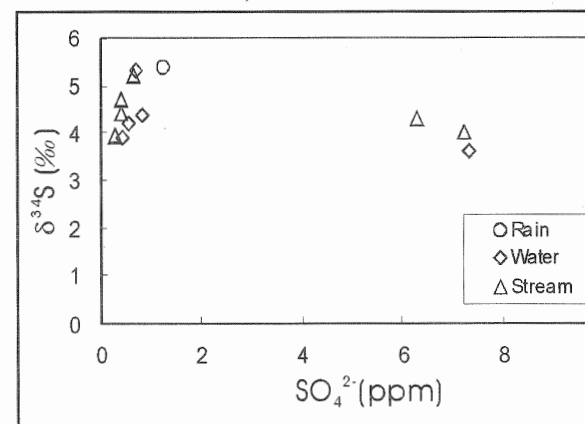


Fig. 3. Plot of the SO_4^{2-} contents vs. the sulfur isotopic compositions of rainwater, cave water, and stream water.

P-28

Origin and diagenesis of the cave corals in the lava tubes of Jeju Islands, KoreaLee, K.C.¹, Choi, D.W.², and Woo, K.S.²¹Department of Resources Engineering, Sangji University, Wonju, Kangwondo, Korea²Cave research Institute of Korea, Kangwon National University, Chuncheon, Kangwondo, Korea**Abstract**

Cave corals that have grown by groundwater seepage, can be found within the lava tubes (Jingaemot, Arirang, Susan, Mosimoru and Bilemot Caves) in Jeju Island, Korea. Unlike other speleothems in many lava tubes, these cave corals should have formed as secondary mineral deposits after the formation of the lava tubes. The mineralogy and formation process of these corals (commonly cited as siliceous sinter) are poorly understood. The cave corals in Jingaemot Cave are composed of opal-A, calcite and aragonite, whereas those in Susan, Mosimoru, Arirang and Bilemot Caves only consist of opal-A. Most cave corals show similar morphology to those found in many limestone caves, however, some of them show the form of anthodites in limestone caves.

The internal texture of the cave corals in Jingaemot Cave show alternated layers of aragonite and calcite. Calcite crystals show isopachous fibrous texture, and aragonite crystals show spherulitic fibrous texture. Most of the terminated portions of both crystals were replaced by opal-A along growth laminae, and replacing opal-A commonly retains relic crystals of calcite and aragonite. Corroded nature of the former carbonate crystals indicate that the growth of carbonate vs. siliceous minerals should have been controlled by the pH conditions of cave water from which they precipitated. Low Mg contents in the calcite may imply that aragonite precipitated due to high CO₃²⁻ contents rather than high Mg/Ca ratio in cave water. The mineralogy in cave corals and diagenetic process appear to have close relationship with chemical conditions of cave water that seeped through overlying carbonate soils and basaltic rocks, and the chemical conditions of cave water were mainly controlled by local climatic variations in the past.

Key word: Cave corals, lava tube, opal speleothem, diagenetic process, paleoclimate

1. Introduction

Jeju Island is the shield volcano formed by basaltic lava. The island contains about 127 lava tube caves which were formed by Quaternary volcanic activities (Cultural Properties Administration, 2003). In most lava tubes, various lava speleothems are present and they were formed during the formation of the lava tubes. Thus, they have the similar compositions like surrounding basalt. However, Jingaemot and Arirang Caves in Namwon area, Susan Cave in Seongsan area, Mosimoru Cave in Seoguipo area, Bilemot Cave in Aewol area, and Socheon Cave in Hanlim area includes cave corals which were formed by groundwater after the formation of the lava tubes. These cave corals have been called 'siliceous sinter' past a few decades by Korean cavers, and the origin and formation process is poorly known. The purposed of this paper is to delineate the formation process of the cave corals in the lava tubes of Jeju Island based on textural and geochemical data. This will aid to infer paleoenvironmental (paleoclimatic) changes.

2. Methods

Cave corals were collected from the Jingaemot and Arirang Caves in Namwon area, Susan Cave in Seongsan area, Mosimoru Cave in Seoguipo area, Bilemot Cave in Aewol area, and Socheon Cave in Hanlim area to examine the textural and geochemical characteristics. Collected samples were impregnated using epoxy resin and cut into two pieces, and the thin

section was made from one slab sample. Routine petrographic examination was carried out using binocular and polarizing microscope, and thin sections were stained with Feigl's solution to differentiate aragonite from calcite. Detailed texture was examined using low vacuum scanning electron microscope (LV-SEM; Hitachi S3500N) with energy dispersive X-ray analyzer (Horiba EDAX) after etching the polished slab samples with 0.01% formic acid for 10 to 15 seconds. Trace elemental compositions of cave water and cave coral were analyzed by ion chromatograph (Dionex DX-320) and inductively coupled plasma spectrometer (Leeman PS950). Mineralogy of the cave corals was determined using X-ray diffractometer (Philips Bruker D5005). Oxygen and carbon isotopic compositions were analyzed using stable isotope ratio mass spectrometer (VG Isotech, Prism II), and this was done at Korea Basic Science Institute. Analytical error range is $\pm 0.2\%$, and all the stable isotope values of water and carbonates in the paper are relative to SMOM and PDB, respectively.

3. Results**3.1 Morphology of Cave Corals**

Most cave corals are either white or transparent, and the size ranges from 0.5 to 0.6 cm. They are concentrated in the wall, ceiling, and floor in caves, from which groundwater seeps out. Cave corals can be six types according to their shapes. The flower type is about 1 to 2 cm long, and displays white color or transparent. It consists of acicular crystals, similar to the shape of anthodites in limestone caves. The size of the popcorn type varies from 0.5 to 0.6 cm in length and the type show various sizes. The tip of the crystals shows the shape of popcorn. The knobby type is about 0.8 cm long and the tip of the coral shows various shape and size of knobs. The arborescent type is about 0.8 to 1.5 cm long. It starts to grow toward one direction, but makes branches towards the tip. The cone type is 1 to 2 cm long. It starts to grow from one point (nucleus), and the crystals become wider making the cone shape. The mixed type shows two types of morphology: columnar or acicular below the pool level, but knobby shape above the water level probably due to the surface tension of water.

3.2 Textural Results

The cave corals in Bilemot and Susan caves are composed of opal, and those in Mosimoru Cave consist of interlayering of opal and calcite. Also, the cave corals in Arirang and Jingaemot Caves are composed of calcite, aragonite, and opal. Caves coral in Socheon Cave is entirely composed of calcite. The cave coral in Susan Cave is composed of opal and grew on the basalt with the thickness of 2 to 3 mm. Even though it is only composed of opal, corroded surface suggests that it was composed of carbonate mineral and replaced by opal. The cave coral in Mosimoru Cave is composed of calcite and columnar calcite with well preserve growth laminae is alternated with acicular calcite. Corroded structure with irregular boundaries due to the replacement by opal can be observed and calcite relic crystals are still preserved in replacing opal. The cave coral in Socheon Cave is composed of isopachous columnar calcite which is about 1 mm thick. The surface of the coral show irregular surface due to corrosion, and argillaceous material (clays?) are included near the tip of the crystals. The cave corals in the Jingaemot Cave, composed of acicular crystals, show the alternation of fibrous calcite and spherulitic-fibrous aragonite. Also, opal has pervasively replaced the carbonate minerals along the growth lines. Partially calcitized parts are observed in 1 mm-thick aragonite layer, and the neomorphic calcite shows equant texture. Spherulitic-fibrous aragnite

relic crystals are clearly visible in neomorphic calcite. Especially, numerous relic crystals of calcite and aragonite are present in opal, suggesting the opal is the replacement product, not the primary precipitate.

3.3 Mineralogy by X-ray Diffraction

All the cave corals analyzed show similar mineralogy. Except for the cave coral in Socheon Cave which is only composed of calcite, the cave corals in Jinggaemot, Susan, Mosimoru, and Bilemot Caves are composed of opal which shows the broad and irregular peak (15–30° 2 θ). The cave corals in Jinggaemot Cave are composed of calcite (29° 2 θ) together with opal.

3.4 Ultra-textural Results

Using the LV-SEM, three replacement types can be observed in the cave corals. The first type is the alternation of opal and calcite. In this case, spheroidal opal can be found along the surface of the acicular calcite. These spheroidal opal crystals coalesced to form the planar opal. The second type is the opal replacing fibrous calcite by cross-cutting the calcite crystals. Thirdly, replacement by opal occurs within the aragonite crystal maintaining the crystal boundary. This type is found only in the corals of the Susan Cave.

3.5 Geochemical Results

Trace elemental compositions of the cave waters in Susan, Socheon, Arirang, and Mosimoru Caves are listed in Table 1. All the caves with opaline cave corals (Arirang, Mosimoru, and Susan Caves) show that the pH values of the cave water are 6.1 to 6.7, which is slightly acidic. Ca and Si contents of the cave water in these caves are 1.4 to 3.6 ppm and 0.5 to 0.8 ppm, respectively, and show very little variation among caves. The Socheon Cave with calcite cave corals has the cave water whose pH ranges from 7.4 to 7.8. (slightly alkaline). Also Ca content of the Socheon Cave ranges from 62 to 66 ppm, which is significantly higher than that of other caves, however Si content is about 0.4 ppm, which is similar to that of other caves. This coincides with the idea of Wray (1999) that precipitation of opal may take place from the small concentration of Si ions in cave water.

Table 1. Trace element compositions and pH values of the cave water and stream water in Jeju Island JJ=Jeju, SS=Susan Cave, SC=Socheon Cave, AR=Arirang Cave, MS=Mosimoru Cave. (Unit: mg/L).

Carbon isotopic compositions of calcite in cave corals of the Jinggaemot

Sample No.	Water type	pH	Ca	Na	Mg	Si	K	Cl	SO ₄	NO ₃
JJ-1	Stream		27.4	23.6	12.9	4.7	4.3			
JJ-2	Stream		27.7	23.8	12.9	4.7	5.2			
SC-1	cave water	7.8	62.62	27.76	11.58	0.39	3.95	66.42	5.74	23.90
SC-2	cave water	7.4	66.18	16.82	11.09	0.44	1.82	44.29	3.33	17.62
SS	cave water	6.7	1.63	6.28	1.99	0.46	1.05	11.48	1.05	1.16
AR-1	cave water	6.5	3.55	4.60	2.27	0.45	2.76	8.58	2.36	5.44
AR-2	cave water	6.5	2.46	3.71	1.71	0.77	1.01	5.25	2.20	3.70
MS-1	cave water	6.3	2.41	2.48	0.69	0.45	0.91	2.99	1.52	4.18
MS-2	cave water	6.1	1.36	3.43	0.80	0.77	1.02	6.24	0.71	0.90

Cave range from -5.0 to -4.9 ‰. Carbon isotope composition of the C3-plants in Korea is about -26 ‰, and that of the carbonate sediments in Jeju Island is about 0 to 1 ‰. Thus enriched carbon isotopic compositions of the cave corals, compared to organic carbon, suggest that carbon was derived both from carbonate sediments which may have been overlying the cave in the past. From the simple mass balance equation, it is estimated that about 77–78 % of the carbon was derived from carbonate skeletons

and 22–23 % is from soil-derived organic carbon, assuming that $\delta^{13}\text{C}$ values of carbonate skeletons are near 0 ‰. Using the fractionation equation by Epstein et al. (1953), oxygen isotopic compositions of calcite, which is precipitated in equilibrium with water at the temperature of 15.5 °C (average temperature of the Jeju Island), should be about -9.3 ‰ (PDB). Thus, the oxygen isotopic compositions (-4.7–5.0 ‰) of the cave corals in Jinggaemot Cave are enriched by 4.3–4.6 ‰, relative to equilibrium values. This may suggest that evaporation process have played the major role for the precipitation of calcite.

4. Discussion

The cave coral of the Jinggaemot Cave was originally composed of the alternating layers of calcite with well-developed growth laminae and spherulitic-fibrous aragonite. For the growth aragonite vs. calcite, it has been known that Mg/Ca ratio or saturation state (CO₃²⁻ content) control the mineralogy. Mills (1965) and Hill and Forti (1997) suggested that the alternating growth of aragonite and calcite resulted from the pH variations of cave water due to the change of evaporation rate. If this is the case for the cave corals in Jinggaemot Cave, growth laminae along with corroded texture should be expected. Conformable growth of calcite to aragonite and its cyclic occurrence suggest that the chemical conditions of the cave water have changed cyclically. Also, replacement of carbonate minerals by opal also indicates the chemical change of cave water, which probably resulted from the environmental changes outside. The cave corals in Socheon Cave, composed only of calcite, were formed by carbonate-enriched cave water, which was supplied by meteoric water buffered with the overlying carbonate sand dunes. The buffering with the carbonate sediments increased the pH of groundwater. Cave corals in Socheon Cave have grown by evaporation of cave water, accompanied by pH increase and saturation state.

Most cave corals investigated in this study grows from thin film of water covering on the surface of cave corals, except for the cave corals in Socheon Cave growing in small rimstone. When cave water entered into the cave, rapid degassing of carbon dioxide and evaporation will result in the precipitation of calcite. As far as the supply rate of water is constant, precipitation of calcite will increase the Mg/Ca ratio of the thin film of water (>2:1) and aragonite will precipitate. If the water supply increases, this will lower the saturation state as well and Mg/Ca ratio, calcite will be formed again.

When the carbonate sediments, present over the Bilemot, Susan, Arirang, and Jinggaemot Caves were removed (re-transported) possibly by wind, meteoric water began to react only with overlying soil (weathered basalt). No buffering with carbonate sediments took place, and rainwater penetrates into the cave only after the reaction with the soil. This cave water has lower pH, thus decreased the solubility of Si, and promoted the replacement by opal. Also, the precipitation of carbonate minerals followed by opal replacement can also be explained by the amount of rainfall. When rain fall was small (thus less humid climate), rainwater had enough time to buffer with overlying carbonate sediments, and increased pH and carbonate contents of cave water will result in the precipitation of carbonate minerals. As the amount of rainfall increased, rapid infiltration of rainwater through the carbonate sediments and overlying soil will be less buffered and have lower pH, thus resulting in the replacement by opal.

5. Conclusions

Cave corals in the lava tube caves in Jeju Island can be divided into 6 types according to morphology, however their internal texture show the similar pattern. Most caves also show the similar diagenetic pathways in cave corals, that is, the precipitation of carbonate minerals followed by the

replacement by opal. However, if the large amount of carbonate sediments is present over the lava tubes, cave corals are only composed of calcite. The diagenetic change appears to be closely related to the environmental change outside the caves, that is climatic fluctuations in the past.

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Biodiversity and ecology of cyanobacteria in a variety of hypogean ecosystems (Greece)

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Abstract

Species composition, distribution and ecology of cyanobacterial populations have been studied in hypogean ecosystems of three types: i) karst caves, ii) metal burdened mines and iii) early Christian Catacombs excavated in pumice stone. The cave of Nympholypton (Attica) is a small natural cave of archaeological value naturally lit through the entrance whereas the karst cave of Perama (Ioannina) has been touristically developed and artificial light facilities have been installed. The mines of Larymna and Lavrion are overburdened with heavy metals e.g. Ni, Cu, Pb, Cr, Zn, and Fe. The early Christian Catacombs of the island of Milos have been excavated in pumice stone. According to the microscopic analysis of natural and cultured material the composition of cyanobacteria, differs in these three unique hypogean ecosystems. In their inner sites where adequate light was available, over forty taxa were identified so far. The diversity of cyanobacteria was significantly correlated to the amount of light and to the chemistry of the substrate. The alkaline nature of the substrate in case of karst caves favor the proliferation of cyanobacteria which reach lush epilithic growths in inner natural and artificially lighted sites. On the other hand, the acidic nature of the substrate in the case of Catacombs and mines, in addition to the toxicity of the heavy metals present in the mines, restrict the cyanobacteria diversity and growth.

Key words: Caves, mines, catacombs, hypogean ecosystems, cyanobacteria, diversity, ecology

Introduction

Karst caves, heavy metal mines and catacombs, represent specific hypogean ecosystems where abiotic and biotic factors are in a delicate equilibrium. Light, humidity, temperature, input of nutrients and chemistry of the substrate are considered the most important environmental factors in such ecosystems (Pantazidou 1997, Albertano and Urzi 1999, Wilkens et al. 2000). However, anthropogenic interventions are sometimes made. For example, artificial light is installed in the caves for touristic development and various treatments are applied for conservation purposes, catacombs are restored and heavy metals are exploited from the mines. Considering all the above, the internal conditions of the hypogean ecosystems are affected. These changes consequently influence the established

delicate equilibrium (Lefevre and Laporte 1969, Cubbon 1976, Leclercq et al. 1983, Albertano 1993, Iliopoulou-Georgoudaki et al. 1993, Pantazidou 1996, 1997, Pantazidou et al. 1997, Elliott 2000).

Because of the low light conditions, the hypogea represent hostile environments with low diversity of photosynthetic communities. However, the area near the entrances and the artificially lighted sites usually support extensive growths of cyanobacteria, eukaryotic algae and bryophytes (Hernandez-Marine et al. 2003). The physicochemical properties of the substrate (pH, rock substance, porosity) also affect the diversity of the phototrophs and the composition of the microbial communities (Anagnostidis and Roussomoustakaki 1988, Pantazidou et al. 1997, Pentecost and Whitton 2000). Some of these organisms play an essential role in the hypogean ecosystems, both by contributing to the alteration of the rock surface and by taking part in food chains (Allen 1972, Iliopoulou-Georgoudaki et al. 1993, Pantazidou 1997, Albertano and Urzi 1999, Hernandez - Marine et al. 2003).

In the present paper the species composition and distribution of cyanobacteria in three hypogean ecosystems (karst caves, heavy metal burdened mines and early Christian catacombs excavated in pumice stone) is presented. The work has been carried out aiming at a taxonomic and ecological study giving information on the cyanobacteria which usually form biofilms and mats in the hypogean ecosystems and play an important role as partners of their microcosmos.

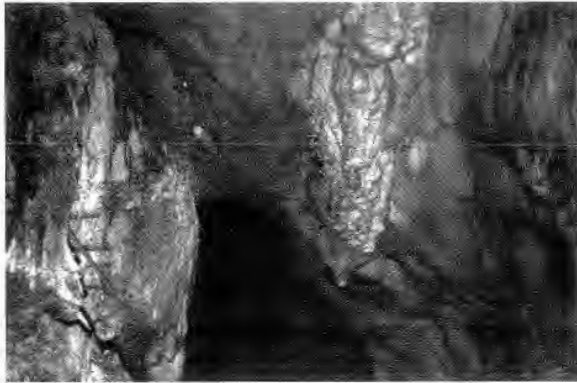
Materials and methods

Study area

Hypogean ecosystems of three types: i) karst Caves (C1, C2), ii) heavy metal burdened Mines (M1, M2) and iii) Milos Catacombs (MC) from continental and insular Greece, were studied. All -as hypogea- are characterized by low light conditions but there are also some differences.

Cave Perama (C1)

Cave Perama is located on a hill called Goritza at an altitude of 480m, near Ioannina. It covers an area of 14,800 m² and its corridors run to a length of 100m. It is one of the most beautiful horizontal caves in the Balkans and among the largest in Greece. It is adored with 19 different types of stalagmites and stalactites in curious shapes and size including the only



stalagmite in the world in the shape of a "Cross". Another unique characteristic of the cave is the fact that its chambers and galleries lie in three different levels. There are also picturesque small lakes. This cave, which belongs to a part of subterranean river, was formed about 1500000 years ago. The cave was discovered accidentally in 1940 and was equipped with facilities for touristic purposes e.g. light installations in 1956 (Anagnostidis et al. 1982, Petrocheilou 1984, Iliopoulou-Georgoudaki et al 1993).

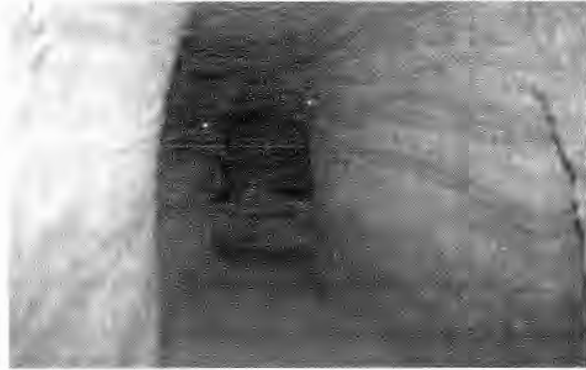
Cave Nympholyptos (C2)



The Cave Nympholyptos is located on the southern slopes of Hymettos Mountain, at an altitude of 270 meters, Attica, Greece. It consists of one main chamber divided into two halls by a wall formed out by columns. It has poor stalactite and stalagmite decoration. It is a small natural cave of archaeological value. The sculptor Archedamos transformed the cave into a temple (ca 5th century BC). On the stalagmite walls, he engraved himself as well as a decorated altar, shelves for the offerings and a divinity seated on a throne. On the floor a pool was dug to collect rainwater leaking through the mouth of the cave (Petrocheilou 1984). The cave, in spite of its archaeological and cultural value, is more or less abandoned. It is not artificially lighted but naturally lit through the entrance since it is open to the external environment (Pantazidou 1997).

Milos Catacombs (MC)

The investigated Catacombs (early Christian) are situated in the northern part of the volcanic Milos island, Greece. They are located at a hillside, approximately 300 meter above the sea level. The main group of Catacombs has been excavated in soft pumice stone and consists of a hypogean network of three, chambers and corridors 184 meters long, 1.0 to 5.0 m wide and 1.7 to 2.5 m high. Many small, open and ruined «Catacombs» are scattered at the area around the Catacombs. The indoor



environment is characterized by high humidity -the relative air humidity ranges from 68% to 89%. The average air temperature ranges from 18 to 24 °C and the pH of the substrate is around 6-6.5 (Pantazidou et al 1997).

Heavy metal Mines (M1, M2)

The investigated mines Lavrion (M1) and Larymna (M2) are located at Attica and Boeotia respectively (Greece). They consist by a wide network



of wet tunnels and corridors. The mining material in Larymna is iron-nickel ore; in Lavrion, an abandoned mine, a complex of ochre, limonite, galena iron-pyrites-sphalerites is present, while the pH is slightly acidic (Anagnostidis & Roussomoustakaki 1988).

Sampling - Cultures - Microscopy

Samples from various lighted sites (entrance area, artificially lighted inner parts of caves, catacombs and mines), were collected under sterile conditions the last twenty years. Part of the material was fixed in 3% formaldehyde solution and part was kept alive for culturing and examination under light microscopy.

For culture purposes selected material was put in flasks or petri dishes with Z (Staub 1961) and BG II (Stanier et al. 1971) media, liquid or solidified with 1,1% agar. In the laboratory, cultures were incubated in an environmental chamber with fluorescent light at 22 °C+1. After 3-4 weeks, cyanobacteria from the mixed cultures were transferred to fresh media. Fresh (wild and cultured) as well as fixed cyanobacteria were studied under Zeiss Light Microscope (LM) and Jeol Scanning Electron Microscope (SEM). The identification of the cyanobacteria was based on the taxonomical works of Geitler (1932), Komarek and Anagnostidis (1986, 1989), Anagnostidis and Komarek (1988).

Results and discussion

A total number of 44 Cyanobacteria were found in the investigated hypogea (Table I). The cyanobacteria, in general, form very thin patches and biofilms in most sampling sites. Growths of cyanobacteria were easily detected near the entrances and at artificially lighted sites.

Only in Perama Cave (C1) luxurious growths with high cyanobacteria diversity (31 taxa) were observed. In Nympholyptos Cave (C2), although the diversity was rather high (24 taxa), the growths were seen in thin patches or in thin biofilms. The other two hypogean, the mines (M1, M2) and the Milos catacombs (MC) were characterized by low cyanobacteria diversity (11 taxa in mines and 4 in catacombs). Thin coatings or extensive mats (e.g. mats of *Ph. subfuscum*) were found.

Thus, a first conclusion is that the main difference between the three types of hypogean ecosystems affecting the cyanobacteria diversity seems to lie on the characteristics of the substrate. The calcareous, alkaline nature of the substrate, -the case of the C1, C2- favors the proliferation of cyanobacteria where the light is adequate. On the contrary, the acidic nature of the substrate (the case of Milos catacombs and mines) and the toxicity of heavy metal burden (case of mines) make the latter hypogean environments extremely hostile for cyanobacteria, restricting their growth. The higher number and the extensive growth of cyanobacteria found in cave Perama comparing to those found in cave Nympholyptos may be attributed to the results of the touristic development of the former e.g. light installations help in development of the phototrophs.

The coccoid and/or colonial Chroococcales (25 taxa) and the filamentous, not heterocytous, Oscillatoriales (16 taxa) dominate. Only 3 heterocytous (Nostocales) were found. In the caves (C1, C2) Chroococcales (23 taxa) outnumber Oscillatoriales (13 taxa). Similar observations have been reported by Asencio and Aboal (2000). The restricted number of cyanobacteria observed in the metal burdened hypogea (M1, M2) and in Milos catacombs (MC) does not allow us to draw a clear conclusion on the proportion of Chroococcales/Oscillatoriales.

In addition to the thin Oscillatoriales, referred on Table I, we found various thin filamentous cyanobacteria resembling *Leptolyngbya* which were very difficult to determine. Such forms need further investigation using additional studies e.g. 16S rRNA.

The genera *Chlorogloea*, *Cyanosarcina* and *Eucapsis* (Chroococcales), *Leptolyngbya* and *Phormidium* (Oscillatoriales) were present in all three types of the investigated hypogea. Among the filamentous cyanobacteria, *Leptolyngbya* and *Schizothrix* were the genera observed in most samples. The most frequently found species were *Aphanocapsa biformis*, *Aphanothece nidulans*, *Chlorogloea microcystoides*, *Gloeocapsa kuetzingiana*,

Leptolyngbya foveolarum and *Plectonema gracillimum*.

Gloeocapsa biformis, *Gl. kuetzingiana*, *Chroococcidiopsis kashaii*, *Pseudocapsa dubia*, have been also found in hypogea by Asencio and Aboal (2000). *Aphanothece castagnei*, *Aph. saxicola*, *Chlorogloea microcystoides* are also referred by Anagnostidis et al. (1982), Dor and Dor (1999). *Scytonema julianum* has been frequently referred from hypogea (Anagnostidis et al. 1982, Iliopoulou-Georgoudaki et al. 1993, Aboal et al. 1994, Pantazidou 1996, 1997, Albertano and Urzi 1999, Asencio and Aboal 2001). Thus, the aspect that these cyanobacteria are among the most common hypogean dwellers is justified. Further investigation on the ecological and physiological demands and role as well as the specifications of these cyanobacteria at the species level could provide useful information.

It is worth noticing that Oscillatoriales form hormogonia, which move by gliding and can colonize new sites in the hypogea. Thus, the "greening", the common phenomenon, problem in artificially lighted caves (see in Lefevre and Laporte 1969, Iliopoulou-Georgoudaki et al. 1993) is promoted by these cyanobacteria.

On the other hand, it must be noticed that most of the coccoid cyanobacteria found, produce thick mucilaginous sheaths (the taxa are marked with an asterisk * on Table I). The sheaths help them to attach to the inorganic substrates and simultaneously the ensheathed cyanobacteria offer a new organic substrate allowing further colonization by other microorganisms. The sheaths favor the aggregation of mixed populations forming various types of mats. They are hygroscopic and protect the cyanobacteria against desiccation and provide advantage to survive in extreme conditions.

In general, the knowledge of hypogea cyanobacteria is restricted. Caves are those who provide a better source for information at this level. The alkaline nature of the substrate in case of karst caves favor the proliferation of cyanobacteria which reach lush epilithic growths in inner natural and artificially lighted sites. On the other hand, the acidic nature of the substrate in the case of catacombs and mines, in addition to the toxicity of the heavy metals present in the mines, restrict the cyanobacteria diversity and growth.

Acknowledgments

Part of this research was supported by the special account for research grants of the National and Kapodistrian University of Athens (NKUA) grant 70/4/5717.

Table I. List of Cyanobacteria found in the Caves Perama (C1) and Nympholyptos (C2), Mines Larymna (L1) and Lavrion (L2) and Milos Catacombs (MC).

los Catacombs (MC).

Taxa	Investigated Hypogean ecosystems				
	C1	C2	M1	M2	MC
Cyanobacteria					
Chroococcales					
<i>Aphanocapsa biformis</i> *	+	+			
<i>Aphanothece castagnei</i> *	+				
<i>Aphanothece microscopica</i> *	+				
<i>Aphanothece nidulans</i> *	+	+			
<i>Aphanothece saxicola</i> *	+				
<i>Chlorogloea microcystoides</i> *	+	+		+	+
<i>Chlorogloea sp.*</i>		+			

<i>Chroococciopsis doonensis</i>		+			
<i>Chroococciopsis kashaii</i>		+			
<i>Chroococcus minor*</i>	+				
<i>Chroococcus minutus*</i>	+				
<i>Chroococcus turgidus*</i>		+			
<i>Cyanosarcina burmensis</i>		+			
<i>Cyanosarcina sp.</i>		+	+		+
<i>Eucapsis minor</i>	+	+			
<i>Eucapsis sp.</i>				+	
<i>Gloeocapsa bififormis*</i>	+				
<i>Gloeocapsa gelatinosa*</i>	+				
<i>Gloeocapsa kutzingiana*</i>	+	+	+		
<i>Gloeothece palea*</i>	+				
<i>Gloeothece sp*</i>	+	+			
<i>Pseudocapsa dubia*</i>		+			
<i>Synechococcus elongatus</i>	+				
<i>Synechocystis aquatilis</i>	+				
<i>Synechocystis sp.</i>				+	+
<i>Oscillatoriales</i>					
<i>Heteroleibleinia kutzingii</i>	+				
<i>Leibleinia epiphytica</i>	+	+			
<i>Leptolyngbya boryana</i>			+	+	
<i>Leptolyngbya foveolarum</i>	+	+	+	+	
<i>Leptolyngbya lurida</i>	+	+			
<i>Leptolyngbya nostocorum</i>	+				
<i>Leptolyngbya tenuis</i>	+	+	+		
<i>Oscillatoria terebriformis.</i>	+				
<i>Phormidium corium</i>	+	+			
<i>Phormidium subfuscum</i>			+		
<i>Plectonema gracillimum</i>	+	+			+
<i>Pseudanabaena lonchoides</i>	+	+			
<i>Schizothrix coriacea</i>	+	+			
<i>Schizothrix cf. heufferi</i>			+		
<i>Schizothrix lardacea</i>	+		+		
<i>Spirulina tennerima</i>	+				
<i>Nostocales</i>					
<i>Nostoc sp.*</i>		+			
<i>Scytonema julianum *</i>	+	+			
<i>Tolypothrix distorta</i>	+	+			

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P-30

Endolithic and epilithic cyanobacteria from thermal spring travertine and spring-related caves (Greece)

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The carbonate-supersaturated water of several hot springs of Greece forms, due to precipitation, travertine deposits around their vents. Samples were collected from a variety of sites at travertine deposits and spring-related caves of certain saline hot springs (56-600C) of Aedipso. Microflora communities of these unique ecosystems have been poorly investigated. Microscopic analyses of fresh and cultured material as well as SEM examinations revealed that the communities develop into epilithon or endolithon on the studied surfaces. Cyanobacteria is the major aerobic, oxygenic, phototrophic component of the communities investigated. The samples contained a wide diversity of cyanobacteria and few diatom frustules. Chlorophytes or other phototrophs were not detected. Over 20 coccoid, colonial and filamentous cyanobacterial taxa were identified. Certain morphotypes of the genera *Aphanocapsa*,

Chroococcidiopsis and *Chlorogloea* exhibit taxonomic and ecological interest. So far, taxa with extracellular calcium carbonate precipitation were not found. Consequently, cyanobacteria do not promote carbonate precipitation and the studied travertine deposits are abiotic (abiogenic) precipitates. Cyanobacteria growths seem to be important in localizing sediment particles and stabilizing previously deposited travertine since the majority of the taxa present secrete sheaths. Cyanobacterial sheaths being extracellular polymeric substance (EPS) are a protective and adhesive material that anchors cells, colonies and filaments to the substrate surface. Exopolymers directly promote the accretion and preservation of microbial growths, which in turn favor sediment trapping. Consequently, cyanobacteria are not passive associates in the microflora communities of travertine deposits studied. Key words: Cyanobacteria, diversity, ecology, travertine, thermal springs and caves

P-31

Distribution behavior of cave fauna according to cave environmental change: An example from the Limestone cave in Korea

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Cave environments can be divided into four subenvironments such as entrance zone, twilight zone, unstable dark zone with variable temperature and stable dark zone with constant temperature. Unstable dark zone refers to the dark zone whose environment can change under the influence of overlying surface environment. All of the fauna tend to live in their own

zones according to their living habits and adaptation to darkness. Triglobite (including stygobite) groups are dark zone dwellers without eyes and pigments. Troglophile (including stygophile) groups are dark zone dwellers with eyes or pigments. Troglaxene (including stygaxene) groups can be categorized into three subgroups such as entrance zone dwellers, twilight zone dwellers and regular cave visitors based on different distribution behavior according to cave environmental changes.

P-32

The "Greening" of Koutouki touristic cave (Attika, Greece). The Importance of the Cyanobacteria

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Koutouki is a large touristically important cave and the most impressive in Attica. It is located on the slope of Mt. Hymettos and its entry shaft is 38.5 m deep. Beyond that it opens up into a single huge cavern subdivided into sections linked by corridors with rows of columns, stalagmites and stalactites. The cave has been touristically developed since 1962 when an artificial entrance and corridor leading to the interior were opened. Artificial lights were installed for the visitors' convenience. To find out the impact of human interventions on the biodiversity, physiognomy and biodeterioration of cave ecosystem, samples were collected during the years 1989-2005. Sampling of microflora and substrate was carried out from various lit sites under sterile conditions. Field observations have shown that its lit inner surfaces support a multitude of phototrophic organisms. The installation and proliferation of rich and diverse photosynthetic organisms were due to the environmental conditions i.e. the adequate level of light and water supply. Cyanobacteria and chlorophyte assemblages as well as bryophytes, were visible with the naked eye. The vegetation covering extensive lit surfaces caused an aesthetic alteration of the cave's appearance resulting in the «greening» of the cave. The microbiological analysis of cave phototrophs (fresh and cultured material) under light microscope revealed that

rich epilithic and endolithic phototrophic microbial communities cover the lit surfaces consisting of cyanobacteria, chlorophytes, diatoms, as well as bryophytes. From the collections of the period 1985-1998 thirteen species of cyanobacteria were determined while from those of the period 2000-2005 nine species were detected. The consequences of the installed flora on the substrate were studied under SEM. The examinations revealed that cyanobacteria were present not only on the surface (epilithic) but also in micropores and between crystals (endolithic). The epilithic, filamentous nitrogen fixing cyanobacterium *Scytonema julianum* present in all collections, tends in the last years to cover extensive dim lit surfaces, and promotes the precipitation of calcium carbonates since it has the ability to precipitate CaCO₃ around its sheaths. Thus, we further studied its bioactive molecules and its antibacterial activity. The lipids of *S. julianum* were extracted, isolated, purified, determined and then tested for their biological activity. Our results showed that, *Scytonema julianum* contains a phosphatidylcholine (C16:0/18:2), even though bacteria very seldom include choline-containing phosphoglycerides. Additionally, two types of biologically active phospholipids were detected. These findings enrich our knowledge about this species and may prove useful to the field of chemotaxonomy. The antibacterial activity of the lipids was tested against certain pathogen bacteria.

P-33

Bryophytes at lamps in selected public caves in the Czech Republic - past and recent situation

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Bryophytes growing close to lamps in regular use were studied in show caves. Data were collected in 2004 in five caves open to the public: Balčarka Cave, Kateřinská Cave, Javoříčko Caves, Punkva Caves, and Sloup-Šošůvka Caves. All of them are situated in Moravia (the Czech Republic). They are formed in Devonian limestone. The cave environment has an even temperature and high air humidity. Previous investigations of the lamp flora were done in the 1960s-70s. The management of show caves (illumination,

chemical removal of plants) has changed since that time. This paper compares the bryophyte lamp flora in the 1960s-70s and the present one. During the previous investigations 51 bryophytes (only mosses) were recorded. In 2004 only 35 mosses were recorded. Overall, 36 % of the bryophyte flora remains the same as in the past. 64 % of the bryophyte flora is different. *Amblystegium serpens*, *Brachythecium velutinum*, *Fissidens taxifolius* and *Leptobryum pyriforme* were frequently observed both in past and in the present.

P-34

Flora and Fauna of Armenian caves

H. Ghazaryan

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Flora and Fauna of Armenian caves Hrach Ghazaryan Armenian Speleological Center Abstract In work the data received as a result of studying of numerous caves of Armenia are resulted. Studying reveals riches of forms

of speleofauna and set of the specific microorganisms adapted to dwelling in conditions of caves. Special interest represents studying cave settlements of the person in territory of republic.

P-35

Speleology in Armenia

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Abstract

Speleology in Armenia Vahan Ter-Khazaryan Anahit Harutunian Armenian Speleological Center Abstract Speleology in Armenia is quite new phenomenon, while the science which studies spelaeon set up from the early palaeolith and comes on till the last quarter of the 20th century. Consequently Armenia can be considered one of the basic hearths of cave

(spelaeon) archeology, where work (research) has recently started. Nearly 95% of the caves of Armenian mountainous island (mountains of Armenia) contain archeological subject-matter. The mentioned scientific field of this biblical country is very important for research and it is considered to the world-wide culture.

P-36

Speleology in Armenia

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Abstract

From the cave dwelling to the surface mounted housing block Ashot Grigoryan Armenian Speleological Center Abstract One of the important conditions for the human existence is his or her living area: inhabited environment. The initial stage of the inhabited area is a natural cave-dwelling. In this natural environment were formed sizes and proportions which form and secure horizontal, vertical, spacious and practical sites of the house and environment. This firstly characterizes perception of the space by the human body sizes and psychological understanding of the environment, in a direct way, as living space. One of the natural measure forms of human body is a shrinking position, however for the living surroundings it is necessary to take into consideration not only minimal convenience. For

the solution to this problem the best proportional unit can be measures of a lying and standing man, during which stretched arms and legs measures should be taken into account. This conventional space conditioned by the man's physical size can be considered initial. And for a more convenient state of the living area from the point of rise (standing man) one step forward, left, right, back as well as state of stretched arms and legs, which will be considered as "comfortable" precondition from the point of view of horizontal measures, while in vertical case: two man sizes or one man size and man's jump up are necessary. What about the space itself, it is regarded more efficient if it provides one family, at least, and one clan at most, and if the area gives an opportunity for a number of such dwellings, here we have an example of the inhabited area.

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P-37

Investigation of Zagedanskaya in the honor of A.V. Alexeev cave system (North Caucasus)

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Abstract

The results of the speleological investigations in 1995-2001 in the earlier unexplored area of Zagedan-Urup karst massif of Abishira-Akhuba mountain ridge (North Caucasus - Karachaj-Cherkessian Republic, Russia) are presented. There was founded and explored rather large cave system named "Zagedanskaya in the honor of A.V. Alexeev" (amplitude is 570 m (+19/-551), longways 5500 m). The description and the history of exploration of the cave system are presented. The tracing of the cave stream allowed us to discover the cave discharge spot (Atsgara vauclisian spring), located at interval of 6 km. We support the discovered karst system joins all the largest caves in the massif.

honor of A.V. Alexeev". Mr. Alexeev was one of leaders of Saratov caving. He was one of the pathbreakers in the caves of Zagedan massif during our first expedition in 1995, and was died in a car accident in 1996.

Geology and geography of Abishira-Akhuba mountain ridge and Zagedan-Urup karst massif

Abishira-Akhuba ridge is located on N.-W. Caucasus, between Bolshaya Laba and Bolshoj Zelenchuk rivers, being a part of the Lateral Ridge and is located in parallel of the Main Caucasus Range. Abishira-Akhuba ridge being separated from the Main Range by Arkhyz-Zagedan tectonic depression.

Introduction

In the last decade of the 20th century former Soviet cavers were cut off from the deepest Abkhazian caves because of the military conflict in Abkhazia. It is given a good impulse for the investigation in caves located in Russia. In result, several new large were found and explored in the "old" N. and W. Caucasus regions (Mt. Fisht plateau, Mt. Dzheniu massif, and Abishira-Akhuba mountain ridge, mainly). One of the new cave systems was found and explored by our team in Abishira-Akhuba ridge (Gusev et al., 2000; Lipchenko et al., 2004). It was named "Zagedanskaya in the

In the tectonic attitude Abishira-Akhuba ridge represents the asymmetric anticline lasting from northwest on a southeast more than on 30 km. The axis of an anticline is displaced to the north from the watershed line of a ridge having marks about 3000 m a.s.l. The southern slope of an anticline abruptly falls aside Arkhyz-Zagedan depression, the northern one hollow goes down aside North-Jurassic depression. The ridge has been shattered into separate blocks of various orientation in Hercynian stage of mountain formation. It tested a raising in the subsequent mountain formation epoch, as a result of which active processes came to life again.

Tectonic processes in aggregate with river erosion and activity of

ancient glaciers have predetermined modern orography of Abishira-Akhuba ridge. Its southern slope is dismembered poorly. Traces of an ancient congelation are expressed here by the small sizes relicts karrens which have placed at altitude above 2750 m a.s.l.. Northern slope is dismembered by the river valleys on spurs. The spurs stretch to the northeast direction and has extent from 5 up to 30 km.

The highest points of a ridge are peaks with marks about 3200 m a.s.l. Glacial forms of a relief (circuses, valleys, karrens) are developed on a watershed line of Abishira-Akhuba ridge and its northern spurs. Heads of the rivers flowing down on northern slope had glaciers in length from 6 up to 18 km with capacity of an ice up to 300 m. Circuses meet on a watershed part of a ridge is more often. Top from its have merged in the uniform cirque. It stretches along the ridge in the form of a trench, representing a chaotic heap of blocks, rocks and taluses. The bulk of sloping snow tongues, feeding the rivers of northern slope (Kjafar-Agur, Kjafar, Chilik, Malyj Urup, Atsgara, Bolshoj Urup) concentrates here. Age of a hydrographic network of Abishira-Akhuba ridge is earlier than Ice Age. Channels of the basic rivers used lines of dumps or axes of syncline folds.

Paleozoic metamorphosed volcanogenic-sedimentary thickness and magmatic rocks take part in a geological structure of a high-mountainous part of Abishira-Akhuba ridge. The most ancient characterized sedimentary rocks in riverheads Urup are Paleozoic (D3-C1) limestones of Dzheniu series. Its stretch along a watershed line of Abishira-Akhuba ridge from Bolshaya Laba river up to Bolshoj Zelenchuk river. The area has a complex structure with a lot of explosive infringements of various directions, depths and ages.

Stated testifies to an opportunity of development a powerful underground karst here. Favorable geological (the pure limestones, tectonic breaches), climatic (an abundance of deposits and presence of an ancient congelation), and geomorphological (monocline seam of rocks) conditions to promote one.

Zadegan-Urup karst massif is located on the western spur of Abishira-Akhuba ridge to the north from the Main Caucasus Range. The massif is separated from the main part of Abishira-Akhuba ridge by Atsgara river valley. West boundary of the massif is Zadegan Mountain, south one is a watershed crest, and north one is Urup Mountain. Surface limestone extends from Zadegan Mountain on the west to Atsgara river to the east. Its length is 8 km and width from 0.5 up to 2 km, altitudes are 1900-3100 m a.s.l. The highest point of the massif is Skala Orlov ("Cliff of Eagles" Peak, 3102 m a.s.l.).

Atsgara and Urup rivers watershed divides Zadegan-Urup karst massif by the west and the east parts. The east part of the massif include Lagernoe plateau (the deepest cave of the plateau is Gorlo Barloga (3000 m/900 m), it is the deepest cave in Russia), Rostovskoe plateau (Rostovskaya Cave System, 4650 m/550 m) and Atsgarinskoe plateau. The west part include Urupskoe plateau (Gorynych Cave, 680m /-383 m) and Zagedanskoe plateau (fig. 1). Explorations of Zagedanskoe plateau are described in this paper.

Zagedanskoe plateau is a westest plateau of the massif. The area of one is about 1 km². The western border of the plateau is the Zadedan Mountain spur, the eastern one is the steep slope to the Urup river valley. Surface karsted rock at the plateau extends from the mountain ridge top (altitude 2740-2800 m a.s.l.) in the northern direction toward Urup river. Limestone goes under an non-karsted rock on the

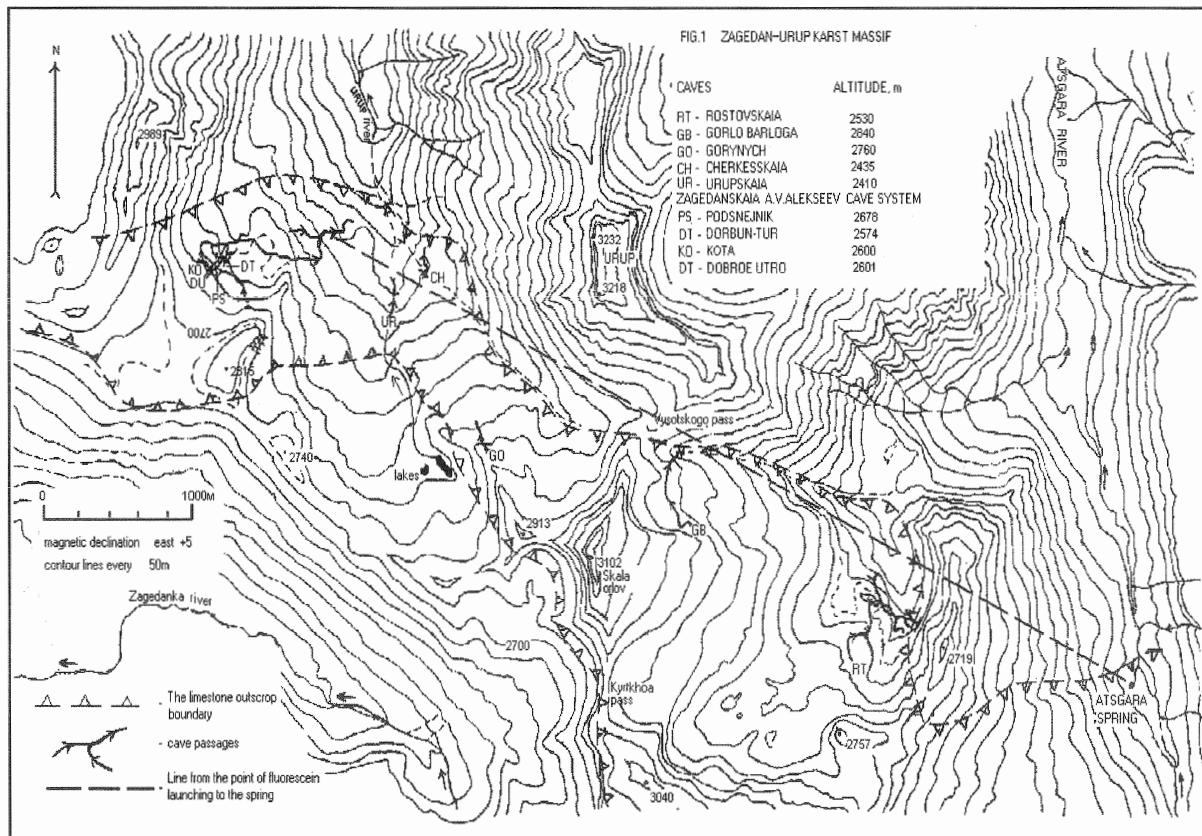


Figure 1. Zagedan-Urup karst massif.

2400-2450 m a.s.l. altitude. Capacity of the karsted rock at the plateau nearly 220 m, the slope is 30-40 degrees with an azimuth is about 0.

There are more ten cave entrances on the Zagedanskoe plateau are known now. All entrances are on the 2500-2700 m a.s.l. altitude. The main ones are marked by greek letter "Ψ". Five entrances was united into a cave system.

Morphology of Zagedanskaya cave system

Zagedanskaya in the honor of A.V. Alexeev cave system have amplitude is 570 m (+19/-551), total length is 5500 m. The system includes 5 caves: Podsněžnik ("Snowdrop", Ψ-1), Dorbun-Tur ("Round Cave", Ψ-2), Ψ-14, KOTA (Ψ-22) and Dobroe Utro ("Good morning", Ψ-3). The altitudes of the entrances are presented in the fig. 1.

The system is divided on the two main parts by morphology. The first part (Podsněžnik Cave) is a dry, more ancient labyrinth with huge rock-slided halls and large passages. A lot of deposits and accumulated formations are observed here. The second, more younger and irrigated part is a channel for modern underground drain. Dorbun-Tur, KOTA and Dobroe Utro caves are the tributaries of the river-bed. This division is clear illustrated in fig. 2. There are two levels of cave development exist. The first (I) is an old dry level inside of limestone. The second (II) is a young irrigated level along lower boundary of a karsted rock. The length of the passages for level (I) is nearly 2 km, the one for level (II) is nearly 3.5 km.

The cave system develops both in the north (vertical and sloping passages) and the east (horizontal passages) directions. Podsněžnik entrance is the uppermost one of the system. Its altitude is 2678 m a.s.l. The entrance is disposed nearly upper boundary of a large sloping snow tongue. The snow tongue have a size nearly 350x120 m. It is a basic spring of nutrition of a system underground drain. The upper part of Podsněžnik cave is a large (diameter 3-6 m) sloping tunnel was named Truba (The Tube). On the -120 m depth it results in a system of rock-slided halls. From this system of halls a lot of passages are begun (Rukavit'sy (Passage of Mitten), Leoshin (Passage of Alexey), Syrnj (Cheese Passage), Obez'yanka (Monkey Passage), and others). Truba is united with a lower part of the cave in two places, through P44 (the largest pit of the cave system) and P21. The lower part of the cave is an irrigated (nearly 10 l.p.s.) meander. It has several small pits. A length of meander is 700 m. We named it "Tropa normal'nykh geroev" (Normal Heroes Path). The end of the meander is a deepest point of Podsněžnik cave (-320 m). It is an irrigated narrowness named Oksankin laz (Manhole of Oxana). In this place Podsněžnik and Dorbun-Tur caves are connected.

Cave Ψ-14 is a narrow vertical 30-m chink entered in Zal Snezhnogo Os'minoga (Snow Octopus Hall). Usually the Ψ-14 entrance is blocked up by snow.

The entrances of Dobroe Utro, KOTA and Dorbun-Tur caves are along lower boundary of the sloping snow tongue. The Dorbun-Tur cave entrance is a lowest one of the Zagedanskaya cave system (2574 m). It begins as series of narrow dry low-sloping passages. The last passage results in the first pit of Dorbun-Tur cave. The 150-m series of irrigated pits of Dorbun-Tur results in meander. In this place (-330 m from Podsněžnik cave entrance) Dorbun-Tur cave stream (5 l.p.s.) is connected with Podsněžnik cave one (fig. 3). Long (the length is about 800 m) quasi-horizontal part of the cave is developed from this point to the east direction. It is an irrigated (30-40 l.p.s.) passage with the several inputted poor (less 1 l.p.s.) inflows. This part have a complex morphology. It is a combination of narrow passages, small halls, projections, siphon manholes, and wide meanders. Semi-siphon (length 4.5 m, air layer 10-15 cm) is located in 250 m from the beginning of the passage. A narrow unexplored siphon is located in 200 m further than the semi-siphon. An entrance to the upper dry level of the cave was found near the siphon. Next 300 m in the cave were explored by the second level (these levels are local ones, different from global levels of the cave system discussed above).

The second level is a narrow dry passage in a clay. There are no de-

posits here, however, we found looses of calcium crystals on the floor. Morphology of the third (upper) level named Vudu Gallery quite different from the second level. Numerous original deposits (excentric stalactites and helictites) are located here.

There are four expanded artificially passages (length 6-15 m), named as "dry siphones", are located in the local drops of the second level passage. Its were real siphones in the past. Second level passage comes to the 11-m pit after the fourth dry siphone. An ascending meander (length 230 m) was found in the top of the pit. The bottom of the pit is a first (lower) level. It is an irrigated (about 40 l.p.s.) gallery goes to the east direction to the last siphon manhole. The path turns to north direction after the man hole. The cave develops by the contact with a bottom non-karsted rock here. This is a high inclined (30-40 degrees) gallery with several projections, named Chiornaya Truba (Black Tube). It is finished as a series of irrigated pits. A hall, named Vishniovyj Liker (Cherry Liquor Hall), were found in the bottom level of the series of pit. There are some paths from the hall. Basic water stream falls away in stones in the bottom of a last 10-m pit. This point is a bottom of the cave system (-551 m). Three passages beginning in Vishniovyj Liker hall were explored. Short descending passage comes to the siphon. The level of the siphon is approximately equal to the bottom of the cave. Two horizontal meanders (length 200-250 m) were explored to the narrow chink in a clay and to the ascending pit, accordingly. At least two last paths are perspective for the further investigation (fig. 3).

Zagedanskaya cave system is a sufficiently cold cavern. Temperature measurements were carried out in Dorbun-Tur Cave, basically. Air temperature grows since +0.2°C in the up of the first pit in the cave (-50 m from the Dorbun-Tur Cave entrance) to +1.0°C in the beginning of the horizontal part (-220 m). Summer air temperature in the first hall in Podsněžnik Cave (+4.6°C) is not constant and depends from a ground air temperature.

Zone of supply of Zagedanskaya cave system is an upper part of a ridge, and the basic source is a large sloping snow tongue. Old borders of the sloping snow tongue are traced by features of a relief. As well as a glacier on Mt. Fisht plateau, the sloping snow tongue was greater size in the past. A valley with precisely expressed channel of the significant surface water stream, coming to an end as ponors on altitude is about 2500 m a.s.l. It gives the instruction on existence on Zagedanskoe plateau of one more large cavity located below on a slope.

History of exploration

Idea of investigation in Zagedanskoe plateau was advanced by O. Tsoy in 1993-1994. Zagedan-Urup karst massif was a poor investigated speleological region with a indefinite speleological potential. Exploration of the massif was begun in 1983. Urupskoe plateau were explored firstly. Caving investigations went to the east direction later. The most western Zagedanskoe plateau was unexplored, in result. Rostovskaya Cave was a deepest one (depth -550 m) on the massif in 1995.

First expedition by leadership of O. Tsoy was carried out in August, 1995. It had an investigated purpose. The team includes four cavers from Penza and Saratov, only. Lagernoe, Rostovskoe, Atsgarinskoe, and Urupskoe plateaus were examined. Basic investigation was carried out on Zagedanskoe plateau. Two large caves were found here. Podsněžnik Cave was studied to the chink on -110 m depth. Dorbun-Tur Cave was explored to the irrigated pit on -90 m depth. Expedition shows a perspective of the caves on Zagedanskoe plateau.

Four cavers from Penza (leader is O. Tsoy) took part in the second expedition in August, 1996. However, three cavers left the plateau soon after beginning of the expedition because of a serious disease with one of cavers. In result, O. Tsoy investigated the caves alone. He stopped near the end of a vertical part in Dorbun-Tur Cave (-210 m), and in the system

of halls in Podsnezhnik Cave on -190 m depth. Entrances in Dobroe Utro and KOTA Caves were detected.

No cavers from Penza and Saratov could go in an expedition in August, 1997. However, large experienced caving team from Moscow (Moscow University, mainly) by leadership of A. Shelepin visited the caves in agreement with O. Tsoy. The team works on Mt. Fisht plateau in 1993-1996 (Reisner and Shelepin, 1997). Numerous passages (Rukavitsy, Leoshin, Syrnyj, Obez'yanka, and others) were explored in Podsnezhnik Cave. Cave "Ψ-14" was found and connected with Podsnezhnik Cave. Most interesting result in Podsnezhnik Cave was obtained in "Khod 1997 goda" (Path 1997). Ultimately narrow chink stopped the cavers in -320 m level in only 30 m by horizontal from Dorbun-Tur Cave. Cavers working in Dorbun-Tur Cave explored a subhorizontal high irrigated part of the cave. The expedition was stopped on an excavation of the second dry siphon. In result, total length of the caves reaches 2.5 km, a general water stream was found, but the caves were not united in a cave system.

The problem of association of the caves in uniform system was reached on joint Moscow-Saratov expedition (leaders are A. Shelepin and O. Tsoy) in August, 1998. Searches of connection of the caves were conducted both from Podsnezhnik and Dorbun-Tur Caves. In Podsnezhnik Cave researchers found the new site, named "Tropa normal'nykh geroev" (Normal Heroes Path). It was the longest and complex path to a bottom part of the cave. However, during its pathfinding it was possible to connect both caves. Thus there was rather improbable event, two independent groups of cavers were in different caves, have heard each other. The established voice communication helped to pass through the narrow passages and to meet in a small Zal Vlyubionnykh (Hall Enamoured) on depth -320 m from the top entrance of the system. In Dorbun-Tur Cave was completed an excavation of the dry siphons (the underground camp

was established). Cavers came to the pit which has deduced again on the irrigated level. Further has begun inclined, high irrigated Chiornaya Truba (Black Tube), to pass which up to the end it has prevented lack of time and equipment. There was explored KOTA Cave, on depth -75 m incorporated with Dorbun-Tur Cave and become by the fourth entrance in the system. Thus, as a result of the expedition in 1998 on Zagedanskoe karst plateau there was a large cave system with total length 4.5 km and amplitude of 465 m, with four entrances and free continuation in several directions.

Cavers from Moscow (leaders are A. Shelepin and A. Rychagov), Saratov (leader is O. Tsoy), Penza, and Ufa took part in the next expedition on the plateau in August, 1999. One of the basic purposes of the expedition was a definition of a cave system underground water unloading place. Tracing of a cave water stream using a fluorescein has been lead (see below). In Dorbun-Tur Cave a series of high irrigated pits was explored. The depth of the system of -546 m was reached. In Podsnezhnik Cave a number of new passages (Aktiniya (Actinium Passage), Kol'tso (The Ring Passage), and others) were found. There is passed connection Dobroe Utro Cave (-115 m) with Dorbun-Tur Cave that has added the fifth entrance in the cave system.

Small expedition of Moscow and Saratov cavers (leaders are A. Gusev and O. Tsoy) was carried out in August, 2000. Researches were conducted in a bottom part of Dorbun-Tur Cave. Two from several passages were explored in Vishniovyj Liker hall. A siphon stopped investigators in the short (50 m) descending passage, and a narrow chink in a clay stopped ones in the horizontal (length 250 m) meander.

Seven cavers from Orenburg (leader is V. Samsonov) has continued an exploration in the final expedition in August, 2001. Two new meanders were found in Dorbun-Tur Cave. The first is an ascending 230-m meander in the top of 11-m pit after the fourth dry siphone. The second is a horizon-

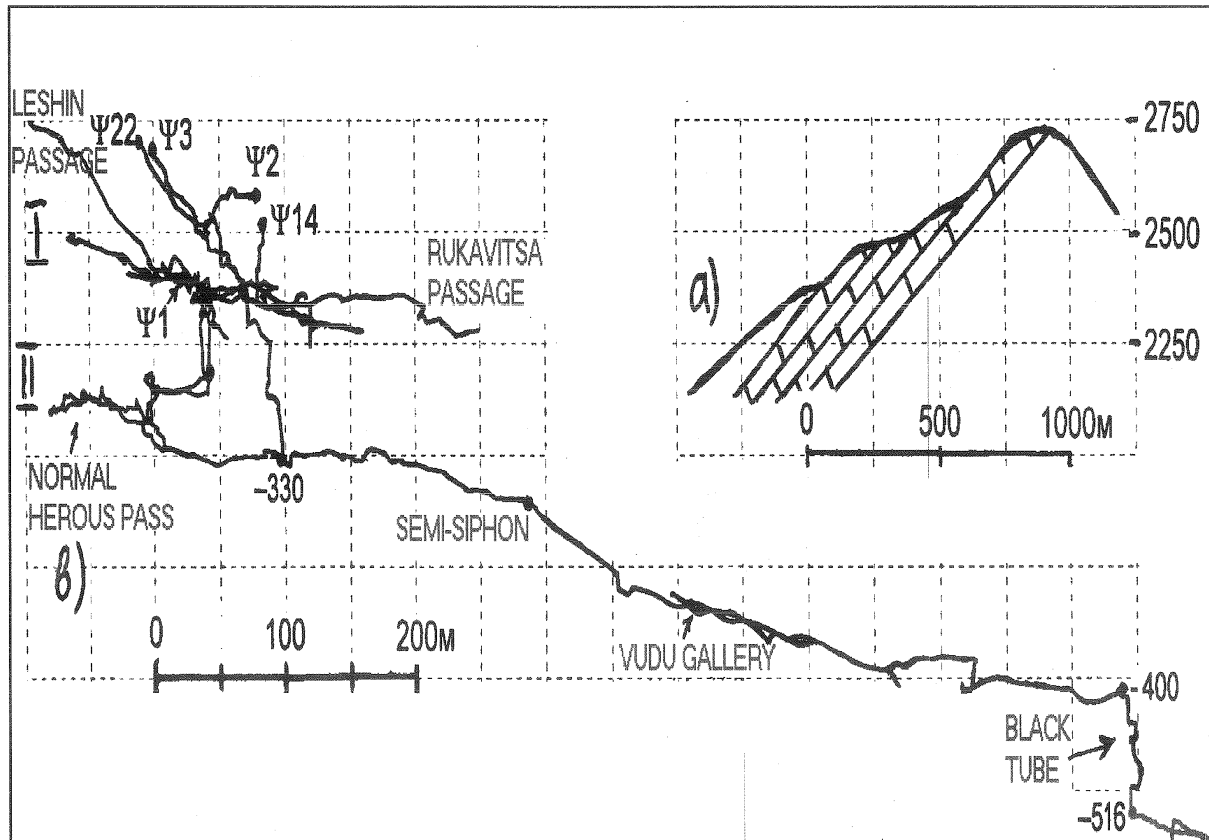


Figure 2. Position of karsted rocks (a), levels of the cave system (b).

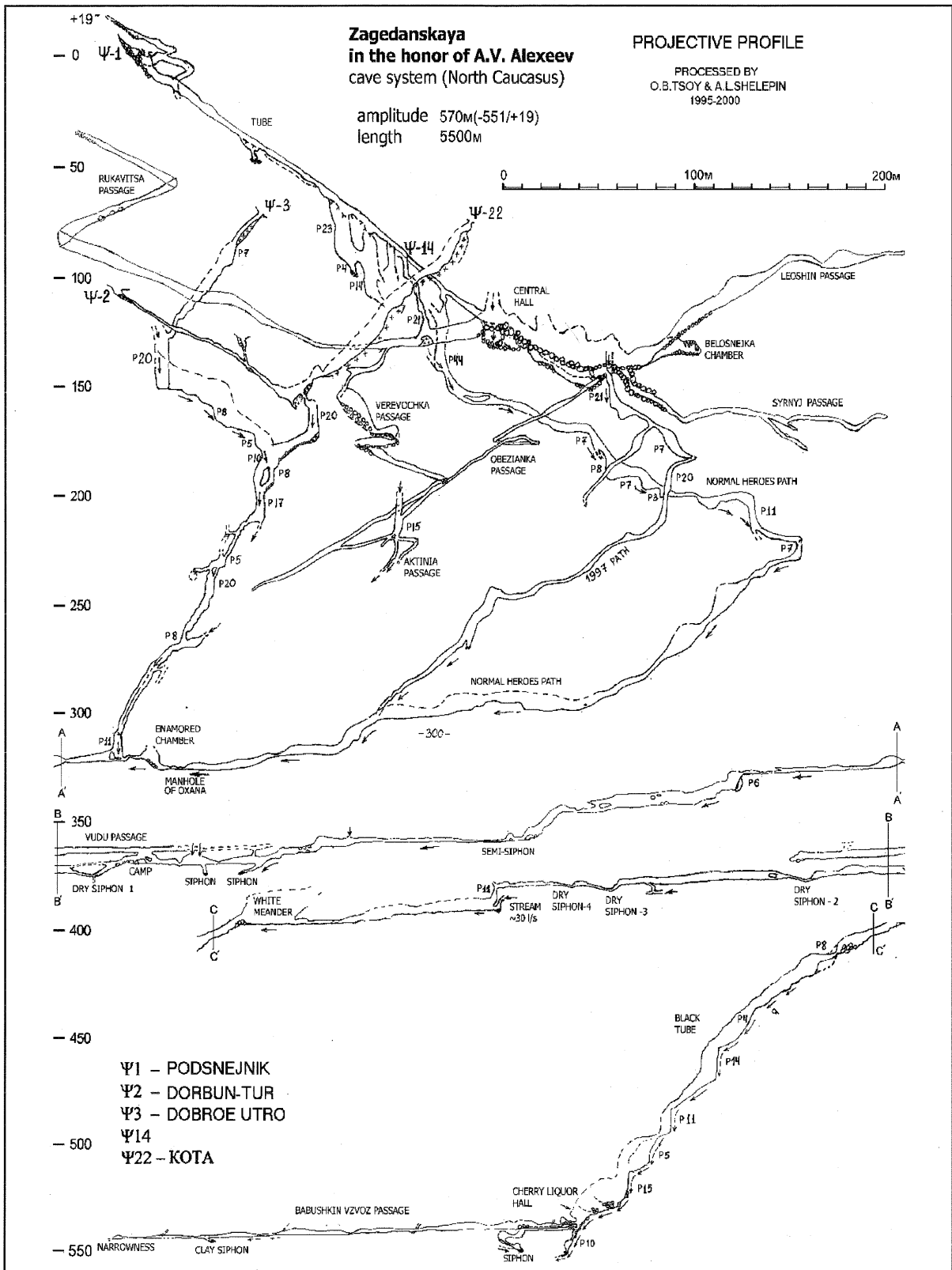


Figure 3. Projective profile of the cave system.

tal 200-m passage in the bottom part of the cave. It comes to an end with the ascending pit. Topo of the last passage was not done. So, an explored part of the cave system has longways 5700 m (it is on 200 m more, than data officially presented by us).

Tracing of the cave stream and hydrology of the massif

The question on unloading underground streams of Zagedanskoe plateau up to 1999 remained opened. The nearest significant surface water stream is Urup river. Falling of karsted layers is directed to Urup river valley. The charge of water in Zagedanskaya cave system at an altitude of 2118 m a.s.l. (nearly 30 l.p.s.) is comparable to the charge of Urup river source appearing in 750 m to the north from a stony talus at 2100 m a.s.l. altitude. Presence of several surface water streams above Urup river source, the several streams flowing into the talus, and also existence of some caves (Urupsкая, Gorynych, Cherkesskaya) with significant water streams in area allowed to doubt that unloading of caves water streams of the plateau occurs in Urup river. The nearest large vauclose (Atsgara river spring) is in 6 km on a straight line from the east edge of Zagedanskoe plateau, at altitude about 1900 m a.s.l. An unloading of Zagedanskaya cave system water stream here is unevident, as the stream would pass under a watershed of Urup and Atsgara rivers in this case.

For the decision of the question an experiment on tracing a cave system water stream was carried out in August, 1999. Fluorescein (1 kg) was mixed with NaOH (1 kg) and diluted up to water (5 lts). The solution has been started in a stream of the last pit in Zagedanskaya cave system (-540 m) at 7 p.m., 20.08.99. The charge of a stream was estimated as 30 l.p.s. Traps were placed on all nearest significant surface water streams 2-4 days prior to the experience (Urup river, altitude 2000 m a.s.l., projective distance to the end of Zagedanskaya cave system is 2 km; Urup river, altitude 1900 m a.s.l., distance 3 km; Zagedanka river, altitude 1500 m a.s.l., distance 4 km; Atsgara river vauclose, altitude 1922 m a.s.l., distance 6 km; Gorlo Barloga Cave, altitude 2000 m a.s.l., distance 3 km).

The traps represented porous kapron packings with 2.5-3 gr (10-12 tablets) the activated coal. Packings were located in the open plastic cylinders (length 8 cm, diameter 2 cm), having apertures on the surface. 3 traps (1 control, and 2 skilled) were established in each point. Control traps have been removed before a fluorescein start, and skilled ones have been removed from both Urup river points at 12 a.m.-1 p.m., 23.08.99, from Zagedanka river point at 10 a.m., 24.08.99, and from Atsgara river vauclose at 2 p.m.-3 p.m., 23.08.99. The traps have been placed in individual polyethylene packages and transferred in laboratory of Saratov State University. Standard technique was used for the analysis: tests were located in 5% alcohol solution of KON, presence of fluorescein was defined both visually and spectrophotometrically.

Output of the water stream dyed in green color has been noted visually by several observers before the removing of the traps from Atsgara river vauclose both in vauclose and in 2-3 km below on current Atsgara river. Unfortunately, duration of an fluorescein output has not been fixed. It has occurred between 2 p.m. and 3 p.m.. So, the traps have lain in the dyed stream of less hour. We estimate an upper level of a fluorescein concentration value in a stream is 0.1-0.8 mg.p.l. (considering a debit of a source is about 2 m³/s and duration of dye output is 10-60 min.). This fluorescein concentration quite allows to define its presence in a stream visually.

However, a presence of fluorescein in an alcohol solution of KON has not been found both visually and using spectrophotometer. The result of the analysis of tests has been explained by laboratory experi-

ment. The traps similar used, were located for various time in different concentration fluorescein solutions. The experiment showed that a necessary concentration of fluorescein in traps must be 1-10 mg.p.l. and endurance of a trap in a solution must be more than 1 hour for reliable identification of presence of fluorescein.

The received results testify, that Zagedanskaya cave system water unloads in Atsgara river vauclose. As the terminations of other large caves of area (Gorynych Cave, Urupsкая Cave, Cherkesskaya Cave, Gorlo Barloga Cave, Rostovskaya Cave) are not further 200 m on a straight line from a line connecting places of start and an output of dye, it is possible to assume, that all of its represent uniform karst hydrologic system (fig. 1). Its characteristics (distance on a straight line is about 6 km, a water stream gradient is 0.12, time of passage of dye is 67-68 hours) are close to results of experiments with the colouring, lead in other areas of Caucasus and in Crimea (Dublyanskij et al., 2002). Velocity of a water stream (2.1 km per day) is equal to a typical water stream velocity in Proval Cave - Krasnaya Cave and Mar-Khosar Cave - Krasnaya Cave hydrosystems in Crimea.

Conclusions

Prospects of the further passage of the cave system are kept. There are some perspective places for the further researches in a ground part of the cave system. Potential of increase in amplitude of the cave system is about 200 m and one of increase in extent of the system is more than 6 km. Prospects of a finding of higher entrances in the cave system are improbable, because an altitude of pass only on 40 m above the upper point of the system. Existence of one more large cavity on the plateau below Zagedanskaya cave system is possible. So, the cave system and the region require the further investigation.

Acknowledgements

The authors are grateful to the cavers from Moscow, Saratov, Penza, Orenburg, and Ufa who took part in exploration of the cave system. We would like to thank Prof. V.N. Dublyanskij (Perm) for helpful consultations.

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ICE CAVES OF PRIOLHONIE /Eastern Siberia, Russia/

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1. Introduction

Priolhonie is situated in the central part of the western shore of Lake Baikal (Fig. 1), geographical position is N 52°30' – 53°30' and E 106°20' – 107°50', the altitudes vary from 460 to over 600 m a.s.l. The region considered is confined by the Primorsky Range on the West and by the Lake Baikal on the East. The area is situated in front of the biggest island of Baikal – Island Olhon, that is the reason of it is named Priolhonie.

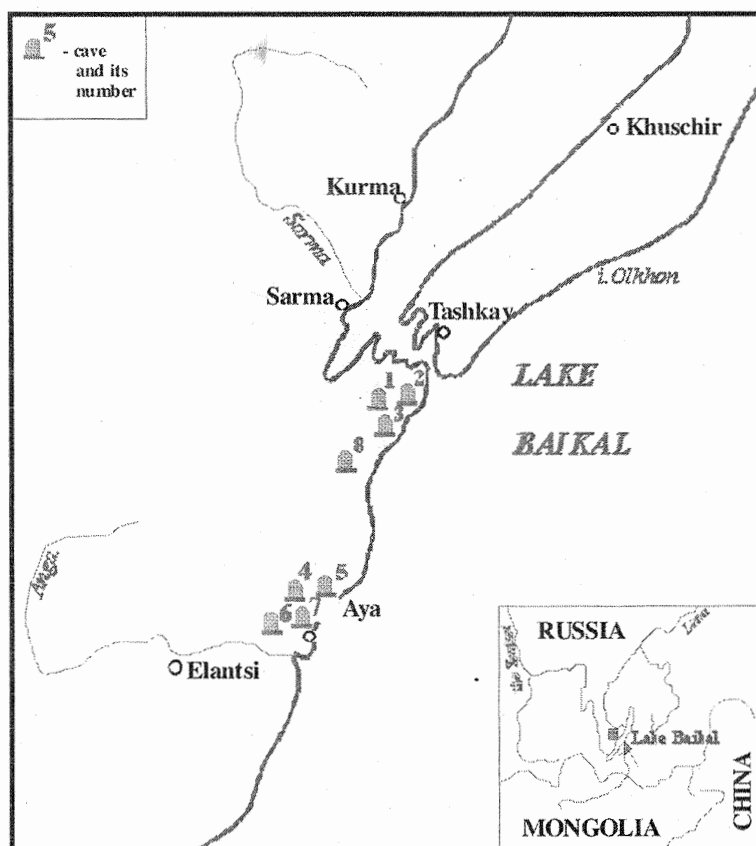


Figure 1 Region of explorations: Caves and its number: 1 – Bolshaya Baidinskaya, 2 – Malaya Baidinskaya, 3 – Mechta, 4 – Ryadovaya, 5 – Oktyabrskaya, 6 – Iya, 7 – Vologodskogo, 8 – Skotomogilnik

The relief of Priolhonie is a typical hummocky topography: gently smoothed out forms of local watersheds (at 350-380 m above the level of Lake Baikal), divided by the dry trough-shaped valleys which have low concave sides and flat bottoms with a width of 300-600 m. By geostructural signs the area belongs to the Sayano-Baikal fold belt. Metamorphic complexes from the Archaean-Lower Proterozoic, consisting of gneisses, amphibolates, schists, marbles and calciphyres, are folded in structures of NE direction. Karstic rocks, represented predominantly by the marbles, have a thickness of strata from 1 to 200-250 m.

Climatic peculiarities are defined by two main factors: the huge water volume of Lake Baikal and the Primorsky Range. Average annual temperature of the air is negative: -0,4°C, the duration of frost-free period is 124 days. The Primorsky Range (maximum absolute altitudes are 1500-1600 m), blocks the predominant western and nord-western winds and detains the moisture of air mass. Therefore the least precipitation in the whole Lake Baikal basin falls in Priolhonie: 182 mm in year, 95 % - in warm season and 5 % - in cold part of the year. Along the shore of Lake Baikal, approximately 3

km in land, snow cover is observed during a cold season only in negative forms of microrelief. The power winds with a velocity of up to 40 m/s in November and December are the reason of this phenomenon. The deep freezing of the soil occurs due to the lack of snow.

8 caves with snow and ice formations are situated within the area considered. The caves are called Bolshaya Baidinskaya, Malaya Baidinskaya, Mechta, Iya, Ryadovaya, Vologodskogo, Oktyabrskaya and Skotomogilnik (Fig. 1).

All underground cavities are disposed near the coastal escarp of Lake Baikal, at the altitude of 300 m above the level of the lake. Morphometric characters of the caves and volumes of its glaciation are represented in Table 1.

Ice caves of Priolhonie

Table 1

Name	Number (see the Fig. 1)	Length	Depth	Volume, m ³	
		m		cave	ice
Bolshaya Baidinskaya	1	45	11	600	120
Malaya Baidinskaya	2	55	8	180	8
Mechta	3	823	52	8500	70
Ryadovaya	4	450	57	2500	3
Oktyabrskaya	5	80	20	290	2
Iya	6	578	32	1200	3
Vologodskogo	7	46	17	350	12

Cave Skotomogilnik wasn't investigated completely.

2. Genetic and morphological peculiarities of cave ice formations

Ice cave observations in Priolhonie are accomplished from 1976.

The caves considered are characterized by wide spread of snow and ice formations. Seasonal ice is formed in places where the summer temperatures of the air rise above 0°C. It is either near cave entrances or inside underground systems under fissures or under roofs situated near the surface. Perennial ice formations are developed in places where average annual temperatures are negative and summer ones are near to 0°C. Underground cavities can be divided into 3 types, according to the origin of the coldness and accumulation of snow and ice in the caves.

Cold caves with a sack-shaped morphology, Bolshaya Baidinskaya, Malaya Baidinskaya, Mechta, Ryadovaya and Oktyabrskaya are grouped in the *first type*. These caves are characterized by the descending winter type of air circulation. Formation of ice is due to the freezing of water which comes into cavity through the fissures, as well as forming from the air through the process of sublimation. In origin they are congelation and sublimated ice. Snow-banks made as a result of accumulation of snow in underground cavities after snow-storms, as well as the falls of ice sublimated crystals are responsible for formation of deposited and metamorphosed ice near entrances, and in Bolshaya Baidinskaya also between upper and lower halls. In its turn the snow-banks play an important role in supporting coldness in cavities.

Ice stalactites, stalagmites and stalagnates formed as a result of supply of water-droplets in zone of negative temperatures are wide-spread in caves of the type considered. Seasonal ice stalactites and stalagmites have been noted every year near the entrances in caves Bolshaya Baidinskaya (Fig. 2A), Malaya Baidinskaya, Mechta, Ryadovaya, as well as in big halls inside both Baidinskaya and the Throne hall in Mechta. Forms and sizes of ice droplets are distinguished by considerable variety. Conic, complicated, keel stalactites and complicated stalagmites occur (description of the forms of stalactites and stalagmites is given in line with [3]). According to data of long-term observations the biggest stalactite was registered in May 1996 with the length of 1,0 m, diameter near the foundation of 55 cm – in Khoroshikh hall in Bolshaya Baidinskaya. Usually the sizes of seasonal ice stalactites in Bolshaya Baidinskaya and Mechta are not more than 0,5 m, and stalagmites not more than 0,3-0,4 m, but in Malaya Baidinskaya and Ryadovaya correspondingly 0,25-0,30 and 0,03-0,10 m. In Ryadovaya the ice droplets thaw by July, in both Baidinskaya and Mechta - by August. The intensity of the thaw is 0,38-0,40 cm per day. Perennial ice stalactites, stalagmites and stalagnates have been recorded in Mechta and Bolshaya Baidinskaya. The following ice formations have been revealed: conic, complicated, keel stalactites, stalagmites-drum sticks, complicated, large ice-mass under stalactites. The following stalagnates (column) have also been observed: conic from below, swollen in the middle part, with a large ice foundation and stalagmites: Ice stalactites reach a height of 1-1,5 m, stalagmites – 2-2,5 m. Of special note are the huge stalagnates in Mechta, with a height of more than 3 m and diameter near the foundation of up to 1 m.

The position of seasonal and perennial droplets indicates the direction of fissures along which the underground waters penetrate into cavity.

Aufeis-layers forming under supply of liquid water in parts of cavities, frozen below 0°C, are wide-spread on the horizontal and subhorizontal areas in Mechta, both Baidinskaya, Ryadovaya and Oktyabrskaya. Seasonal aufeis-layers have been fixed near entrances in all caves researched. Areas of these aufeises not exceeding 8-10 m², they thaw completely by July. Perennial aufeis-layers are developed in Mechta, Bolshaya and Malaya Baidinskaya. The area of aufeis body in Mechta reaches to 200 m², in Bolshaya Baidinskaya to 50 m², in Malaya Baidinskaya to 20 m², ice depth varies from 0,1 to 0,4 m in all caves. Aufeis in Mechta is characterized by hydro-carbonate-calcium composition with mineralization 118 mg/l.

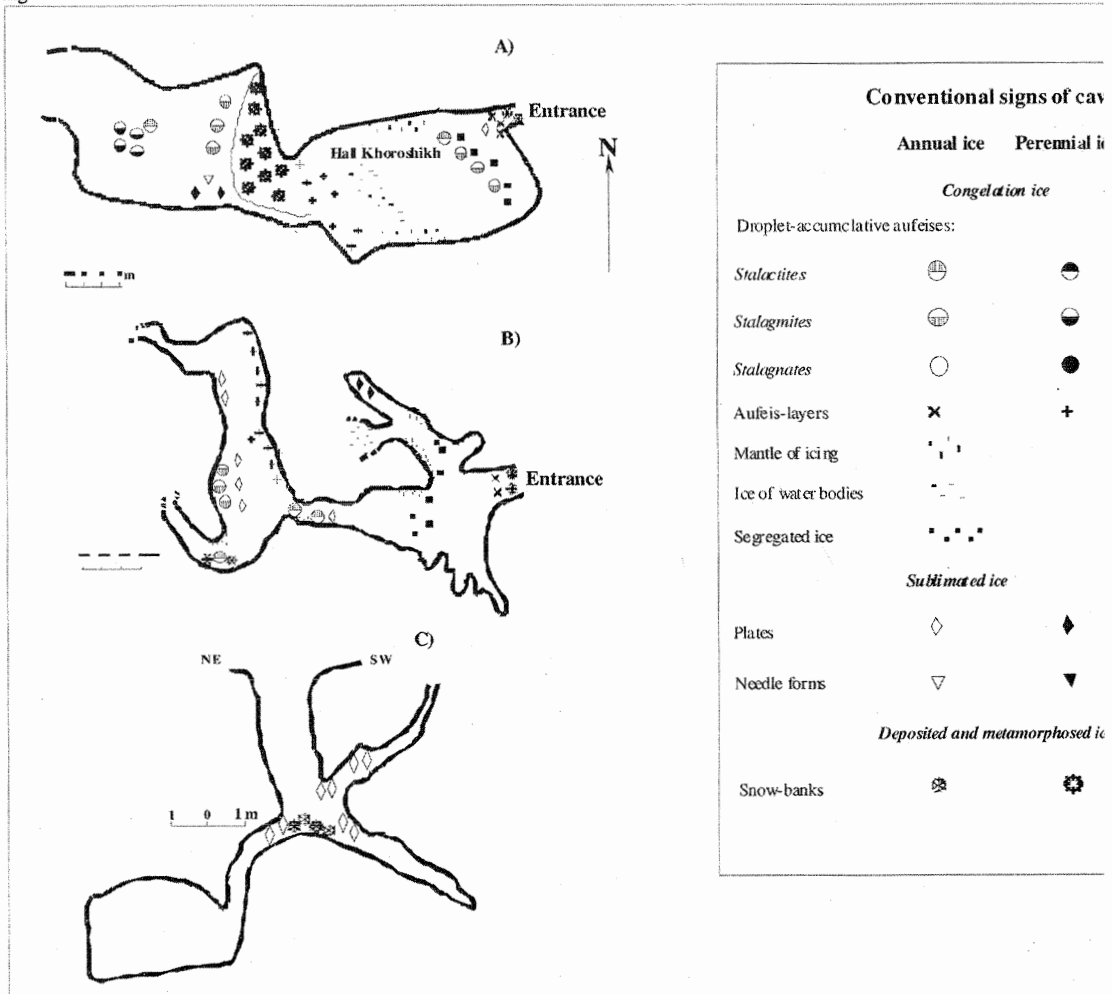


Figure 2 Cave ice of Priolhonie: A – Bolshaya Baidinskaya, B – Iya, C – Vologodskogo

In cold period of the year in Bolshaya Baidinskaya, Malaya Baidinskaya, Mechta and Ryadovaya condensed-congelation ice has developed. Inverted distribution of air temperatures in underground systems conditions the formation of this ice. For example, the vertical gradient in Bolshaya Baidinskaya in the winter season is 0,8-1,4°C per 1 m. Condensed moisture forming in upper parts of the walls and on the roofs of underground cavities flows down and

freezes in the zone of negative temperatures. The mantle of icing with depth 5-15 cm, as well as ice conic stalactites with a length of 15-20 cm and diameter near the foundation of up to 5 cm are formed in the lower parts of passages in caves considered.

Small lakes of 15-20 cm depth are situated in Bolshaya and Malaya Baidinskaya and Mechta, the sizes of the lakes are 4,5 x 2,2, 2 x 1,5 and 5 x 1,5 m respectively. They freeze in winter. Seasonal segregation ice forming under slow chilling of ground have been found at the bottom of upper halls in both Baidinskaya.

Seasonal and perennial crystals of underground hoarfrost are widely represented in caves Mechta, Bolshaya and Malaya Baidinskaya, Ryadovaya and Oktyabrskaya. Crystals are formed as a result of the fall of atmospheric moisture on the surfaces with a temperature below 0°C. Seasonal formations have been noted near entrances in all underground cavities considered, they thaw completely at the beginning of the summer. Perennial crystals have been registered directly near perennial aufeis-layers in both Baidinskaya and Mechta: on the one hand, humidity of the air is supported by sublimation of ice and on the other hand, a zone of negative temperatures is set up near perennial aufeis-layers. The latter defines the minimum thaw of ice crystals. Sizes of crystals change during the year, maximum ones are noted from March to June. Usually the ice crystals have a form of the hexahedral plates, maximum sizes are 3-4 cm in diameter. Hoarfrost in the shape of needles with a height of 0,3-0,5 cm have been observed in Bolshaya Baidinskaya only. Spring snow-banks with volume of snow-icy accumulation up to 5-15 m³ have been noted in Bolshaya and Malaya Baidinskaya, Mechta, Ryadovaya and Oktyabrskaya. They thaw by June. A perennial snow-bank made by snow, firn and ice is disposed in Bolshaya Baidinskaya, ice depth is 8,2 m, volume is 110 m³. Remains of malacofauna found in lower part of snow-bank date it from Pleistocene-Holocene [4]. Question about origin of this snow-bank is being discussed.

Cave Iya is one of the second type, thermoventilated one, a cave opens at both ends, which is distinguished by the change of direction of air draught in the cold and warm seasons (Fig. 2 B). Congelation and sublimated ice have been observed here. Seasonal stalactites are noted in central parts of the underground system, with a length of not more than 12-15 cm, diameters near the foundation are 3-5 cm. Until to 1997 the perennial aufeis-layer was disposed in Ice hall, the ice had hydro-carbonate-calcium composition, mineralization was 189 mg/l. Seasonal hoarfrost has been registered near Entrance 1, it is the hexahedrons with sizes 1-3 cm in diameter. During the whole year crystals of hoarfrost cover the roofs and walls of the Ice hall and the underground system adjoining it. In the Ice hall there are ice needles with a height of up to 0,5 cm but in the adjoining system there are ice hexahedrons. The sizes of hexahedral crystals increase in direction from the second (lower) entrance to inside parts of the cave – from 0,5 to 3-5 cm in diameter. Seasonal aufeis-layers and spring snow-banks have been fixed near the entrances of the cave.

Vertical cave Vologodskogo represents the third type (Fig. 3 B), a karstic pit with snow and ice, ice is formed as a result of recrystallization of snow supplied to the cave through the entrance (its sizes are 3,5 x 2 m) in cold period of the year. Summer snow-banks with a volume of snow and ice of 10-12 m³ (in accordance with the climatic conditions of the year) are developed here and are conserved until August. Seasonal hexahedral ice crystals have been noted near the entrance.

Types of ice in caves of Priolhonie are represented in Table 2.

Table 2

Cave ice of Priolhonie

Cave	Congelation ice							Sublimated ice				Deposited and metamorphosed ice		
	Droplet-accumulat ive aufeis		Aufeis -layers		Ma ntle of ice	Ice of the lake	Segre gated ice	Hexahedral plates		Needle forms		Snowbanks		
	A*	P	A	P				A	P	A	P	Sp	S	P
Bolshaya Baidinskaya	+	+	+	+	+	+	+	+	+	+		+		+
Malaya Baidinskaya	+		+	+	+	+	+	+	+			+		
Mechta	+	+	+	+	+	+		+	+			+		
Ryadovaya	+		+		+			+				+		
Oktyabrskaya			+					+				+		
Iya	+		+					+	+		+	+		
Vologodskogo								+					+	

* : A – annual, P – perennial, Sp – spring, S – summer

3. Dynamics of cave glaciation

Observations of the dynamics of cave glaciation in Priolhonie stretch from 1976 to the present. It is in this short period that the essential changes in its state were registered. From the seventies of last century the considerable decrease of the sizes of cave glaciation has been observed. So, complete degradation of the aufeis-layer occurred from 1976 to 1997 in Ice hall of cave Iya: in November 1977 the area of one was 226 m² with an ice depth from 1,5 to 2,5-2,8 m; in July 1993 its size have decreased to 6,9 m² with an ice depth from 6 to 88 cm, in July 1996 – to 1,5 m² and maximum ice depth 7-8 cm. Complete thaw of aufeis-layer was registered in July 1997. Within the span of twenty years, the annual thaw of aufeis-layer averaged 11,3. The same considerable degradation of aufeis-layer was observed in Bolshaya Baidinskaya: in July 1993 the area of ice in Khoroshikh hall was 23,3 m², in October 1998 – 14,4 m², in June 2003 – 10,5 and in May 2005 – only 7,8 m². Within the span of twelve years, the annual thaw of aufeis-layer averaged 1,2 m².

Observations of the dynamics of aufeis-layers in both Baidinskaya and Mechta were marked. In Bolshaya Baidinskaya marks were done on the walls at observations points to the left, in the centre, to the right of the ice body and on the frozen block, in Malaya Baidinskaya – on the frozen block too, but in Mechta – they were on the walls to the left of the ice stalagmites named Organ and Ded Moroz. During every following visit the measuring of the distance, for which the ice limit was moved away by comparison with the previous state, was accomplished. As may be inferred from Table 3 considerable degradation of cave ice is noted in both Baidinskaya and Mechta, starting from 1995. During last ten years the rate of ice retreat varies from 3,2 cm (in Mechta) up to 11,7 cm per year (in Bolshaya Baidinskaya). The rate of the thaw (observations by the frozen blocks in both Baidinskaya) achieves from 1,7 up to 12,9 cm per year. And as for

Table 3

Degradation of perennial aufeis-layers in caves Bolshaya Baidinskaya, Malaya Baidinskaya and Mechta
(marks from 26th July 1995)

Date of observations	Bolshaya Baidinskaya				Malaya Baidinskaya	Mechta	
	left	in the centre	right	on the block		Organ	Ded Moroz
16 th September 1995	4,5	8,5	2,5	3,2	1,3	0,8	
1 th May 1996	2,5	10,3	12,0	9,7	1,0		
13 th April 1997	10,0	12,0	9,0	collapse	1,0		
26 th October 1998	12,5	27,5	16,0			3,5	marking
22 th November 2003	62,0	32,5	64,5			11,8	22,5
1 th May 2005	16,5	27,0	21,5			4,7	7,0
Average intensity per year	10,8	11,8	12,6	12,9	1,7	2,1	4,2

Mechta, in autumn 1976, in system Metro, milky-white ice was characterized by a depth of 0,5-0,7 m, in autumn 1998 the dirty-black ice had a depth not more 20-21 cm, but in spring 2005 the ice was absent on the whole of the system considered, the temperature of the ground was +0,2°C. The intensity of the thaw is 3 cm per year.

It is evident that the climatic changes cause the considerable degradation of cave glaciation in Priolhonie. In effect, as it is illustrated by Fig. 3, until 1967 the small fluctuations of average annual temperature of the air, conditioned by the

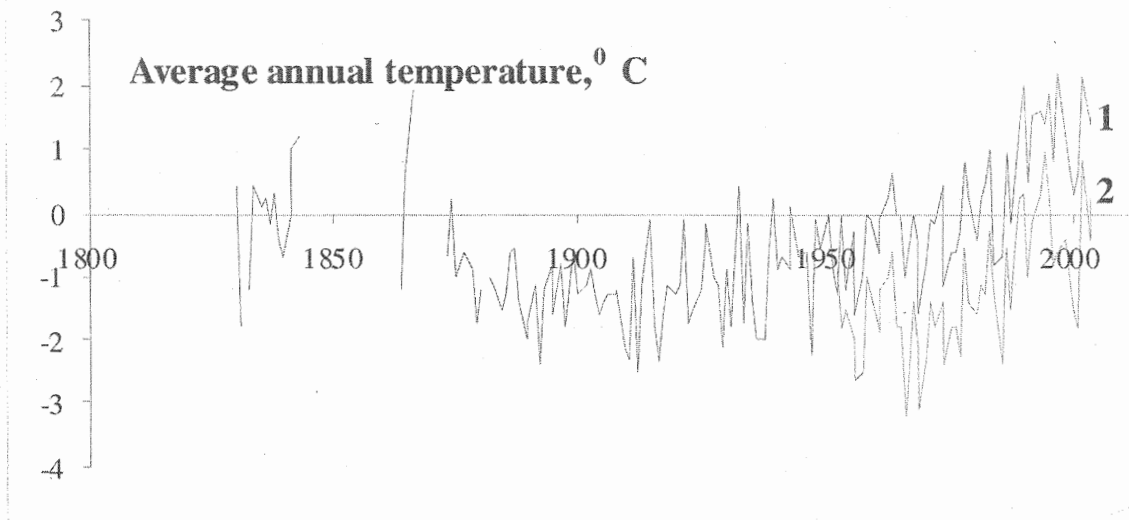


Figure 3 Dynamics of average annual temperature by the meteorological station: 1 – Irkutsk-observatory, 2 - Uzur

cyclicality (25, 11-years, etc.) of nature processes, are revealed. After 1967 the steady trend in increase of average annual temperature of the air is noted. It has been just this increase which is responsible for the degradation of cave ice in region researched. The following meteorological data were used for analysis: observations at the meteorological station Irkutsk-observatory, characterized by the longest period of observations in Irkutsk amphitheatre – duration from 1830 interruption and from 1882 to 2003 – without interruption, as well as observations at the Uzur station, which is situated 75 km to the NE from Bolshaya Baidinskaya, with the same period of meteorological observations. Both data published [1, 2] and unpublished (starting from 1965 the materials were received by the treatment of average month temperatures by Meteorological monthly books) were used. And its turn, the considerable degradation of cave glaciation is the foundation to consider the cave ice as an indicator of the warming of the climatic conditions in Priolhonie.

4. Conclusions

- Three main types of cave ice are observed in 8 karstic caves of Priolhonie: congelation, sublimated and deposited-metamorphosed.
- According to the origin of the coldness and accumulation of snow and ice three types of cavities are distinguished here: cold sack-shaped caves, thermoventilated cavity characterizing by the change of direction of air draught in the cold and warm season and vertical pit.
- The system of topographical signs for the presentation of cave ice formations on the underground maps is proposed.
- The rate of ice retreat varies from 3,2 up to 11,7 cm per year and the rate of the its thaw achieves from 1,7 up to 12,9 cm per year.

5. References

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Soil and gypsum caves microbial communities of karstogenic landscapes of Archangelsk Region (Russia)

Semikolennykh A.A.¹, Ivanova A.E.², Dobrovolskaja T.G.², Gorlenko M.V.²¹ - Russian Geographical Society, Academy of Science² - Soil Science Faculty, Moscow Lomonosov's University**Abstract**

The structure and functional specifics of microbial communities and fungi from cave deposits and near-by surface soils have been studied in caves of the Archangelsk Region of Northern European Russia. The caves are all undergoing the active process of modern karst development. Cave microbial communities were overall quite similar to those from surface soil horizons located over the caves, with some substantial structural differences, including: replacement of dominant species and the appearance of new, rare species; the prevailing growth of oligotrophic and psychrotolerant forms; and the changes in kinetic growth parameters of microbial populations.

Introduction

Karstogenic landscapes are widely spread around the world and are characterized by high contrast of ecological niches. A special position among them belongs to cave habitats that have various degrees of connection with the surface. There is a constant influx of matter and energy from terrestrial biotopes to the caves undergoing the active process of modern karst development. Various microorganisms also get here from surface with the help of air streams, infiltration waters and flood karst waters. In the new environmental conditions the introduced microbial pool may undergo substantial changes. However, it is not known, which features and properties of microbiocenoses that grow in surface environments are inherited by the microbial communities that form in the cave habitats.

The site and samples collection

The caves involved in this study are located at the site of "Pinezhsky" State Natural Reserve and special natural reserve "Golubinsky" near settlement Pinega in Archangelsk region (64°32' north latitude, 43°15' east longitude) in the northern taiga (boreal forest) natural subzone. At this site there are specific karstogenic and typical glacial landscapes. The caves lay in gypsum and anhydrites 4 to 50 meters deep from the surface and have the following attributes [Structure and dynamic..., 2000]: stable average annual atmospheric temperatures 1-4° C; temperatures of ground waters 0,1-10° C; annual spring floods; sulfate-calcium mineralization of waters ranging from 0,4 g/l during flood period to 2,5 g/l during low-flow period; oligotrophic conditions (the content of biophilic elements in gypsum is much lower than in cover loams. Loose deposits in caves were represented mainly by moraine clays eroded by surface waters. Several samples of cave deposits and surface soils were collected in August 1998 for microbiological analysis. The following samples were considered as taken from rich habitats:

1) SLA - the soil litter of "albeluvisol" soil (Note: Here and below soil types are named according WRB Soil Classification [WRB, 1988]), (typical eluvial-illuvial forest soil in northern humid climate), located above a cave, which was developed in draining position on a smooth slope;

2) SLL - the soil litter of "gypsic leptosol" soil (organic accumulating soil on hard gypsum bedrock), developed on single gypsum residual hills;

3) SLCave - the fragment of soil litter removed from the surface into a cave by spring flood waters.

The following samples were considered as taken from barren habitats:

4) MIA - the mineral illuvial horizon of "albeluvisol" soil (typical eluvial-illuvial forest soil in northern humid climate), located above the cave, which was developed in draining position on a smooth slope;

5) GPL - the gypsum powder of "gypsic leptosol" soil (organic accumulating soil on hard gypsum bedrock), developed on single gypsum residual hills;

6) MDCave - the mineral sediment on the cave floor which is flooded not yearly.

Methods of analysis

Field assessments of esterase activity (Index of vital biomass). Determination of vital biomass index in field conditions was based on the intensity of fluorescein diacetate (FDA) (achromatic form) hydrolysis to fluorescein (green coloring) by a complex of esterase enzymes of microbial cells in vivo. It is known from previously published reports [Ingham & Klein, 1982] that intensity of FDA hydrolysis has strong positive correlation with the amount of biomass of active microorganisms, which allows to perform indirect estimation of biomass in samples of natural substrates. One gram of fresh soil or deposits was used for analysis (three replications taken). The specimen was immersed in 50 ml of phosphate buffer (pH - 6.47) and then was shaken manually for 10 minutes. After that 1 ml of 0.001 % aqueous solution of fluorescein diacetate was added to the obtained homogenate. The specimen was put into a warm place (20° C - 25° C) for 2 hours. After that exposition, 10 ml of colored solution was filtrated into a calibrated test tube and compared to the scale of standards under illumination with wavelength of 480 nm. Ten-point relative scale of standards for hydrolysis intensity was utilized for result estimation. Score of 10 corresponded to 100% transformation of fluorescein diacetate into fluorescein (resulting concentration of fluorescein 0.0002 mg/ml). Score of "0" corresponded to the absence of fluorescein diacetate destruction for the incubation period mentioned.

Cellulose decomposition tests. The test of cellulose decomposition was carried out using the application method with cotton strips [Jones & Mollison, 1948]. The method involved complete placement of preliminary dried, weighted and sterilized cotton strips into soil or cave deposits. After completion of exposure time (2-8 weeks) the cotton strips were taken out, washed, dried and weighted. Percentage of mass loss was measured.

Characteristics of bacterial communities. Biodiversity and structure of bacterial community of soil horizons and cave deposits were studied by culturing 1:100-1:10,000 dilutions of soil suspension on solid. Two weight specimens of each sample were taken. The cultures were incubated for 10 days. Bacteria were studied on glucose-peptone-yeast agar at temperatures of 28° C and 5° C. There were three replications of Petri dishes with cultures used. Genus identification of bacteria was performed [Bergey's manual..., 1997] using morphological, cytochemical (Gram stain) and physiological-biochemical signs (test for oxidase and catalase).

Characteristics of fungal communities. Biodiversity and structure of micromycetes community of soil horizons and cave deposits were studied by culturing dilutions of soil suspension on solid medium. Dilution 1:100 was used for micromycetes culturing. Five weight specimens of each sample were taken. Microscopic fungi were grown on Czapek agar and Water agar at temperatures of 25° C, 15° C and 5° C. In all cases for each weight specimen we performed replication three times. The cultures were incubated for 10 days, after which the pure cultures were counted and iso-

lated for genus and species taxonomic identification of fungi. Identification was performed using the keys [References are abridged]. Biodiversity and structure of micromycetes communities and the quantitative ratio of species was characterized using the following indices: a) frequency of occurrence (percentage ratio of samples/replications, in which the given species were found, among all the investigated samples/replications); b) relative abundance (percentage ratio of the colonies of the given species to the total number of fungal colonies for every replication, and subsequent calculation of the mean value for the sample among all replications); c) assessment of rank distribution of species abundance [May, 1975]; d) assessment of species diversity according to Shannon's diversity index, based on the values of species occurrence [Megarran, 1983].

Determination of temperature optimum for cultures initially cultivated at different temperatures. For model experiment of temperature adaptation determination an elementary bacterial association isolated by "diminishing streak" technique from one of the colonies from MDCave sample after primary inoculation at +28° C was used. Association was stable (did not split into components by terminal dilution with further inoculation on glucose-peptone-yeast agar) and included two components: Myxococcales spp. and Aquaspirillum sp. The elementary association was reinoculated into Petri dishes at +5° C and +28° C to get biomass of "mesophilic" and "psychrophilic" lines. After accumulation of biomass in the new temperature conditions the temperature range of growth was determined by reinoculation into several Petri dishes, incubated at different temperatures. Capability for growth at different temperatures was studied.

Multisubstrate testing for investigation of functional structure of microbial communities. Method of multisubstrate testing (MST) was utilized to analyse functional patterns of natural microbial communities using spectrum analysis of consumed monosubstrates. A special microtitre plate, which included 47 test substrates, was used for implementation of MST. Weight specimens of 2 gram were taken from samples at field moisture for the test. Each weight specimen was mixed with 100 ml of Serenson's phosphate buffer (pH = 6.5). Vital dyes were added to the obtained centrifugate:

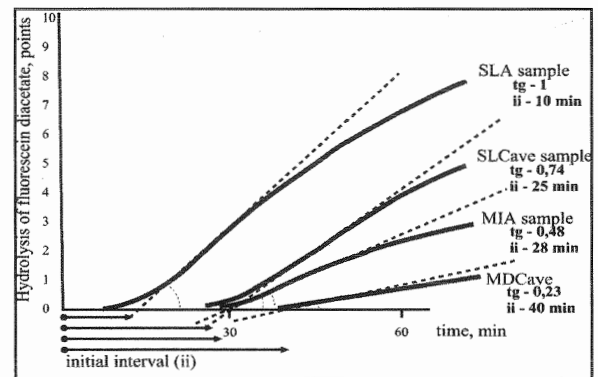
- 1) in the first series of tests, an aliquot of centrifugate was mixed with solution of TTB (concentration 3 g/l) in 10:1 ratio (final concentration of the dye — 0.27 mg/ml), as an indicator activity dehydrogenase enzymes;
- 2) in the second series of tests, FDA (fluorescein diacetate) was used as an indicator of esterase vital activity. The FDA solution was added to the centrifugate until final dye concentration of 0.0001% (0.001 mg/ml).

The obtained sample was thoroughly mixed and 0.2 ml of it was placed into each cell of plate using multi-channel butcher. The plates were incubated in thermostat at +28° C. Optical density of the cells was measured by photometry at 1st, 2nd and 3rd days of incubation. Measurements were performed at wavelength of 510 nm for TTB-containing plates and at wavelength of 480 nm for FDA-containing plates. The data obtained were categorized using algorithms of cluster analysis by means of SPSS 10.0 software. Numerical data of the device (optic densities of solutions at 510 nm and 480 nm minus control sample values) were used as index values of growth energy. Simple summation method was used for the device readings from all cells of the plate. It was called "community performance" and was used for demonstration of global intensity of metabolism.

Results and discussion

Results of cellulose decomposition tests. The table below shows the results of 8-week experiment measuring the intensity of decomposition of cotton strips exposed in soil and cave environmental conditions. The cellulose in "cave environment" decomposes significantly slower when compared to soil environment. This is likely to be associated with predominance of copiotrophes (Aquaspirillum) in the psychrotolerant pool of microorganisms in cave clays, while hydrolytic bacteria - cellulose decomposers - are passive at low positive temperatures, although maintaining vitality.

Index of vital biomass in samples of soil and cave habitats. The results

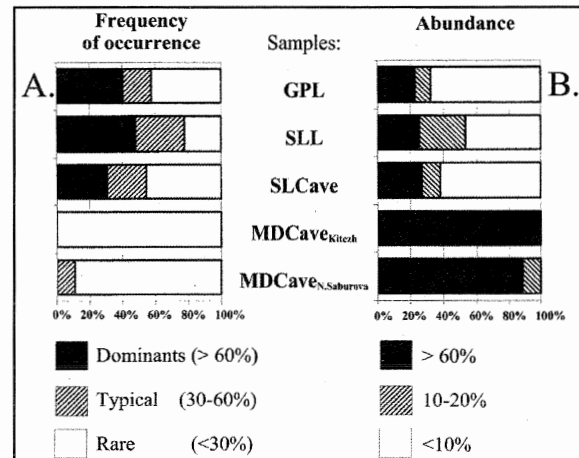


Samples		Index of "vital biomass". 0-10 Points	% _m cellulose utilization (the mass loss during 8 weeks)	
Soils	Albeluvisol soil under the Cave	Upper horizon of soil litter	30	
		Lower horizon of soil litter		
		Eluvial (Albic) horizon, mineral		
		Illuvial (Argic) horizon, mineral		
		Horizon transitional into morine, mineral		
	Gypsic leptosol soil near the Cave	Soil litter (like dry peat)	8	12
		Gypsum powder	4	3
	Histosol soil at the bottom of karst sink-hole near the Cave	Organic illuvial horizon	10	18
		Clay deposit with organic illuviation	6	Traces
	Regosol soil at the slope near the Cave	Soil litter	8	28
Horizon transitional into morine, mineral		3	8	
Caves	Soil litter on the ceiling of the Cave	7	No data	
	Plant remains at the distance from 100 m from the entrance	9	Traces	
	Clay deposit in the middle part of the Cave	2	Traces	
	Clay deposit at the distance from 200 m from the entrance	3	Traces	
	Clay deposit in the far part of the Cave	2	Traces	

of field assessment of vital biomass index using method of FDA hydrolysis are presented in the table. Despite of high diversity of vital biomass indices for different soil types, existing in different environmental conditions, one cannot say that cave deposits contain substantially less biomass of microorganisms. Rich organic cave deposits have values of vital biomass index which are very comparable to many soil litters. Mineral deposits of caves have values of the index, typical for moderately barren soil horizons. Meanwhile, the process of FDA hydrolysis by microorganisms in different samples varies substantially. Figure shows kinetic graphs of this process for some of the samples. It demonstrates that in the samples from habitats experiencing constant influence of low temperatures the FDA hydrolysis begins with delay and has a lesser activation energy (tangent to the curve at the initial stage) (Fig).

Taxonomic structure of saprotrophic bacterial communities in soil and cave habitats. Features noted for bacterial communities of litters and illuvial horizons of surface soils (SLA, MIA samples) were similar to the typical characteristics of most soils of taiga region. For these soils, dominating microorganisms of the litters are cellulose-decomposing bacteria of Myxococcales order and Cellulomonas, as well as typical pedobionts of mineral horizons, such as Arthrobacter. In the bacterial community of gypsic leptosol significant percentage is occupied by representatives of Actinomycetales order: 17% in SLL and 31% in GPL. This soil also has maximum abundance of Myxococcales and Bacillus compared to albeluvisol. In the bacterial community of SLCave there were found the same groups of microorganisms as in SLA, with domination of Myxococcales. The structure of bacterial communities of these biotopes differed in the ratio of bacteria of Cellulomonas genus and Aquaspirillum genus: 10:1 in the albeluvisol and 1:10 in cave habitats respectively. The domination of Aquaspirillum, which are typical hydrobionts, in SLCave is associated either with their influx with spring flood waters, or with constantly high humidity of cave atmosphere. Usually, Cellulomonas are isolated in high numbers from forest litter in autumn periods, when the process of mineralization of seasonal abscission of leaves begins. That is exactly what we observed in the analysis of SLA sample, which was taken in the beginning of autumn. Considering that material of SLCave sample got into the cave in the spring with spring flood waters, but was taken for tests in Autumn, there weren't found Cellulomonas genus bacteria. This appears to indicate some indirect evidence of absence or great suppression of seasonal dynamics in caves when compared to terrestrial habitats. Bacterial communities of MDCave have similar features to MIA bacterial communities. The dominant position in these communities is occupied by bacteria of Arthrobacter genus and Aquaspirillum genus.

Biodiversity and structure of microscopic fungi communities in soil and cave habitats. The communities of microscopic fungi isolated from samples of organic horizons of surface soils and caves were significantly richer in terms of species diversity than fungal communities of mineral horizons of the same habitats (Look the table below). Micromycetes communities of soil horizons and SLCave sample had pronounced structure, which included two to three dominating in occurrence and in relative abundance species, several typical and frequent species, and several sporadic species. However, the percentage of low-abundant species exceeded one half. At low temperatures the percentage of rare, low-abundant species with relative abundance values less than 10% increases. The communities of micromycetes isolated from cave spring flood clay had low species diversity and the lowest values of Shannon's diversity index (Table). Structure of fungal communities of these cave deposits was different from typical soil habitats and even from mineral soil horizon: there were only rare species of micromycetes that had at the same time high abundance (Fig.). Appearance of these species in the inoculate was random and did not depend on the cultivation conditions (temperature and nutrient medium). High values of relative abundance were observed in all the fungal species isolated from this sample. These values exceeded 10% and



usually were 50% to 100%. Therefore, the patterns of species distribution may be described by a model of community composed of several discretely distributed (i.e. rare, with low spatial occurrence) and absolutely prevailing in number (i.e. abundant) species, and at the same time rare and not numerous (i.e. not abundant) species are completely absent in the community. The prevalence of rare but abundant species of fungi together with their "dotted", random pattern of isolation is caused by barrenness and discreteness of organic substrates existing in cave clays, which is a specific feature of the given habitat.

The massive growth of one predominant population (one species) within such discretely distributed substrate-containing areas is possible in the absence of interspecific competition in the circumstances of disruption or termination of continuous progression of fungal succession which takes place in the process of decomposition of organic substrates. This indicates global unsaturation of cave fungal communities. The species composition of micromycetes communities of cave deposits has hereditary similarity to the communities of surface soil horizons. For instance, in the community of micromycetes in a soil litter fragment, brought into a cave by spring flood, there were many fungi species isolated, which were also found in a soil litter taken from daylight surface (Table above). These were fungi that grow in the seasonal abscission of leaves, decaying plant remains and tree remains: *Mucor hiemalis*, *Geomyces pannorum*, *Cladosporium cladosporioides*, and nematophagous fungus *Arthrobotrys arthrobotryoides*. At the same time, the data on species structure show that when soil litter is moved from surface into cave habitats, which are different in physical, climatic, and trophic parameters, substantial and rapid restructuring of fungal community occurs, and species that were dominant in surface habitats are forced out of the community by fungi that are more adapted to the new conditions.

Differential significance of temperatures and organic matter supply for studying of structural and functional features of communities. Population numbers of bacteria in the communities of soil litters were 2-4 orders of magnitude higher, than in mineral horizons, and were equal to 10^7 to 10^9 CFU/g (Table below). Incubation at different temperatures allowed to reveal substantial differences in mesophilic and psychrotolerant bacteria groups ratio in biotopes of daylight surface and cave biotopes. The percentage of psychrotolerant pool of bacteria in MDCave was 20%. At the same time the numbers of bacteria, grown at 5° C and at 28° C, were within the same range of magnitude. In MIA sample the pattern was opposite: percentage of psychrotolerant pool of bacteria was only 0.05%, and numbers of bacteria grown at 5° C were two orders of magnitude less than numbers of those grown at 28° C. Analysis of bacterial communities grown at 5° C demonstrated that the spectrum of bacteria taxons was significantly narrowed when compared to the spectrum obtained at 28° C. At 5° C the vast majority of colonies isolated from mineral substrates was

represented by bacteria of *Arthrobacter* genus and *Aquaspirillum* genus, while there were no representatives of other genus found. Analysis of litters showed much lesser influence of factor of the temperature on psychrotolerant pool of bacteria.

Species	Soil habitats		Cave habitats		
	(GPL)	(SLL)	(SLCave)	(MDCave, Cave 1)	(MDCave, Cave 2)
<i>Acremonium charticola</i> (Lundau) W. Gams	XXX	X	X		
<i>Acremonium kiliense</i> Grutz	X		X	X	
<i>Acremonium</i> sp.			XX		X
<i>Artrobotrys artrobotryoides</i> (Berl.) Lindau		X	XX		
<i>Aspergillus niger</i> van Tieghem	X				X
<i>Aspergillus wentii</i> Wehmer	X				
<i>Chaetomium globosum</i> Kunze ex Steud.			XX		X
<i>Chrysosporium merdarium</i> (Link ex Grev.) Carn.				X	
<i>Cladosporium cladosporioides</i> (Fres.) de Vries	X	X	XX		
<i>GeomycesChrysosporium pannorum</i> (Link) Hughes		XX	XXX	X	X
<i>Mucor hiemalis</i> Wehmer		XX	X		
<i>Oidiodendron tenuissimum</i> (Peck) Hughes	XXX		X		
<i>Penicillium aurantiogriseum</i> Dierckx			X		X
<i>Penicillium canescens</i> Sopp		X			X
<i>Penicillium chrysogenum</i> Thom			X		
<i>Penicillium crustosum</i> Thom	X	X	X	X	X
<i>Penicillium decumbens</i> Thom	X	XXX			X
<i>Penicillium expansum</i> Link ex Gray		X			
<i>Penicillium funiculosum</i> Thom	X	X	X	X	X
<i>Penicillium janczewskii</i> Zaleski		XX			X
<i>Penicillium janthinellum</i> Biourge		XXX			
<i>Penicillium minioluteum</i> Dierckx				X	
<i>Penicillium oxalicum</i> Currie & Thom	X				
<i>Penicillium roquefortii</i> Thom	X				
<i>Penicillium rugulosum</i> Thom	X	X			
<i>Penicillium spinulosum</i> Thom		XX			
<i>Penicillium thomii</i> Maire		XXX			
<i>Phialophora cinerescens</i> (Wollenw.) van Beyma			XX		
<i>Rhizopus oryzae</i> Went & Prinsen Geerligs	X				
Sterile dark-colored mycelium			X	X	
Sterile light-colored mycelium		X		X	
<i>Trichoderma viride</i> Pers. ex Gray		XXX			
<i>Verticillium lecanii</i> (Zimm.) Viegas	XX				
Shannon's diversity index	1,99	2,45	2,27	1,93	2,06
Evenness	0,75	0,86	0,84	0,95	0,94

Species frequency of occurrence: X - rare (< 30%); XX - typical (30-60%); XXX - dominant (> 60%).

		Samples					
		Albeluvisol soil (typical forest soil in humid climate)		Gypsiric leptosol (primitive soil on gypsum rocks)		The Cave	
		Soil litter (SLA)	Illuvial mineral horizon (MIA)	Soil litter (SLL)	Gypsum powder (GPL)	Soil litter (SLCave)	Clay deposit (MDCave)
Quantity of colony forming units/ 1 gram of dry sample	28°C	3,92 x 10 ⁹	6,10 x 10 ⁷	1,30 x 10 ⁸	2,00 x 10 ⁶	1,14 x 10 ⁹	1,58 x 10 ⁵
	5°C	1,35 x 10 ⁷	0,31 x 10 ⁵	No data	No data	0,68 x 10 ⁷	0,37 x 10 ⁵
The ratio of psychrotolerant to mesophilic pools, %		0,34	0,05	No data	No data	0,60	23,42

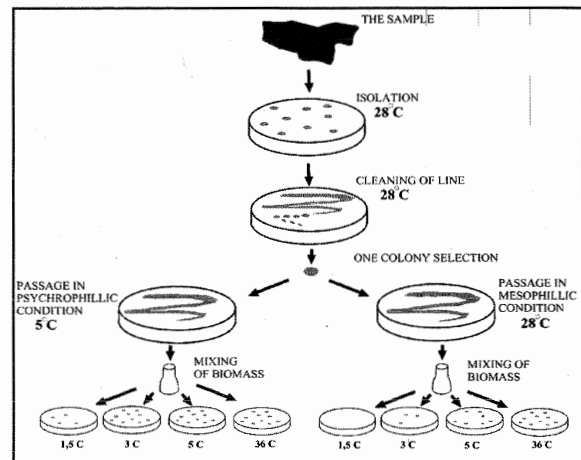
In the studying of influence of soil and cave habitats on microscopic fungi communities we utilized different cultivation conditions for their isolation:

barren and rich mineral mediums (Water agar, Czapek agar); low (5° C, 15° C) and standard for soil microbiological analysis (25° C) temperatures. Substrate limitation (growing of micromycetes on poor medium — Water agar) caused reducing of total numbers of fungal colonies isolated from the study samples. Also substrate limitation determined the structure of communities, their composition and percentage of infrequent species in fungal community. For instance, isolation of fungal cultures from rich in organic matter litters on Water agar resulted in the increase of percentage of infrequent and scarce (low abundant) species by 15-20%. And, on the contrary, cultivation of fungi from oligotrophic soil mineral horizon on Water agar resulted in community composition with several highly abundant fungal species, while the percentage of low-abundant species was significantly lower than obtained when grown on rich medium. Isolation of fungi from cave clay deposits on Czapek agar resulted in abundant growth of sterile mycelium, which inhibited growth of any other fungi. The factor of temperature also played a significant role, as it determined global diversity of species in isolated communities of micromycetes. In fungal communities of oligotrophic habitats (e.g. cave clays and mineral soil horizon) the increase of cultivation temperature from 5° C to 15° C and 25° C resulted in the increased number of species isolated. And vice versa, in fungal communities from surface and cave litters that had lots of organic substrates the increase of diversity of species was noted when reducing temperature from 25° C to 15° C and 5° C. Apparently the shift of thermal range of growth into less typical zone for these substrates activates the reserve microbial pool and initiates development of resting fungal forms, which are present in the given substrates. Increase in the diversity of species of fungal communities occurred as a result of greater percentage of low-abundant species which grew from 30-50% to 75-90%.

The data of complex analysis of multisubstrate tests results. Using FDA as a metabolism indicator, the reduction of incubation temperature resulted in predictable decrease of all calculated indexes: Shannon's index, amount of substrate consumed and value of "community metabolic performance". Notably, the decrease in the indices depended on the initial values. It may appear to be the evidence that organisms with prevailing r-strategy (hydrolytics) — which are presumably determined in FDA assessment — are equally depressed at low temperatures in both soil and cave habitats.

In the TTB-analysis relatively high values of diversity index and evenness in cave clay sample (MDCave) when compared with other oligotrophic samples are worth attention. However, the amount of substrates consumed and community performance for that sample did not exceed the corresponding values for MIA and GPL. SLCAve and SLA samples taken in winter season featured relatively higher values of evenness and community performance. It is likely to be caused by activation of community in mesophilic conditions of incubation after being exposed to cold environmental conditions. Most probably that the response of community is just a single-event reaction.

To address the assessment of rapidness and grade of temperature adaptation response we performed a series of experiments with elementary association (refer to "Methods of analysis" section). The results showed differences in the growth capabilities of cell association pool at low temperatures depending on the previous temperature of cultivation. For instance, if the initial cultivation temperature was +5° C, then the range of temperatures in further reinoculation was widened towards lower temperatures: +1.5° C and +3.5° C. If the association was initially cultivated at +28° C, further it wasn't capable to grow at temperatures lower than +5° C during the same period of time. For temperatures higher than incubation temperature of previous culturing there were no similar patterns observed. For instance, at +36° C the cultures cultivated earlier both at +5° C and at +28° C grew with similar intensity. The patterns observed and the experiment conditions are demonstrated at Figure 6. Most likely those rapid changes in the ecology of microorganisms are associated with predominant propagation of adapted psychrotolerant cellular pool which



exists inside a population of a single genus. It is evident that bacteria multiplication at low positive temperatures causes the appearance of modification changeability or divergence of elementary association components (micropopulations), which occurs later in sequential cell generations. Determination of temporal stability of this feature was not included in the objectives of the present study.

Conclusions

In conclusion, based on the presented data we can emphasize the following specific features of structure and functioning of microbial communities in environmental conditions of caves undergoing active process of modern karst development and closely connected with daylight surface:

- In caves undergoing active karst development we observed basic diversity of zonal soil microorganisms in vital state presented in numbers that are comparable to the terrestrial habitats.
- The main features of microbial communities of cave habitats were caused by influence of environmental factors and adaptation of microorganisms to the specific climate of cave environment. It was manifested by inhibition of hydrolytic organisms growth (which nevertheless preserved vitality), predominance of psychrotolerant and oligotrophic forms, discrete development of mono-species populations resulted from the absence of significant natural competition for nutrients.

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ABOUT THE SEISMIC STABILITY OF ANCIENT ENGINEERING CONSTRUCTIONS

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Abstract

In their analyses scientists, examining the consequences of Spitak earthquake, arrived at various conclusions concerning different questions. But they were unanimous on one point. The general quality of engineer works didn't meet the security requirements of Armenian seismic zone.

But the problem is more serious. In town-planning and different engineering works the geological, seismic, hydro-geological, petrographical structure, the peculiarities of landscape and geomorphological structure of the area were not taken into consideration.

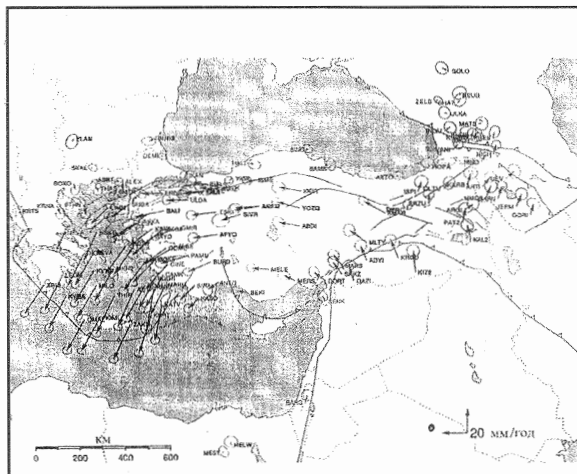
In the given report the author brings up several examples of underground constructions, built from 300-3000 years ago and in spite of the destructive earthquakes preserved till our days. Some of the examples are the Orgov tunnel, II BC, the Ashtarak and Shirak stone-door caves, built 700-3000 years ago, the multi-piece underground settlement in Spitak coming from Middle Ages, the cave settlements of Ani and Akhourian, built 800-1500 years ago, in VII BC built water channel of king Argishtu, up to these days irrigating the gardens of Dalma.

The reason of seismic stability and longevity of the ancient constructions was the profound knowledge of nature and its correct use by the builders and the settlers.

The destructive earthquake of Spitak (1988, Spitak, Armenia, 25 000 victims) almost razed to the ground the cities of Spitak and Gyumri. It took 15 years to cover the damage caused in numerous settlements, but the psychological stress people suffered at times still makes itself felt.

The whole process of origination of modern man in the Armenian Highland was accompanied by active geotectonic processes - earthquakes, volcanoes and etc. These geological phenomena as ecological factors have influenced the formation of local population's mode of life, way of thinking and relations with the surrounding environment.

Pleistocene and Oligocene earthquakes have been common phenomena in the Armenian Highland, which however have played a great role in the fate of the people. The capital cities of Armenia were often moved not because they were invaded by the enemy, but mostly because the natural phenomena made life impossible. Thus for instance in 200 B.C. as a consequence of a destructive earthquake river Araks changed its course, bringing about unbearable conditions for health and the capital city moved from Armavir to Yervandashat. In I B.C. as a consequence of tectonic



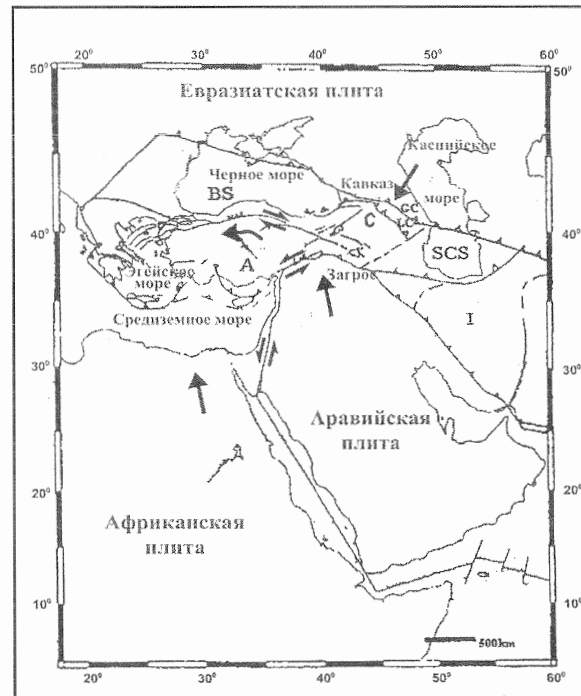
The horizontal deformation of surface (GPS). 1991-2002 (reilinger et al,1997)

processes a huge gap opened on the way to Nakhijevan, causing the draining of Ararat lake water, creating arid landscape around Yervandashat and the capital city of Armenia was again moved to Artashat. These geological processes were also mentioned in Strobe's work "Geography". In 330-338 A.D. again caused by an earthquake, river Metsamor changes its course and the whole area of Artashat bogs up. They were obliged to once again move the capital city - this time to Dvin. However this area too was in an active seismic zone; in only 42 years from 851-893 there had been 5 destructive earthquakes, during one of which in 893 Garm earthquake there were 120 thousand victims, which makes 5% population of Armenia today. The capital city is then moved to Ani, which however after the 1064 earthquake loses its forts, is captured and destroyed by Turks.

Volcanoes also have been the constant companions in Armenian history. Here are the periods of several volcano eruptions (acc. to A. Kazanchyan) Porak - coordinates (40°01', 45°47') the end of V millennium, 780 B.C., Ararat - coordinates (39°42', 44°18') middle of XXX millennium, I-IV cc., 1783, 1840, Zschook (35°44', 46°01'), middle of IV millennium, Vayots mount (39°48', 45°30') and Smbatar (38°37', 42°13') 1441 and etc.

Naturally, one who had lived over 10 000 years in such an active geotectonic zone should be able to prevent the destructive influence of earthquakes and volcanoes. We have explored and taken measurements of numerous anthropogenic caves and tunnels, which were built by taking into account the conditions of the surroundings. These caves are valued not only from engineering point of view, but also from archeological point of view, as they were built from 800-4000 years ago. As to compare we will mention that none of the faces and tunnels dug in 1900-1930 is good for usage today, and the Arpa-Sevan 45-km-long tunnel put in 1960's has been completely repaired 3 times in 400 years.

Stone-Door Caves



The Caucasus, African-Arabic and Eurasian blacks. Tectonic stability situation.

In Armenia these caves are spread in the region of Aragatsotn, in the surroundings of Saghmosavank, Dzorap, Avan, Agarak, Kosh and Ujan villages, also in Shirak region and in the territory of historic Ani. These caves were built in the I millennium B.C. till XVc.; already in XVIIc the historians mention that these type of buildings were no longer built (Artemi from Ararat, S.M. Shahinyan). These are caves that were dug in volcanic rock layers and at first (I-II millennium B.C.) most likely served as mausoleums and parish places, while later (from the middle of I millennium B.C. till XVc.) as storages for keeping food. Some caves are designed for hiding for a long period.

Subterranean Tunnels

Such tunnels come across in the area of almost all Bronze Age fortresses and sanctuaries, however, only very few of them have preserved today. We will present two of them. One is the Anberd secret flee way that lost its military significance in XIIIc, the other is the 2-km-long secret tunnel going to the gorge from a Bronze Age Cyclopean fortress.

Anberd tunnel was first explored by Pyatrovski and Ajan, then by Tokarski and at last in 1986, 2002 by the expedition of Armenian Speleological Center. Only 110m of Anberd tunnel were explored, the other two tunnels were little examined. These tunnels were built two-storied. The architectural scheme reminds of a Dolmen building. The cover is from relatively regular 1.5-2.0 m long-slabs, while the sides are from huge rock pieces.

The Orgov Tunnel is an exceptional construction. This was built in the clay layer between two lava layers. The builders must have known very well the surrounding environment and the geology of this mountainous area. This is why despite the building being over 3000 years old, it's over 80 m long section has wonderfully preserved up to our days.

Having observed these constructions we think that it would be right for the engineers to examine today the experience of our forefathers and apply it in construction today. A thing that should solve some seismic security problems.

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The details of stone door cave.300 B.C. Aragatsotn region



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Revue historique de la spéléologie de la Sibérie et de l'Extrême-Orient

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Dans la région de la Sibérie et de l'Extrême-Orient les roches karstifiées occupent une surface de plus de 15 % du territoire global. Là se trouvent de nombreux d'avens, grottes et gouffres. La plus longue, la grotte Bolichaïa Orechnaïa (Saïan Oriental) possède des galeries qui se développent jusqu'à 47 km. Le plus profonde, le gouffre Écologique (Altaï de Montagne), possède une dénivellation totale de -345 m. On peut diviser l'histoire de la spéléologie de la région selon les étapes suivantes: la période des premiers renseignements fragmentaires (de 1722 au début du XX siècle); la période d'accumulation des connaissances (du début du XX siècle aux années 1958-70) et la période d'approfondissement et de systématisation de l'information (des années 1958-70 jusqu'à présent). La première description des grottes sibériennes a été réalisée en 1722 par le chercheur suédois Ph.J. Strahlenberg pour la celle Eniseïskaïa (près de Krasnoïarsk). Et jusqu'au début du XX siècle l'intérêt principal a été pour les grottes comme l'objet de résidence probable de matériaux archéologiques et paléontologiques, à savoir, pour les grottes situées dans les vallées des grandes rivières. Dans les années trente du XIX siècle, ce sont les travaux de F.V.Gebler et A.N.Koulibin qui ont été ensuite généralisés par F. Brandt en 1870. Il a montré 37 espèces de mammifères dans les cavités souterraines d'Altaï. En 1875 I.D. Tchersky a collecté des os d'animaux dans la grotte Nizhneoudinskaïa (Saïan Oriental) et a déter-

miné 19 espèces de mammifères. En 1892 P.S. Proskouriakov a découvert de la faune pléistocène dans les grottes de Kranoïarsk. À partir des années vingt du XX siècle l'envergure des explorations géographiques, géomorphologiques et géologiques grandisse dans la région considérée. Au cours des relevés géologiques une multitude d'entrées de grottes se sont décelées et portées sur les cartes mais les cavités souterraines elle-même ne sont pas recherchées. On note la publication de la description de la grotte célèbre Bouhtarminskaïa en 1925 par V.P. Nehorochev. En 1934 V.P. Maslov a exploré la grotte Balaganskaïa (vallée d'Angara) et en 1957 P.I. Kostromin a inspecté la grotte Mokrouchinskaï (Primorie). En 1954 les nombreuses cavités souterraines d'Altaï de Nord-Ouest et de Nord-Est note S.P.Souslov. La dernière période liée avec la naissance des clubs spéléologiques dans les centres administratifs du territoire: en 1958 à Krasnoïarsk, en 1966 à Vladivostok, en 1969 à Irkoutsk, etc. La quantité des grottes explorées augmente, par exemple, dans la région d'Irkoutsk en 1969 n'ont été découvertes que 20 grottes et à la fin des années quatre-vingt-dix déjà plus que 200. Mais les clubs sportifs d'amateurs ne réalisent que les découvertes et au mieux les relevés topographiques des cavités. Les participants des expéditions s'intéressent peu aux particularités scientifiques des manifestations endokarstiques. Et d'autre part, les régions s'étendant au-dessus de 56° N n'ont pas été incluses dans les itinéraires spéléologiques jusqu'à présent. C'est l'affaire de l'avenir.

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Conservation of Ballet Cave, Minas Gerais, Brazil

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The Ballet cave is located approximately 40km to the North of Belo Horizonte, Minas Gerais, in the Environmental Protection Area of Lagoa Santa Carste, one of the most important carstic areas of Brazil, with a great number of archaeological, speleological and paleontological sites where the vestiges of Lagoa Santa Man had been studied. The cave in limestone has about 150 meters of development and the panels of prehistoric rock art are located in the entrance. The paintings are very peculiar, forming a special group with stylistics proper characteristics. The disordered visit, without the previous preparation of the site, caused a series of degradations, mainly of the walls, due to action of vandals who had left its marks in a lot of graffiti made with coal, chalk, clay and incisions. The main objectives of the intervention proposal had been the conservation of the cultural patrimony, the adaptation of the site for the visitation and the diffusion of its importance. The intervention was divided in: graphical and photographic documentation of the panels before and after the intervention, identification of pigments of paintings and the materials of the degradations, removal of the graffiti and the implementation of visitation structure.

Introduction

The Environmental Protection Area of Lagoa Santa Carste, created in 1990, is situated approximately 40km to the North of Belo Horizonte and embraces part of the municipalities of Lagoa Santa, Pedro Leopoldo, Matozinhos and Funilândia. Its total area of 3590 square kilometers com-

prises one of the most important carstic areas of Minas Gerais state and of Brazil, as it shelters a great number of archaeological, speleological and paleontological sites where the vestiges of Lagoa Santa Man were studied (FIGURE 1).

In this archaeological site surveys were accomplished in 1956, by Hurt and Blasi, and in 1973 for the Franco-Brazilian Mission coordinated by archaeologist Annette Laming-Emperaire. The archaeological work already accomplished in Lagoa Santa area evidenced human occupation at least 12000 years before the present, with an important heap of information on the biological characteristics of populations, its rituals, technologies and artistic production.

The Ballet cave is located in the property of mining company Lafarge Cimento that by demand of environmental authorities carried out in the area a wide environmental project including the conservation and adaptation of the cave for visitation. The conservation proposal privileged a minimum intervention approach and was divided in two different phases: cleaning of the graffiti and implementation of the visitation structure.

The cave and the rock art

The cave is placed halfway down the slope of a dark grey limestone massif, partially hidden by vegetation. The entrance is open to the East, being about 10 meters wide and 8 meters high. The floor is uneven, with fallen blocks and sediment. From the entrance room can be seen the painted panels in the first landing. A large group of speleotems, composed of



Figure 1 - Localization

stalagmites and stalagmites, separates the first room from the main room. The height of both rooms is similar to the entrance decreasing progressively to the end of the cave that it ramifies into smaller proportioned galleries. The total horizontal development of the cave reaches approximately 150 meters (FIGURE 2).

The panels are placed at the right side at entering the cave, in two levels of landings, divided in six panels in the walls, in the roof and in an isolated block on the first landing. All the paintings can be observed by natural lighting.

The rock paintings found in Ballet cave have been included in two graphic groups that also show up in other sites of the area, the Planalto Tradition and the Ballet Stylistic Unit (PROUS, 1992). The Planalto Tradition was the first group to develop in the area, its older illustrations being probably associated to the early Holocene geologic period, between 12000 and 8000 BP. The Ballet Stylistic Unit presents peculiar representations, forming a special group, with its own stylistic characteristics, composed essentially of line drawings of human illustrations, with rising heads of birds that give a sensation of lightness and suggest the use of masks. The sex is well indicated, be it for men or for women, and childbirth scenes are pictured. The thematic expresses a culture linked to a dramatic-ritual representation, showing very complex socio-artistic aspects (BAETA, 1995).

The man panel, named Fertility Ritual, is about 5 meters high from the floor. It includes mostly anthropomorphic illustrations, with arms and legs in movement, suggesting pregnant females and a childbirth scene. All the pictures, in procession, seem to walk toward the cave entrance. The color employed is predominantly black, and the largest illustrations are about 80cm height.



State of conservation

The Ballet cave is very close to densely urbanized areas, with easy access and intense visitor flow since many years. And the visitation without organization had brought many types of problems: touching, apply of water and other actions on the pictorial layers. Several speleotems are broken and garbage is spread over the floor, from the entrance to the dimness zone.

In the middle of the decade of 1990, the cave entrance was fenced off with concrete posts and barbed wire, causing great visual impact. The fence, however, didn't impede vandals from continuing to enter the cave.

The kind of alteration found on the paintings panels was: insect nests; animal excretions; mineral deposits (probably caused by the successive applications of water to the paintings); dust accumulation (probably caused by wind action and trampling of the sediment provoking the suspension of particulate material); stains and countless graffiti (done with coal, chalk, clay and by incision). Almost all the cave surfaces, whether of rock, concretions or speleotems, shown the action of vandals, in the most varied places (floor, roof, wall), at different times, through drawings, names and dates.

Intervention

As first measure the cave was surveyed to mark the location of the paintings panels and of the alterations. A detailed photographic survey of the cave, the painting panels and other surfaces to be cleaned was carried out, before, during and after the interventions.

Samples of pigments for identification had been collected. The chemical analyses had been made in the CECOR/UFMG - Centro de Conservação e Restauração de Bens Culturais da Universidade Federal de Minas Gerais. The material was identified by FTIR - Fourier Transform Infrared Spectroscopy, PLM - Polarized Light Microscopy and Microchemicals Tests, where the results of the techniques have been combined. It was possible to identify to types of black pigments: manganese dioxide (pyrolusite) and charcoal.

The following stage was the carrying out of solubility tests on the wall deposits. Based on the results of the tests was carried through the removal of the dust deposits, animals excretions, insect nests and graffiti on the paintings and other wall surfaces of the cave. The intent was to eliminate the interference that accelerates deterioration and harms the aesthetic reading of the panels and of the cave as a whole, inhibiting also new acts of vandalism since a defaced wall incites new strikes.

During the process of cleaning and removal of the deposits, the floor of the cave was covered with plastic, to avoid water penetrating the archaeological sediment and provoking changes in the cave's microclimate. Measures of Relative Humidity and Environmental Temperature had been taken during the intervention process with intention of accompanying the possible alterations.

All the walls where they had graffiti had passed for the cleanness process with the removal of coal, clay, chalk, etc. In the case of the defacing by incisions, those will be camouflaged in an attempt to hide then and to return, to the panels, aesthetic characteristics closer to the original (FIGURE 3, 4, 5).

The whole proposal was thought out seeking minimal intervention and impact, whether by the removal of the defacements and other deposits in the wall surfaces of the cave. With the execution of this work it was possible to discover a new recorded figure and two painting vestiges.

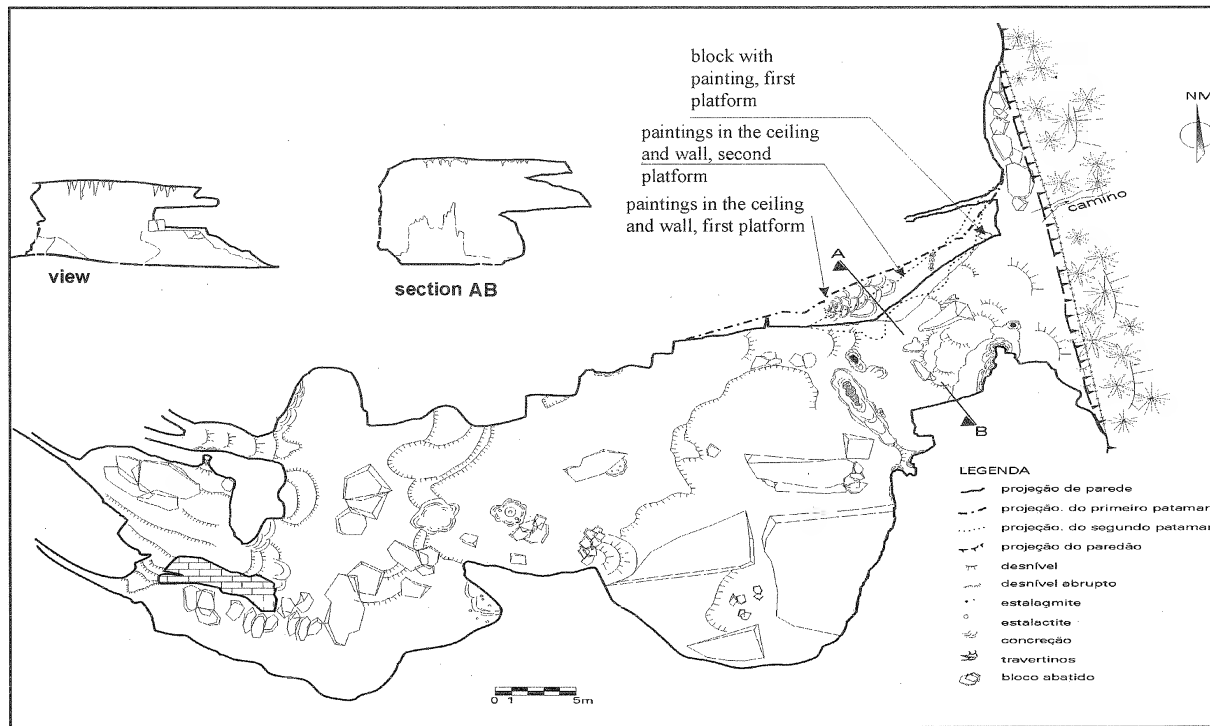


Figure 2 - Maps and sections of Ballet cave.

Acknowledgements

The author wish to acknowledge to the substantial support of this work by the Grupo Bambuí de Pesquisas Espeleológicas.

Also had participated of this work Vitor Moura (architect and espeleologist) and the archaeologist Alenice Baeta.

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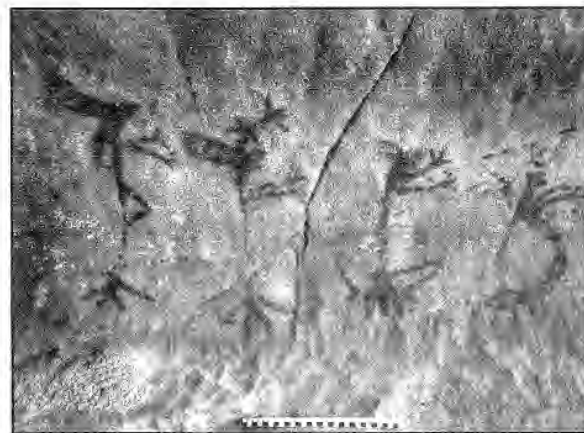
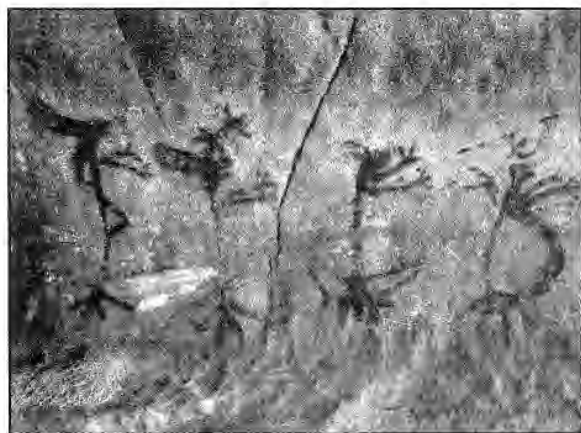


Figure 3 - Fecundity Ritual before and after the intervention



Figure 4 - Detail of one of the rock art panels before and after the intervention

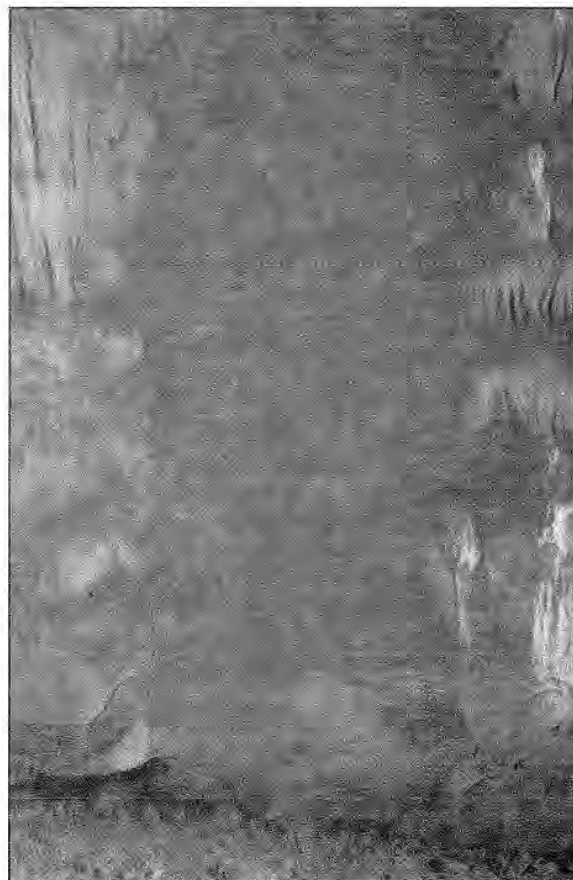
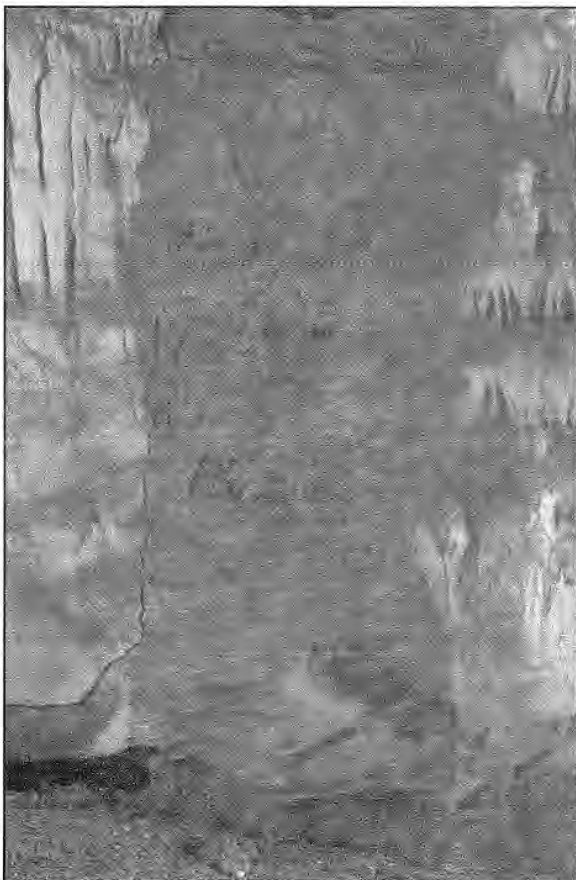


Figure 5 - Detail of one of the walls before and after the intervention

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Assessment of recreation resources in the karst terrains of high atlas mountain (Morocco) and Vitosha Mountain (Bulgaria)

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*Geological Institute, Bulgarian Academy of Science, Sofia, Bulgaria***Abstract**

The terrains studied are characterized as endokarst domains within High Atlas Mountain (Morocco) and Vitosha Mountain (Bulgaria). They include the biggest underground karst systems discovered so far in Bulgaria and Morocco. Both cave systems are attractive tourism objectives. According to us their resources are not evaluated enough. They have a high degree of ecological preservation. The natural forms of surface and sub-surface karst (geological, tectonic, geomorphological, hydrological and hydrogeological, mineralogical, climatic, soil, vegetation, animal, etc.) are combined with unique historic monuments from the remote past till the present days. The nearness of both karst phenomena to extremely urbanized territories of Agadir and Marrakesh towns in Morocco, and Pernik and Sofia towns in Bulgaria put them also in good communication

relations with different types of monuments (natural, historic and cultural of local importance and protected by the international conventions) of very close territories. Their immediate neighboring to the highly urbanized centers put also a number of questions about the preservation of these unique karst eco-systems. Their rich natural, historic and economic specifications make them attractive objectives of sustainable tourism in both countries. An assessment of the recreation potential of both karst domains based on geographic location, geological conditions, tectonic, hydrology and hydrogeology, relief, climate, biosphere, historic and economic specifications, etc. is made in the work presented for the needs of esthetic, scientific-informative, educational and cave tourism. The terrains studied might be used for performance of nature-protective, scientific and educational programs within their territories, too.

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The impacts to the environment and the creation of «pseudokarst» landforms, from the bauxite mining activity in the mountain of Ghiona (Central Greece)

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The Bauxite mining activity in Ghiona has resulted in the deterioration of the natural environment of the area. These deteriorations also include the changes in the relief and the geomorphs which are mainly due to the use of the surface exploitation method for the mining of bauxite. The abandoned mines and especially the surface exploitations show, as far as the morphological characteristics are concerned, significant similarities with the karstic forms of the relief, which are called "dolines" and are responsible for the formation of a "pseudokarst" relief in the area. This work presents: (a) the evolution of the "pseudokarst" relief in the northeastern side of Ghiona Mountain and (b) the effects - changes in the natural environment, the geological - geomorphological characteristics and the relief in the study area, from the mining activity of bauxite.

Key-words: Artificial cavities, Environmental geomorphology, Environmental Impact Assessment Studies, Ghiona mountain, Mining activity, Pseudokarst.

1. Introduction

Strictly speaking, the Karstic types of the relief are the types that are formed as a result of the solvent action of water on calcareous rock. This karstic relief is characterized by valleys with closed cavities of various shapes and dimensions, due to the absence of surface hydrographic network and the presence of too many underground caves. Main conditions for the creation of karstic forms, are the presence of easily water soluble rocks and the heavy rainfall which alter the soil mechanical behaviour of the calcareous rocks. (Theodoropoulos and Zamani 1972, Psarianos 1986, Mariolagos et al. 1987, Monroe and Vicander 1989, Papapetrou-Zamani 1990, Papadopoulou-Vrynioti 1996, Castiglioni 1997, Papadopoulou-Vrynioti and Kotsis 2004).

Monroe (1970) uses the term "pseudokarst" to define those areas that have landforms that resemble the Karstic areas which though are not the product of karstic processes. Castiglioni (1997) uses the term "parakarstic" phenomena for those processes and landforms that are created from the weathering and erosion of the non calcareous rocks, while he calls "pseu-

dokarstic" the landforms that resemble the karstic ones but originate from quite different processes. Also the term "doline" determines the natural closed cavities of various dimensions and shapes (cylindrical, conical, bowl-or dish-shaped) which in most of the cases drain through underground ways. Usually the dolines have a diameter of 10 up to 1000 meters and depths from 2 to 200 meters.

In the study area where we have the presence of bauxite ores and these are mined mainly using the surface and underground mining method, there are large areas, that show extensive karstic phenomena mainly due to the calcareous background. These surface exploitations of the bauxite ores, which increased significantly during the decade of the seventies exhibit significant similarities to the natural karstic forms of the relief which are called "dolines". For this reason the term "pseudodolines" was used in order to describe these artificial landforms.

The impacts to the natural environment and especially the changes in the geological - geomorphological characteristics of the north eastern side of the Ghiona Mountain, in combination with the increase in number of surface exploitations of the bauxite ores and of the "pseudokarst" relief, constitute the object of this study.

2. Materials and methods**2.1 Research site location - Geomorphology**

This study deals with the surface bauxite exploitations that are found in the northeastern side of the Ghiona Mountain. More specifically, the study area is located within the bounds of the imaginary triangle with points of intersections being Liritsa Crest (altitude 2.007 m) and the villages Kastelia (430 m) and Mariolata (340 m).

The morphology of the relief of the greater area is shaped by the Mount of Ghiona which has as highest point the Pyramida Crest (altitude 2.507 m) west of the study area and by the secondary lower highest points Plativouna (2.316 m), Vraila (2.177 m), Liritsa (2.007 m), Pigadoulia (1.024 m), Kastrinou (1.424m), Tsouka (1.099 m), Stirfari (805 m), and Alefando (829 m). The natural banks of the northeastern side show significant morphological slopes with deep crevices alternating with rounded and deeply

karstic crests and are differentiated depending on the nature and position of the geological formations, going from limestone (slope 60-85%) to flysch (slope 20-60%). Lower down we have subsequent limestone elevations ending in alluvial areas of the plain that extends between Mariolata - Gravia - Kastelia and Brallos.

2.2 Methods used for the mining of bauxite

The mining of bauxite in the greater area is done: (a) from the surface, using the method of "upright grades" by uncovering the deposits during which procedure vertical or step mining fronts are formed until the surface of the ore, while at the same time the non usable materials are removed, (b) underground using the method of "chamber and poles" during which galleries are opened up in order to reach and obtaining the ore, (c) in several cases a combination of the above mentioned methods is applied.

The basic criterion upon which the method used for mining is chosen is economic considerations and it is determined from the ratio $l = \text{volume of unused materials (m}^3\text{)} / \text{Bauxite weight (tn)}$. When $l < 5$, it is economic viable to use surface mining, while when $l > 5-6$, then the underground mining is preferred. Nowadays in order to comply with environmental legislation (L. 998/79 and L. 1650/86), in deciding which method to use, amongst other things one has to seriously consider environmental criteria that ensure the protection of the environment since land restoration is now imperative.

2.3 Characteristics of "pseudodolines"

"Pseudodolines" are artificially formed landforms which in their entirety form the "pseudokarstic" relief and which exhibit significant similarities to the natural karstic forms of the relief that are called "dolines" but differ in the way they were created.

The main similarities of the "pseudodolines" to the natural dolines are:

- They are both closed or semi closed cavities of various forms and dimensions that exceed a height the 30 meters. This height corresponds to the excavation front and the volume of the calcareous formation that is removed as unused material. In certain cases the height of the excavation front exceeds 200 meters as it is in the case of the large mine "Koukouvista 5". The diameter of "pseudodolines" on the top of the cone varies from 50 -250 meters.

- These "pseudodolines" are located on calcareous formations which constitute the roof and the floor of the bauxite mines.

- As far as the hydrogeological characteristics are concerned, the "pseudodolines" present significant similarities to the natural dolines due to the calcareous composition of their walls and their floors and due to the capability of these formations to show an increased permeability and thus their ability to drain the surface waters through underground karstic ways. In many cases where we have similar underground bauxite exploitations, these tunnels facilitate the drainage of the surface waters and act as artificial drainage networks, thus substituting the natural drainage.

The main differences are:

- They differ in the way they were formed. The natural dolines are landforms that are created by the solvent action of water on calcareous rocks, while the "pseudodolines" are created as a result of human activity and specifically from mining activities.

- They differ from the natural dolines in the stepwise development of the slopes of their cavities, resembling a flight of stairs, which result from the artificial levels formed from excavation works and the removal of unused materials during the bauxite mining activities. It was observed that in the older mines the angular shapes of these levels tend to become rounded as a result of the intense action of external factors which, assisted by the long periods of snow coverage during winter time, enforce the erosion-decay phenomena of calcareous slopes of "pseudodolines". These phenomena are more intense where we have weak soil mechanic

characteristics due to existing discontinuities in the rock, or cases of serious breakage, where the rock is broken to pieces.

- The depositions of unused materials in or outside the cavity of the "pseudodoline" are characteristic of man made interference.

2.4 Investigation method

In order to record the existing environmental situation in the near and the greater area of study, we used topographical and geological maps as well as vegetation maps. Also for the recording of the time evolution of the number of mines as well as the assessment of impacts and the changes in the natural environment and especially the geological - geomorphological characteristics of the area, we used air photographs of the Hellenic Military Geographical Service (H.M.G.S.) of the years 1945, 1960, 1970 and 1986, in scale 1: 42.000, 1: 30.000, 1: 15.000 and 1: 30.000 respectively.

The data from the aerial photographs were combined with data from the evolution of the phenomena that arised from observations in the area that are related to natural and man made activities in the mining area which have to do with the formation of cavities "pseudodolines" and formations due to depositions of unused material. Observations were carried out over time, every five years during the months of February, June and September, for the time between 1989 - 2004 and every month, from January to May 2005, at ten (10) "fixed points - witnesses" in selected places at the mines of "Maganiara", "Kranies", "Koukouvista 5", "Paliampela" and "Alefando".

3. Results - Discussion

3.1 Bauxite mining and its impact to the natural environment - The creation of "pseudokarstic" landforms

The result of the surface mining method for the mining of bauxite, was significant changes over the time in the relief and the landforms which originated mainly from the stepwise excavation fronts and from the cavities formed from the process of revealing the ore and the depositions of the unused materials. In the rapid deterioration of the characteristics of the relief and the creation of the "pseudokarstic" landforms also contributed the use of improved drilling machines as well as the use of contemporary heavy duty machinery which mine and transport with great speed large quantities of ores and unused materials. This "pseudokarstic" entity extends and covers large parts of vegetation free slopes, forests and forest areas and consists of alternating excavations "pseudodolines" depositions and an extensive road network constructed in order to make the mines accessible.

The expansion of the surface exploitations was limited significantly after to the implication of Laws 998/79 and 1650/86 according to which the development of surface mining was prohibited, while Environmental Impact Assessment Studies and the enforcement of environmental restrictions became compulsory when it came to mines that were found in forests and forest areas. The exploitation and development of the deposits was counterbalanced with the application of the underground method of mining. Also the restoration of land of the abandoned mines was judged as imperative. The data and references relating to the temporal evolution of the mining activity of Bauxite in the Northeastern side of Ghiona, from the beginning of the 20th century, verify the fact that mining activity, in combination with forest fires, illegal woodcutting, and grazing, constitute the main burden in the ecosystems of northeastern Ghiona.

The main impacts to the natural environment of the study area due to the bauxite mining activity and especially due to the surface exploitation methods used are described in detail below, and these are:

- (a) Changes in the geological - geomorphological characteristics of the area and the formation of "pseudokarstic" landforms. These changes are due to the artificial formation of cavities "pseudodolines" heaps from the

deposition of unused materials and the construction of an extensive road network in order to make the mining sites accessible, which are mainly represented by the disorder in the morphology of the relief and the creation of "pseudokarstic" landforms, changes in the erosion-deposition characteristics of the ground and the creation of acquired unstable ground conditions or changes in the geological order of the rocks as well as in their cracking, dislocation, compaction or overlapping of the surface layer of the ground and the geological formations. More specifically, as far as the increase in the erosion rate of the ground, this is due to the large size of excavation fronts. The excavation fronts that constitute the walls of the "pseudodolines" show artificially formed upright slopes on the order of 80-90%, in relation to the already existing relief and in combination with the deforestation of the land, are responsible for the changes in the direction of movement and the natural flow rates of the surface waters which flow in the uphill parts of the basins, according to the conditions of the water level flow. Those conditions are also amplified by the construction of the extensive road network in order to reach the mines with new slopes in the road surface (7-10%) and longitudinal excavations that force the resulted ground waters to alter their natural direction of flow due to condensing and waterproofing of the road and follow its grade or to overflow above the filled in slope. This results in the amplification of the erosion phenomena of the in-depth/ ravine causing and backstepping erosion. (Tsochos 1997, Vavizos and Mertzanis 2003).

(b) Changes in the surface and underground waters. These changes have to do with the differentiation of their flow direction or their course, their quality and quantity as well as changes in the rate of absorption of the surface waters or drainage routes, or the rate and the quantity of land washings. An important point in the above mentioned changes is the differentiation of the natural characteristics of water drainage. The steep slopes of the excavations in the excavation fronts, that is in the walls of the "pseudodolines" and the deforestation in the area result in the increase of both the quantity and rate of the outflow of the surface waters and the restriction of penetration in these locations. The opposite phenomenon, that is the increase of penetration, is seen in the bottom of the artificial cavities and of the "pseudodolines" as well as in the depositions of unused materials, especially in those cases where these cover large areas and their condensing and granulometric graduation allows it. (Papaspirou et al. 1983, Kaminari et al. 1989, Mertzanis et al. 2004)

(c) Landscape deterioration of north eastern Ghiona, due to the differentiation of the character of the relief and the creation of visual changes as a result of the destruction of its natural characteristics (vegetation, soil, rock formations). The destruction of the natural characteristics is accompanied by the disappearance of the visual characteristics of the natural environment (lines, texture, colour) and their replacement with new man made visual characters of intense coloration, geometrical lines and shapes, different texture and sizes that dominate the landscape, due to the removal of volumes from the excavation sites and the depositions of unused materials in heaps downhill. (Brofas 1987).

(d) Changes in air quality, due to the creation of dust and the emission of exhausts from the heavy vehicles that transport the ore and the unused material, as well as during the excavation procedures of the bauxite mining (excavation, drilling, blasts), which can also create health problems to the people working there as a result to their continuous exposure to them. (Crouse et al. 1983).

(e) Changes in the microclimate, due to uncovered surfaces of the excavation fronts and the deposition of unused material which act as heat collectors and result in high temperatures in the area, especially at midday during summer. This phenomenon is also blamed for the loss of a fir plantation due to dryness in a mine in Ghiona (Brofas 1989).

(f) Creation of noise and vibration due to blasts and excavation procedures which are noisy with negative effects to the workers, the inhabitants and also to the wild life.

(g) Changes in the flora and the fauna and most importantly the de-

struction of the dwellings (Veresoglou 2002) and the shrinkage of forests and forest areas and grazing land due to the creation of successive vegetation free areas as a result of excavations and deposition of unused materials. (Adamakopoulos et al. 1988). An important point to consider is the disappearance of the multiple functions of the part of the forest that became extinct. Those functions are wood production and secondary products, the protection of the soil against erosion, the effects on water balance, the supply of food for the necessities of wild life, the climatic balance and aesthetic considerations (Brofas 1987). Alongside the excavation procedures, multiple fires have worsened the negative effects in the fauna of the area, as many nesting and food supply spots for a variety of species disappeared taking along with them those species too, thus limiting the kinds of those species.

3.2 Development of the surface exploitations of bauxite and of the "pseudokarstic" landforms

Nowadays, the relief of the area is characterized by the "pseudokarstic" landforms which appear to have a lot of "pseudodolines", that come to 0.15 per km². More specifically the number of surface exploitations with similar characteristics to the "pseudodolines" is for the years 1945, 1960, 1970, 1986, 1989, 2004 and 2005, to 1, 11, 18, 26, 26, 26 and 27 respectively.

The rate of evolution of the number of surface exploitations of bauxite show an increasing tendency for the time from 1930 until the end of the 1980's while from that time onwards and up to date this tendency falls. This fact is attributed to the implication of environmental legislation (L. 998/79 and L. 1650/86), which significantly restricts the surface exploitations of bauxite and at the same time makes mandatory the restoration of land at the end of mining activities. A similar evolution is seen also in the size of surface exploitations which in their majority were made wider as time went by and reached sizes of excavation fronts and depositions of unused material of over 150 meters high and the longest diameter approximately 200-250 meters. Also we estimate that the surface that the unused material take up has a size more than 3,5 times the size of the quarry - excavation. Indicatively we refer to the case of "Koukouvusta 5" mine, which when calculating the excavation front and the unused material depositions, the size of the derangement exceeds 0,3 km² (height 350 m and width 950 m approximately).

4. Conclusion

The way that the bauxite was mined until now in the northeastern side of the Ghiona mountain, mainly using the surface exploitation method, consists the most significant burden to the ecosystems in the area and resulted in the deterioration of the characteristics of the relief and the formation of a peculiar environmental entity that is characterized by the strong presence of "pseudokarstic" geomorphs and "pseudodolines". This "pseudokarstic" entity consists of alternating: (a) excavations and cavities "pseudodolines", which originated mainly from the scaled bauxite mining excavation fronts, (b) heaps in the ground created from the deposition of unused materials from the mining operations and (c) a dense road network that was necessarily constructed, in order to make the mining sites accessible. The "pseudodolines" formed show a significant similarity to the natural karstic forms of the relief, what is called "dolines" but differ in the way they were formed.

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The Barrois covered karst (NE France): a recorder of valley incision and cover retreat

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Abstract :

The study of three karsts (Poissons, Cousance, Rupt-du-Puits) of the Barrois (NE France) can be used to propose a geomorphological model of karst migration associated with the incision of the hydrographic network and the retreat of the non-carbonate formations of the Cretaceous. Poissons karst is older than the Cousance karst, itself older than that of the Rupt-du-Puits. Through this three karsts, their geographical position, their morphostructural context, it is therefore possible to mark out the evolution and establishment of the reliefs of the calcareous plateau. This evolution is marked by the incision of the Marne hydrographic network, by the retreat of the Cretaceous cover and by the karstification and exhumation of the limestone masses.

Keywords : Karst record, geomorphological evolution, Rupt du Puits, Barrois

In limestone country, valley incision leads to constant readjustments of underground karstic flows expressed in stepped landforms. In the particular sphere of covered karst, the removal of a clay-sand cover leads to the migration of karst structures.

A covered karst

The karstic infiltration zone is bracketed between two thickness of 1 and 30 metres of overlying Cretaceous deposits. Without such cover, the diffuse infiltration does not allow organised karstic water flows. Over 30 metres, no infiltration appears possible since most of the drainage follows surficial pathways [Devos *et al.*, 1999]. This part of the Paris Basin (fig. 1) gently dip westward and these two thickness limits define a roughly N-S area, about 20 kilometres large, of potentially very active karstic infiltration. Vertical incision of the Marne and its tributaries locally eroded the Cretaceous sediments and allows the outcropping of the underlying

Tithonian limestones. The study of three karsts of the Barrois (Poissons, Cousance, Rupt-du-Puits) between the valleys of the Marne and the Saulx, can be used to propose a geomorphological model of karst migration associated with the incision of the hydrographic network and the retreat of the non-carbonate formations of the Cretaceous.

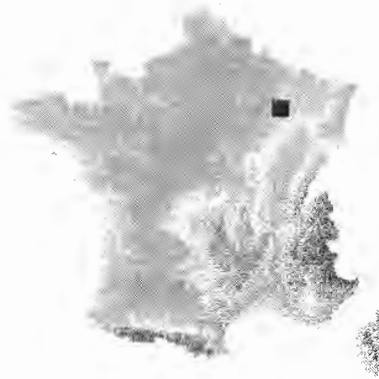


Figure 1 : Location of the Barrois area.

Three karsts studies (fig. 2)

The Poissons karst is inactive and filled with iron ore coming from the weathered overlying Cretaceous sediments. He is perched +120 / +150 m above present-day baselevel. A 400 k yrs U/Th age obtained on a speleothem exceeds the limit of the dating method and suggests its genesis at least during the Middle Pleistocene (isotopic stage 7 and over) [Jaillet, 2000]. The karstic morphologies and associated endokarstic deposits testify during its activity the presence of Early Cretaceous outcrops about 10 kilometres eastward from their present-day position. Towards the North, the Cousance karst system displays a first +75 m horizontal phreatic drainage pattern subsequently bored by vertical shafts related to a +10 / +15 m drainage level. Speleothems related to this second incision stage define at least an Eemian *s.l.* (+100 to +120 k yrs) activity (isotopic stage 5) (Jaillet *et al.* 2004). Last, the active Rupt-du-Puits karst system displays perched +15 m paleodrainage patterns compatible in relative height with the "Cousance" Eemian karstic evidence. As yet, U/Th dating on speleothems and ^{14}C dating on organic rich sediments did not allow to define ages older than isotopic stage 2 [Jaillet *et al.* 2002].

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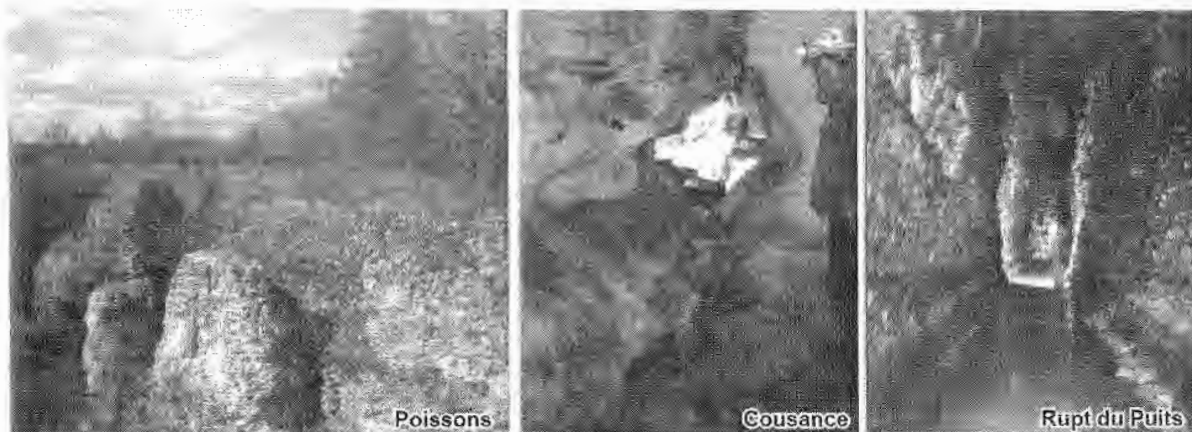


Figure 2 : Photos of three studied karsts : Paleo-karst of Poissons, paleo-karst of Cousance, and the active karst of Rupt du Puits.

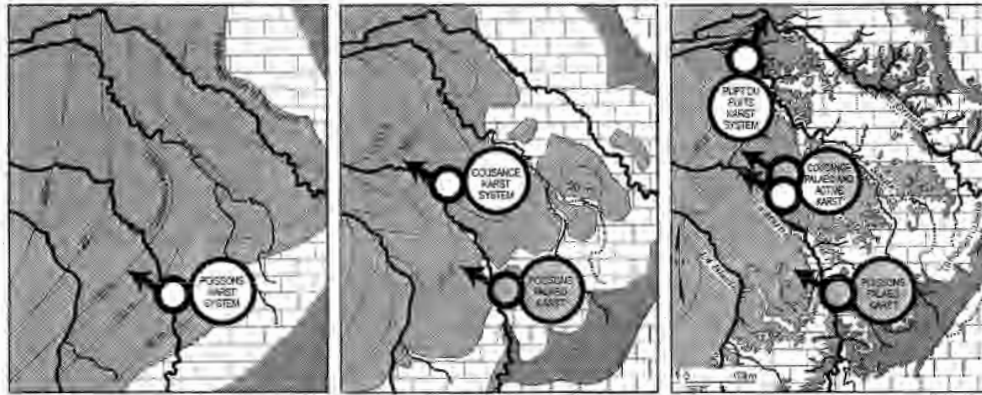


Figure 3 : Cartography of the migration of the karsts of Poissons, Cousance and the Rupt-du-Puits. Three stages are linked to the incision of the hydrographic network and the retreat of the cretaceous cover. The extension of the cretaceous cover of stage 1 (Le Roux, 2000) holds account of a generalized ablation of around fifty meters. The extension of stage 2 is schematized between stage 1 and the current extension.

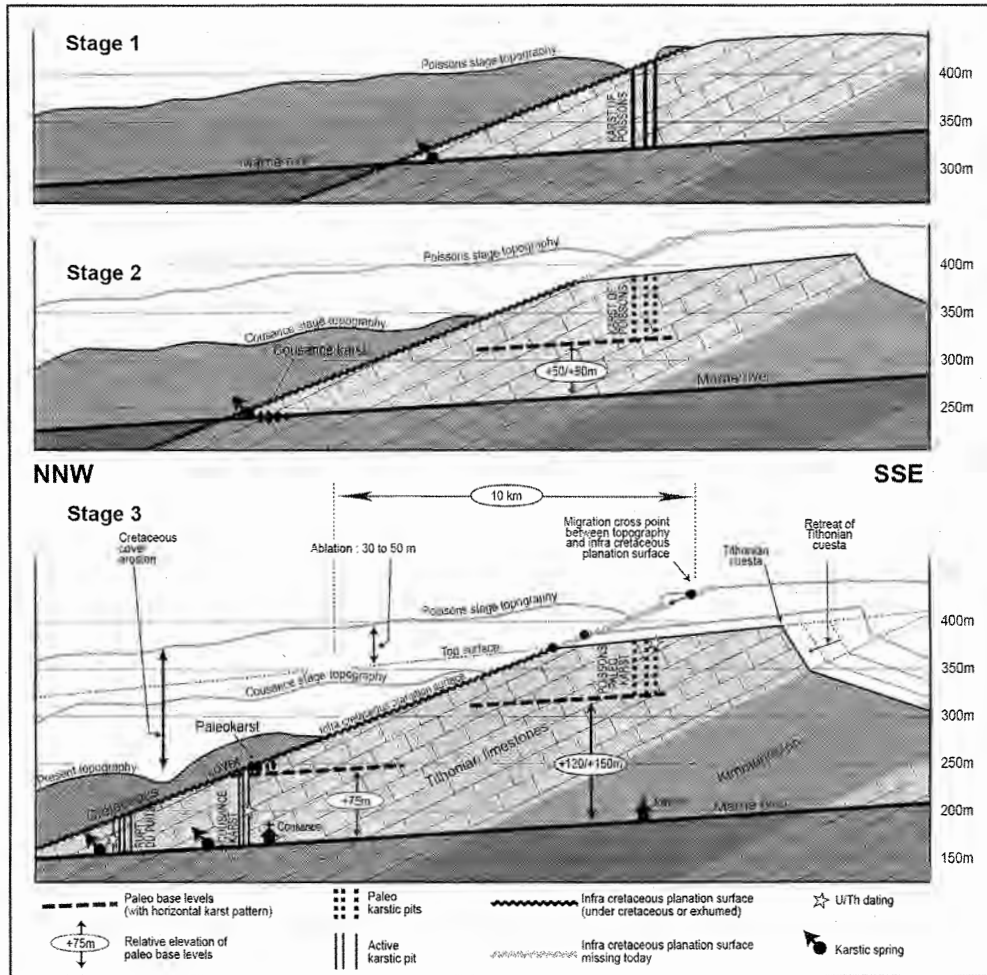


Figure 4 : Synoptic vertical profile along the Marne valley. The three studied karsts are setting in their morphostructural context. Note the contact between the ante-cretaceous planation surface and various reconstituted topographic surfaces. Note also the position of the paleo piezometric levels together with the position of the three karst systems.

Migration of karsts

This migration of karsts in the Barrois from south to north is demonstrated by the simultaneous karstic record of the base paleo-levels and the cover paleo-extensions (fig. 3). This could be recognized in these different karsts from the following elements:

- the structure and elevation of the drainage channels and paleo drainage channels of the different karst systems;
- the survey of the cover thicknesses needed for the genesis of these channels;
- the amount of cover eroded for causing the limestone slab to outcrop;
- the nature of the infills of these channels;
- the hydrodynamic activity of these channels (active / inactive).

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The Karstic system of the Kerketio Mountain (Koziakas) and its exploitation.

by George Bathrellos*, Efthimia Verikiou**, Hariklia Skilodimou***

Abstract

The Kerketio or Koziakas Mountain is the eastern continuity of the mountain range of Pindos towards the plain of Thessaly, and belongs to the homonym geological unit of Koziakas. In this unit, some karstic formations are present within transgressional oolitic limestones of Jurassic age, or within successions of limestone and irestone that date from Triadic up to Lower Jurassic. The recorded karsts are dolines, caves, and springs.

When studying the geographical distribution of these karstic forms it is concluded that they follow the territorial development of the mountain Koziakas from the North to the South. In the study area the tectonic activity, along with the composition of the formations (lithology), are favorable conditions to the rock permeability and dissolution. This also results to the formation of an underground drainage network. It is of outmost importance to thorough investigating the continuity of the found caves by experts.

Apart their geological interest, the karsts constitutes an attractive pole for the visitors. A further scientific study and exploitation of the karstic combined with the development of the general natural and cultural elements of the Prefecture may promote alternative types of tourism.

Introduction

The study area, which is the Kerketio or Koziakas Mountain, is located at the western edge of Thessaly, in the Central Greece. (figure 1), and is the eastern continuity of the mountain range of Pindos towards the Thessaly terrain. The direction of Koziakas is N-S.

The presence of limestone, from the stratigraphic unit of Koziakas, along with other parameters, insinuate the co- existence of karstic formations. In addition to this, there are tectonic disruptions and joints contributing to the rock permeability. Their nature, frequency and order are responsible for the generation of karsts. Furthermore, the intense tectonic activity favors the rock permeability and dissolution, which lead to the development of an underground drainage system.

This paper involves the description of the karstic system of the mountain Kerketio in association with the tourist development of the prefecture of Triakala and the further impact of this research to its growth.

Description of the karstic system of mountain Kerketio

According to in situ study, along with the support of the published or oral references, the existence of karsts is confirmed. The karstic system

is distributed along the mountain Kerketio (or Koziakas) starting from the northern up to the southern. The total number of the reported locations and the ones from previous publications is nine. In fact, the real locations may be more than nine, since the biggest part of the mountain Kerketio is inaccessible to typical researchers because special training and alpine equipment is needed. In the following paragraphs the locations of the karst are described as shown in figure 2. The topographic background of figure 2 is a reference from the survey maps of the Military geographical Service (scale 1: 50 000, sheet Kalambaka and Mouzaki) (Bathrellos, 2005).

In the northern part of mountain Koziakas, at the location Antallaxima, close to the western part of the village Megarhi, a cave bearing the same name as the village with extraordinary stalagmites and stalactites is found. (Location 1, figure 2) (Photographs 1 & 2). This cave was reported from Th.Nimas (1987) and G.Ziakas (1992). The entrance of the cave is located at a height of 850 meters.

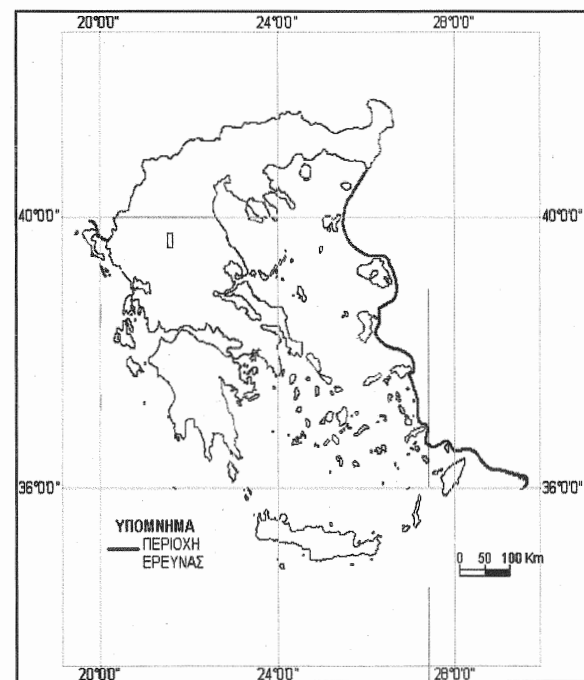


Figure 1: The study area.

At the southeastern part of Koziakas, western to Filyra, there is a cave with a good variety of stalagmites and stalactites. (Photograph 3). The inhabitants call this cave as "the Cave of Bei" thanks to the spring close to its entry at a height of 1450 meters; it still remains inaccessible.

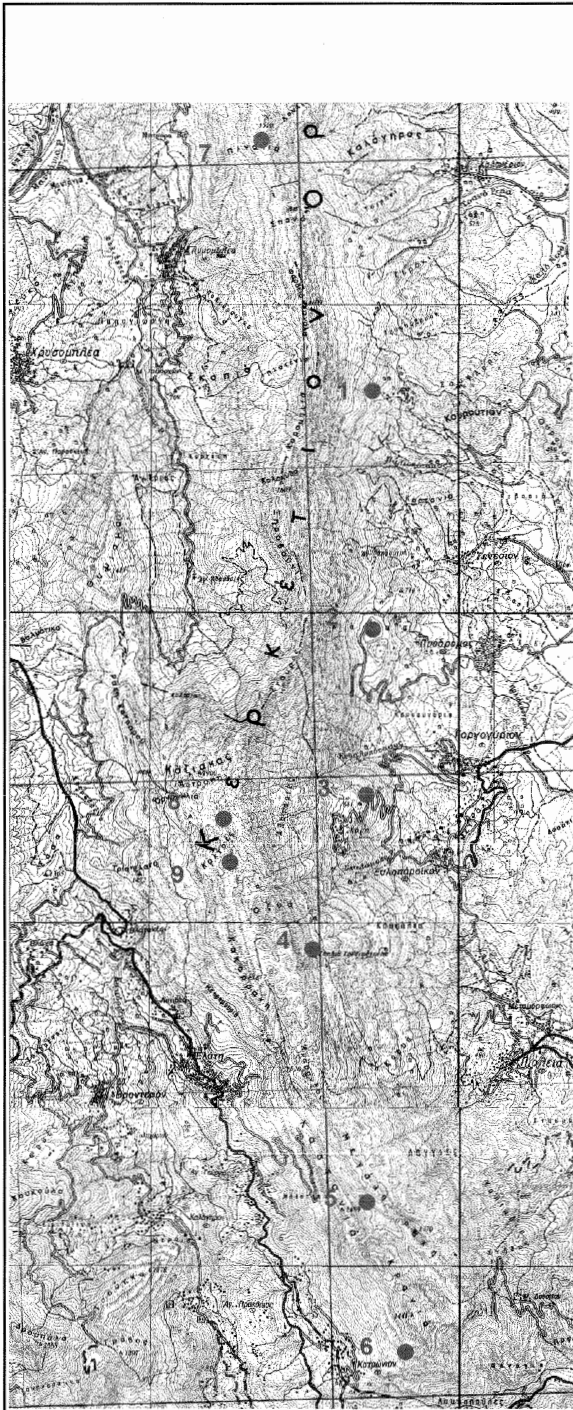


Figure 2: The locations of karstic features of the Kerketio Mountain (the topographic maps was published by Hellenic Geographic Military Service, scale 1:50,000, sheets "Kalambaka", "Mouzaki")

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Northern of the cave above, southwestern of the village Xilopariko and northern to Pialia the cave Chrysikotripa exists. (Location 4, figure 2). The entrance of this cave is located at a height 1400 meters.

It would be advisable to systematically study the cave "Aeras" at Paleokaria under which a river flow occurs.

On a slope of the road from Gorgogyri to Kori, on the mountain Kerketio, northern to Kori, some small karstic formations are present. (Location 3, figure 2) These characteristic stalagmitic forms were revealed during excavations to construct the road (photograph 4). The formations are visible from the road and the karst is typical though of a small size. They are located on 800 meters height.

According to the inhabitants' reports, another cave also exists in the region but it was impossible to confirm during the site survey. The possible location is considered to be at the limestone, eastern to Kotroni (location 6, figure 2). It is alleged that treasure hunters destroyed the entrance.

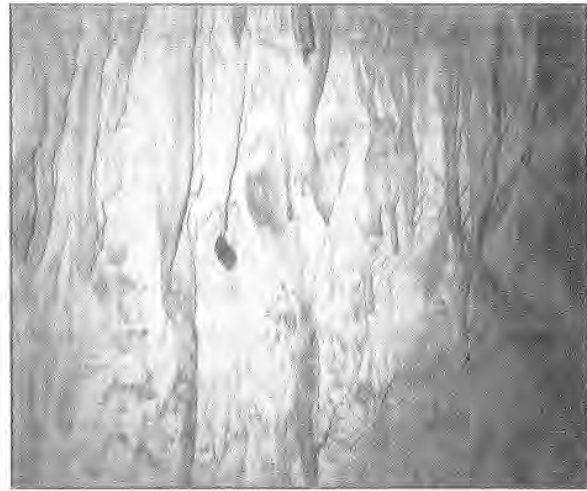
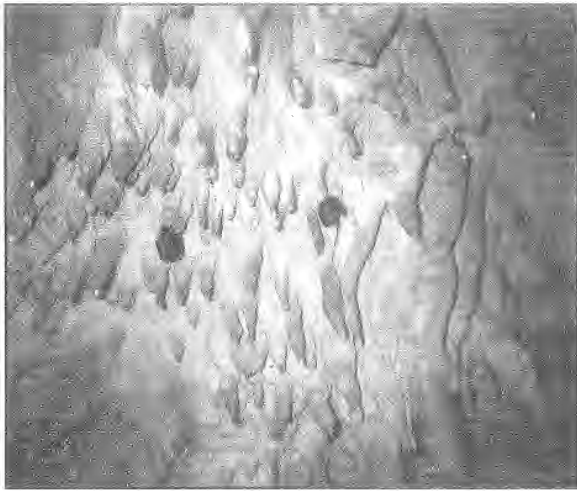
Another karstic form found in the study area is the doline - karstic plain, western to Koziakas at a height of 700 meters (Location 2, figure 2). The location is called "Lakka" but it is commonly known as "Baltitsa" (photograph 5). A lot of streams end up there and during the winter and the spring much water is accumulated and cover its bottom. There is a subsurface drainage in the doline. Nowadays, it is covered by flora, there is sediment yield disposed on its bottom.

Moreover, some small dolines are situated on the top line of Koziakas: two of them are found at the village Kori at a height of 1700 meters (locations 8 & 9, figure 2) and another one western to Kaloneri and northwestern to Glykomilia at the site "Pinakia", 1500 meters height (locations 7, figure 2).

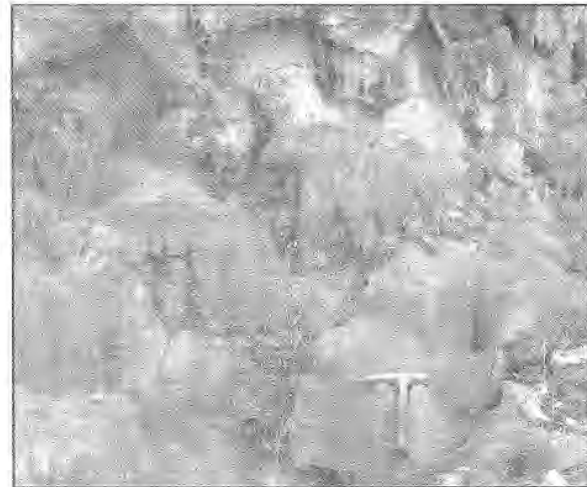
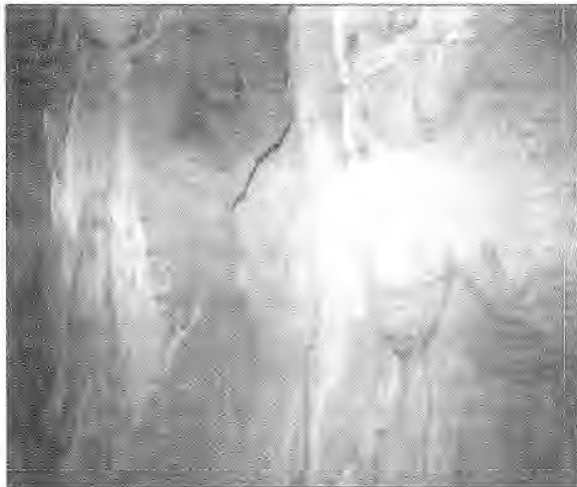
Finally, the karst behind the new bridge of Pili, on the way from Pili to Elati- Pertouli must be reported. Based on reports of MAVRIDIS et al., (1985), the Portaikos river should have run underground and flew out to the location of the old stone-made bridge. Other karst is developed locally, along the perimeter of the basin. These karsts supply a good quantity of water and are drained from springs at their lower part.

The tourist development at the prefecture of Trikala and the exploitation of the Kerketio Mountain

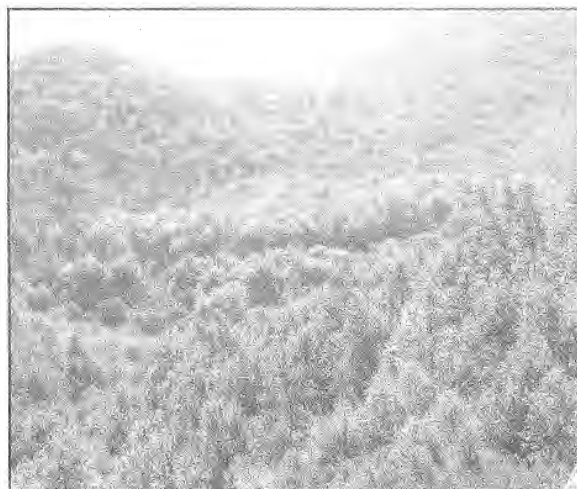
Meteora is a characteristic Natural Monument of the Prefecture of Trikala that has attracted tourists all over the year and leads the population of Trikala to be involved with tourist activities. Though the area is continental and does not favor the massive tourism, a tourist current has been developed the last years. This current launched the construction and operation of tourist accommodation. Within twenty years, from 1975 to 1996, the official reports reveal the doubling of tourist accommodation: in 1975 the beds to rent were 1254 and in 1996 approached the 3417, that was an increase of 172,49%. The funds of the emigrants and the financial support of the EU (Leader project etc) were responsible for this increase. (The following data, in table 1, come from the National Statistic Service for the years 1983, 1985, 1987, 1990, 1993, 1995 & 1999, and STAVROU, 1984).



Photos 1 & 2: The internal "decoration" of the cave in Antallaxima.



Photos 3 & 4: The internal "decoration" of the cave of Bei and karstic formations on the slope of the road from Kori to Gorgoryri.



Photos 5 & 6: The doline - karstic plain "Laka" at Prodromos.

YEAR	Number of stays overnight per arrival								
	From abroad			From Greece			Total		
	stays overnight	arrivals	average	stays overnight	arrivals	average	stays overnight	arrivals	average
1975	71.552	63.440	1,13	112.008	62.387	1,80	183.560	125.827	1,46
1976	90.847	85.363	1,06	103.639	59.013	1,76	194.486	144.376	1,35
1977	96.585	92.426	1,04	105.026	59.771	1,76	201.611	152.197	1,32
1978	123.353	117.733	1,05	105.659	58.456	1,81	229.012	176.189	1,30
1979	117.557	109.581	1,07	106.235	55.363	1,92	223.792	164.944	1,36
1980	151.868	136.637	1,11	104.126	56.319	1,85	255.994	192.956	1,33
1981	109.565	101.877	1,08	91.623	49.573	1,85	201.188	151.450	1,33
1982	117.636	108.994	1,08	87.152	47.972	1,82	204.788	156.966	1,30
1983	121.452	113.726	1,07	81.472	45.195	1,80	202.924	158.921	1,28
1984	132.830	125.403	1,06	82.874	48.025	1,73	215.704	173.428	1,24
1985	119.859	111.477	1,08	75.189	43.350	1,73	195.048	154.827	1,26
1986	103.712	96.995	1,07	67.162	39.722	1,69	170.874	136.717	1,25
1987	112.098	105.367	1,06	68.453	44.065	1,55	180.551	149.432	1,21
1988	105.736	101.354	1,04	72.959	47.950	1,52	178.695	149.304	1,20
1989	97.399	91.742	1,06	65.498	41.103	1,59	162.897	132.845	1,23
1990	92.441	86.322	1,07	88.502	50.931	1,74	180.943	137.253	1,32
1991	61.075	55.204	1,11	95.757	51.758	1,85	156.832	106.962	1,47
1992	91.220	83.142	1,10	116.151	68.153	1,70	207.371	151.295	1,37
1993	71.604	64.493	1,11	102.327	59.609	1,72	173.931	124.102	1,40
1994	107.376	96.813	1,11	103.149	62.506	1,65	210.525	159.319	1,32
1995	94.806	84.883	1,12	106.184	62.999	1,69	200.990	147.882	1,36
1996	101.800	93.282	1,09	106.504	61.903	1,72	208.304	155.185	1,34
1997	124.699	112.219	1,11	129.029	75.830	1,70	253.728	188.049	1,35
1998	149.404	130.925	1,14	136.500	81.451	1,68	285.904	212.376	1,35
1999	113.951	100.169	1,14	131.872	81.238	1,62	245.823	181.407	1,36
2000	137.022	121.219	1,13	150.078	91.830	1,63	287.100	213.049	1,35

Table 1: The stays overnight per visitor arrival in the Prefecture of Trikala.

The tourist development, especially after 1975 when data are available, is upcoming until the mid- 80's.

Then a recession was recorded until the beginning of the 90's. From the mid-90s up today the number of tourists from Greece and abroad has been increased steadily. The recorded decrease was the result of the luck of accommodation background; but when modern constructions or services were developed, after 1985, an important increase of the visitors occurred.

Table 1 demonstrates the number of arrivals and stays overnight of the visitors (from abroad and from inland) in the prefecture of Trikala.

Figure 3 shows the changes of the arrivals and stays overnight of the tourists (from abroad and from Greece) in the Prefecture of Trikala. The increase of the arrivals did not result to a respective increase of covering the tourist accommodation of the Prefecture of Trikala. This was due to the irrelative increase of the beds in relation to the increase of tourist arrival. The fullness of the tourist accommodation fluctuates between 50%, in 1980, and 32.5% in 1995, and 1999. The biggest percentage belongs to Greek tourists except the years 1978-1980 and 1990-1996. Therefore, a remarkable decrease of the fullness of the total of visitors and tourists from abroad is observed. On the contrary, the fullness from Greek tourists is potentially increasing, though less from the one of years 1970-1980.

The most important remark of the tourist activity for the development

of the Prefecture of Trikala is the number of stays overnight per visitor arrival as shown in Table 1. The stays overnight of tourists from abroad fluctuate from 1.04 per arrival (in 1977 and 1988) up to 1.14 (in 1998 and 1999). On the other hand, the stays overnight of the Greek tourists in the Prefecture of Trikala fluctuate between 1.52 per arrival (1988) to 1.92 (1979). This is not a remarkable increase though the developing number of tourists from abroad: every visitor does not stay over one night in the Prefecture of Trikala. Thus, the bulk of tourists just passes by the Prefecture of Trikala, only for sightseeing (e.g. Meteora) and is considered an intermediate stop of a longer trip. The explanation of this conclusion is based on the luck of alternative activities that may stir tourists' interest within the prefecture of Trikala, which is what the tourist-developed countries apply. As for the Greek visitors, they stay in the available accommodation for almost two nights: they select the prefecture of Trikala for short holidays and/or in combination with a visit to the prefecture of Karditsa. The most preferred locations are Elati, Kalambaka, Trikala in the prefecture of Trikala, and the Lake of Plastiras in Karditsa.

Figure 4 shows the changes of the stays overnight per visitor arrival to the Prefecture of Trikala. (Total of Greek and tourists from abroad): the stays overnight per visitor arrival fluctuate from 1.20 to 1.47.

The last years some alternative activities have been developed in the

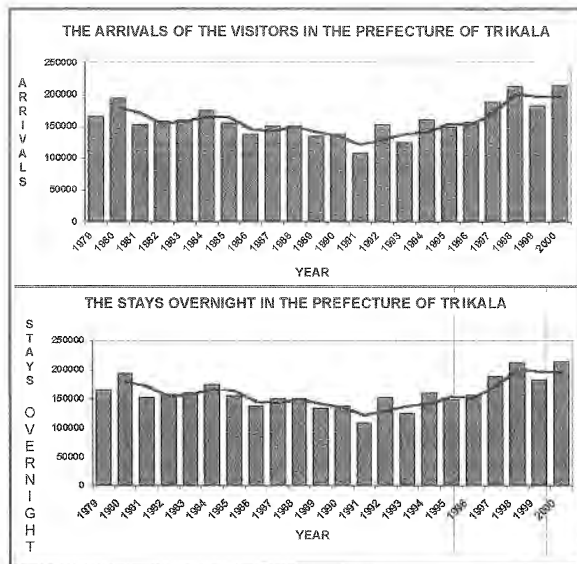


Figure 3: The changes in arrivals and stays overnight of the tourists in the Prefecture of Trikala.

prefecture of Trikala apart from sightseeing, such as the winter sports in the snow center of Pertouli, hunting in the controlled area of Koziakas, horse riding, mountain trekking, archery, trekking to Meteora, agro-tourism, etc.

The thorough study of the karstic system of the mountain Kerketio will result to the exploitation of the region since it can be a tourist attraction. The growth of the caves of Koziakas and the potential of visiting the area may lead to the increase of the stays overnight per tourist.

The development of such activities combined with similar policies in terms of tourism, providing better quality services, will end up to the change of the reason of the tourist current from "simply sightseeing" to "holiday resort". Hence, the agricultural economy may be enhanced with a tourist character. If the number of stays overnight increases, all other forms of employment are developed under certain condition, which is basically, the rational land planning.

Conclusions

A karstic system has been developed along the mountain Kerketio in nine locations. These locations are extended from North to South spread all over Koziakas and it is necessary to further study them because of their potential communication. The karst comprises dolines, caves, and springs.

The study, investigation and development of the karst, as well as the growth of the caves of Koziakas Mountain will boost the tourist activity of the prefecture of Trikala, leading to the increase of average of the stays overnight per visitor.

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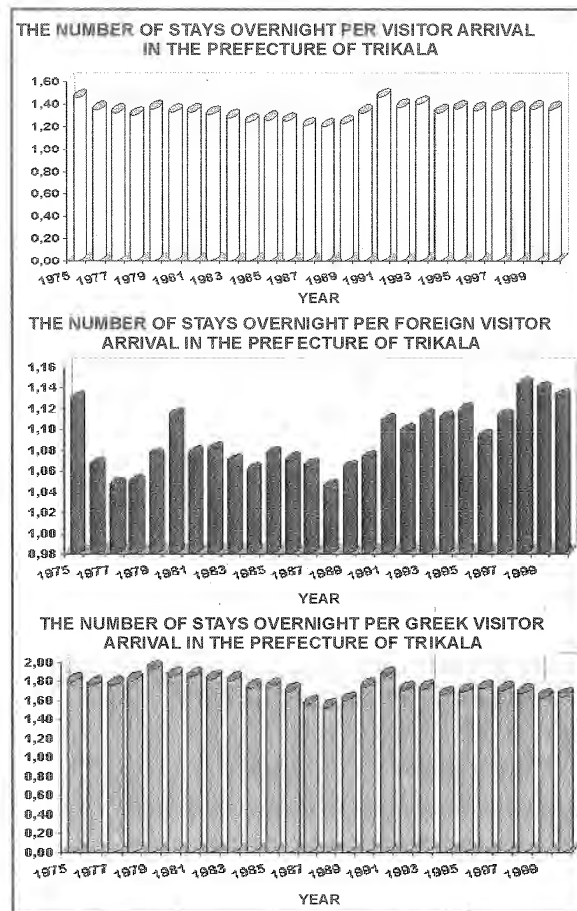


Figure 4: The changes in stays overnight per visitor arrival in the Prefecture of Trikala.

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Reconstruction of vegetation changes in Western Tatra Mts. (Poland) basing on Carbon isotopic composition of speleothems calcite

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*Institute of Geological Sciences, Polish Academy of Sciences, Warszawa, Poland***Abstract**

Detailed analyses of Oxygen and Carbon isotopic composition of speleothems calcite is a standard method for palaeoclimatic reconstructions. Usually, attention is focused on Oxygen composition changes as a main indicator of temperature changes. The number of work on Carbon isotopic composition as an indicator of palaeoenvironmental changes is limited. Three stalagmites from Czarna Cave (2 stalagmites) and Szczelina Chochołowska Cave (1 stalagmite), both located in Tatra Mts. (Southern Poland) have been analysed. Szczelina Chochołowska Cave is located ca. 40 m above Chochołowska Valley floor, Czarna Cave is located ca. 400 m higher in Kollcieliska Valley. Time span of stalagmites deposition, covering most of Holocene period, is ca. 10 2 ka. Carbon isotopic composition is in the range of 2 ‰ and 5 ‰ in Czarna Cave stalagmites and from 2.5 ‰ till 6.2 ‰ for Szczelina Chochołowska Cave stalagmite. There are three periods (ca. 10, 8.5 - 6.5 and 5.5 - 4.5 ka) with differences in Carbon

isotopic composition between these caves ca. 2.5 - 3 ‰. In all of them, lower value of $\delta^{13}\text{C}$ is in speleothems from Szczelina Chochołowska Cave. Main factor controlling the Carbon isotopic composition in speleothems' calcite is proportion of biogenic and "mineral" carbon dioxide in water entering the cave. Higher proportion of biogenic CO_2 is reflected as lower values of $\delta^{13}\text{C}$. We can assume, that lower $\delta^{13}\text{C}$ is an indicator of more intensive vegetation above the cave. Taking account of differences in altitude of Czarna and Szczelina Chochołowska cave the easiest explanation is strong vertical gradient of vegetation intensity in Tatra Mts. in periods marked by different $\delta^{13}\text{C}$: ca. 10, 8.5 - 6.5 and 5.5 - 4.5 ka. These periods are separated by much uniform vegetation intensity (similar $\delta^{13}\text{C}$ in both caves). From ca. 3.5 ka Carbon isotopic composition in both caves are similar. Systematic trend of lowering of biogenic carbon is visible.

P-48

DIKTAEON ANDRON: ENVIRONMENTAL IMPACTS AS A RESULT OF HUMAN ACTIVITIES AND TOURIST EXPLOITATION OF THE CAVE (CRETE-GREECE)Mertzanis A.¹, Vavizos G.² & Zannaki A.²*1 Technological Educational Institute of Lamia, Annex of Karpenisi, Department of Forestry, 36100 Karpenisi, Greece. amertz@hol.gr**2 Eco-Consultants S.A., 5 Aetideon str., 15561, Hologargos, Athens, Greece. vavizos@ath.forthnet.gr*

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Abstract

The thousand year's use of the cave "Diktaeon Andron", initially as a worship place during the last Minoan times and as a tourist attraction during the contemporary times and especially from the decade of 1960 until today, led to the change of the non biotic characteristics of the cave and resulted in the change of its biotic coefficients as well. The existing natural environment conditions of the inside of the cave have been affected by the fall of part of its roof as well as from the means used for the lighting of the cave, while they have been significantly deranged because of its use as a tourist attraction which was done without the prior suitable protection measures being taken. Also significant were the damages caused in the beginning of the twentieth century from the archaeological excavation works in order to reveal the hefty archaeological material it contained. This work describes the environmental condition of the cave "Diktaeon Andron" as it is today, while estimating the impacts in the ecosystem of the inside of the cave as a result of human activity and especially from its tourist exploitation that was carried out without any plan.

Key-words: Cave of Psychro, Crete, Diktaeon Andron, Environmental Impact Assessment Studies, Speleology, Tourism development.

1. Introduction

The protection and the showing off of the environment of the caves constitute, in combination with their rationally planned development, the basis for the preservation of these important ecological, geomorphological and cultural deposits. In many cases, the unplanned "tourist exploitation" of the caves, was seen as an appealing means for the short term economic development, with significant however effects on this "tourist asset" itself.

The cave of Psychro or "Diktaeon Andron", in the northern side of the Dikti Mountain, is according to mythology Zeus's birth place. According to mythology, Rea found shelter in the "Diktaeon Andron" cave and gave birth to Zeus because his father Kronos has vowed that he would swallow all his children in order to keep his kingdom to himself forever.

Human presence in this cave is known from the late Minoan era, during which it was used as a place of worship, while the environment of the cave has degraded significantly during the near past and especially in the last 40 years where it was touristically exploited without any prior suitable protection measures taken. Most serious were the damages due to the use of candles for lighting purposes until the year 1999 when it was electrically lighted. Also serious were the damages to the cave in the beginning of the previous century, when there were excavation works in order to reveal the rich archaeological material it contained. The excavation works that were carried out mainly by foreign archaeological missions such as Fr. Halbherr-I. Hatzidakis, J. L. Myres, J. Demargue, D. Hogarth, contributed to the destruction of the chamber which constituted a distinctive level in the interior of the cave. In this part, which is referred to as the Upper Cave were located most of the archaeological findings which were also amongst the most important ones, of the late Minoan era (altar, cyclopean wall, temple, libation places, copper statuettes, weapons, etc). It is noted that the Upper Cave did not have stalactites. The fall of the Upper Cave which was helped by the use of explosives, had as a result, apart from the change in the morphology of the cave, the fall of rock volumes and fragments which covered a large part of the Lower Cave where the stalactites were found (Platakis 1973, Watrous 1996).

These relatively recent human interventions in the morphology of the cave and the pollution that resulted from its use as a tourist attraction, interfered with the environmental conditions and the fauna naturally oc-

curing in the cave and caused serious but reversible effects in the cave's ecosystem. In order to deal with these effects there is a need for elimination of the burden to the environment, as well as the implementation of suitable environmental protection and restoration measures.

2. Materials And Methods

2.1 Research site location

"Diktaeon Andron", which consists the object of this study, is located in eastern Crete in the Lassithi Prefecture, in the geographical area of the community of Psychro. It is a cave with a width of 14.8 m which extends in the northern side of mountain Dikti (or Lassithiotika) in an altitude of 1,025 m uphill the plateau of Lassithi (altitude 820 m) and in a distance of 800 m from the community of Psychro. The entrance to the cave is connected, via a poor quality stone footpath, to the main road leading to the Psychro dwelling area, which is in turn accessible to all the villages of the Lassithi plateau and to the road network of Crete. The Psychro community is 12 km away from Tzermiado community which is the largest village in the Lassithi plateau and it is 31 km from Mallia, 64 km from Agios Nikolaos and 70 km from Heraklion.

2.2 Climatic-Bioclimatic conditions

The climate of the area according to data from the Meteorological Station of Tzermiado village is mild continental and is characterized by high temperatures and dryness in summer and by low temperatures and heavy rainfall in winter. The relative humidity in the area is kept in high levels throughout the year and lies from 66% in July to 84% in January. More specifically: (a) the average yearly rainfall is 1,489.5 mm and has an average height of over 100 mm from October to April, which is when approximately 94% of the rainfall is recorded in the area. The average monthly rainfall shows a high in January (309 mm) and a low in July (2.9 mm). (b) Snowfall has been recorded from November to April, period during which the snow remains on the ground. (c) The average monthly temperatures in the area range from 5.5 °C in January to 20.1 °C in July. The average high is in July (25.1 °C) and the average low in January (2.5 °C). The absolute low is in January and the absolute high is in July. (d) the prevailing wind direction is N by NW throughout the year, while in December prevail humid and warm NW winds. The force of the winds is weak or medium. (e) According to Emberger classification, the bio-climatic vegetation level corresponds to a wet type, with cold winters and (f) According to the UNESCO-FAO classification of the bio-climatic levels, the area is classified in the intense medium-Mediterranean bio-climatic vegetation level, with a number of biologically dry days of 93.7.

2.3 Ecology - Flora - Fauna

2.3.1 Flora - Fauna of the area around the cave

The vegetation in the area around the cave and more specifically in the perimeter of the existing archaeological site, is characterised by the presence of types of bushes such as the *Quercus coccifera*, which has developed into a tree form. While we have the appearance of individual specimens of *Quercus perescens* and Cretan maple tree (*Acer creticum*). The lower level consists of *Euphorbia acanthothamnus*, *Arum macubatum* and *Urginea maritima*. We also observe quite a few species of *Origanum dictamnus*, *Primula vulgaris* and *Cyclamen creticum*. It is not known if in the past there were any rare or endemic species of vegetation in the area, but the intense pastoral stockbreeding in the area around the cave does not rule out the disappearance of rare or endemic species which possibly existed there previously.

More generally the area is characterised by intense degradation of the vegetation. The main cause of this degradation is on one hand the intensive grazing and on the other hand the repeated fires some out of negligence and others deliberate aiming at creation of more graze land (Zach-

aris, 1977). According to information from the community of Psychro, in the area there are approximately 1,000 goats and lamb. Over-grazing and fires have repeatedly destroyed the vegetation in the greater part of the wider area of the cave and this resulted in the erosion of the land the revelation of the mother rock in a percentage of about 80% of the surface. The remaining 20% consists either the fenced area around the cave, or the place of cracks and karstic limestone cavities which are covered by shallow depositions of terra rossa and exhibit poor and degraded vegetation. This land degradation resulted in increased dryness and caused the backward evolution of vegetation which can be seen by the substitution of the original species of the plant-community group "climax" with other species that were able to adapt to the new deteriorated conditions and thus changed the character of the area.

In the greater area that surrounds the cave nowadays we do not come across *Cupressus serpevirens*, *V. horizontalis*, a species that according to the bioclimatic conditions in the area should have been the typical species in the area. This species has disappeared ever since ancient times, as its wood was initially used in ancient shipyards (Zacharis 1977). In the bare land and here and there we see *Quercus coccifera*, in a bush form as well as kinds of firewood such as *Euphorbia aranthothamnus*, *Coridathymus capitatus* and *Urginea maritima*.

The land fauna of the greater area consists of the kinds: *Lepus europaeus*, small rodents of the Mouridae family, *Erinaceus europaeus*, while there are also a few reptiles. The poultry species in the greater area includes apart from the usual kinds, predatory with the most important representative of its kind the *Gypaetus barbatus* which is an endangered species, as well as the kinds *Hieracetus pennatus* and *Falco* sp.

2.3.2 Ecological niches of the cave

The most significant niches which exist in the cave today are:

(a) Ecological niches chiroptera of the Vespertilionidae and Rhinolophidae families are located near the entrance of the cave in the blind corners to the left and to the right of the alleys going up and down respectively. The chiropteran kinds that have been recorded in "Diktaeon Andron" are: *Plecotus austriacus*, *Rhinolophus ferrumequinum* and *Rhinolophus hipposideros*. The presence of the endangered species *Plecotus austriacus* in the "Diktaeon Andron" cave is confirmed in relevant references (Paragamian 1991, H.Z.S.-H.O.S. 1992). Additionally, chiroptera were found from the research team on the remainings of the Upper Cave, in its outer part, which was not disturbed from the excavation works. The residence period inside the cave of the above kinds of chiroptera coincides with the hibernation season and possibly with the nesting season. In Greece these specific kinds hibernate from November to March. In May, they give birth to 1-2 young which they nurse for 21-28 days and the young ones become independent after 45-50 days. In the summer they can be found in trees or buildings. They prefer agricultural and forest areas and low altitudes and feed on insects. The kinds found in the cave form small colonies which do not exceed 5-10 individuals during wintertime.

(b) Ecological niches of poultry species are located in dents and cavities near the entrance of the Lower Cave and in the ruins of Upper Cave. In these areas is located a limited number of species of the following kinds: *Pyrrhocorax graculus*, *Hirundo rustica*, *Monticola saxatilis*, while previously the ruins of Upper Cave was a nesting place of the kind of *Alectoris graeca*.

(c) Ecological niches of cave-dwelling invertebrate arthropods are located in the interior of the cave in dents of the geological formations.

2.4 Geomorphology - Geology - Surface and underground waters

"Diktaeon Andron" cave is located at the southwestern boundaries of the Lassithi polje which is directly connected to the morphological characteristics and the geomorphological evolution of the cave. This polje is the result of the tectonic reactions of the Quarternary Era, while its present

morphology as well as the evolution of its peripheral karstic phenomena (Diktaeon Andron cave, etc), were differentiated later as a result of the dissolving action of water (Psarianos 1961, Theodoropoulos and Zamani 1972, Mariolagos et al. 1987, Papapetrou-Zamani 1990, Papadopoulou-Vrynioti 1996, Castiglioni 1997).

2.4.1 Geomorphology - Characteristics of the Cave

The altitude of the plane part of the Lassithi polje which extends to an area of approximately 45 km², is between 814-870 m, while over the village Psychro, at an altitude of approximately 1,025 m and inside the limestone formation is located the cave "Diktaeon Andron". The morphological surface slopes have values which in their greater percentage range from 0-10% in the plane part of the polje, they extend to the south from 10-35% and are then evened out again in the intensely in the karstic top Moutsouna Toumba (altitude 1,537 m).

Morphologically, the cave "Diktaeon Andron" consists of two main parts: (a) the western part with a length of about 40 m, width 19 m and maximum height of 6.50 m and (b) the northern part with a length 20 m, width 10 m, and height that ranges between 1.30-4.00 m. The entrance area with a width of 18 m and height of 14 m is covered from a calcareous volume that has fallen of the ceiling and from large volumes of stalagmites. The main chamber has a north-south direction and a high slope, while its floor is covered with a clay layer and is slippery due to the increased humidity and the clay substrate. At the back and to the eastern side there is an opening of a small chamber, while in the western side there is a bigger chamber partitioned into two parts by a group of columns. In the first part there is a small lake and the area surrounding the lake is lavishly and spectacularly decorated by large columns, stalactites and stalagmites.

2.4.2 Geology

From a geological point of view, the near and the greater area of the cave mainly consist of: (a) Quaternary depositions which cover the bottom of the Lassithi polje and consist of mud, clay, sand and gravel, (b) Limestones of the Tripolis zone and (c) The Series of phyllite-quartzite, which includes rocks of different ages, origin and degree of transformation. The main part consists of clay slates, phyllites, quartz phyllites and quartzites of the Permian-Upper Triassic era (Creutzburg 1977, I.G.M.E. 1977, I.G.M.E. 1987).

More specifically the limestones of the Tripolis zone, which consist the main formation from which the "Diktaeon Andron" cave is formed, are of Jurassic until Eocene age and are usually found on top of the layer of «phyllites-quartzites». These are limestones and dolomites found in thick layers up to compact rocks and locally breccia or micro crystalline, which include in their mass the "Diktaeon Andron" and other caves. They are heavily fragmented and have large intervals due to cracks, fragments and karstic phenomena and come to dimensions of the cave under study, the Tzermiado cave etc.

2.4.3 Surface and underground waters

The superficial hydrographic network of the greater study area is represented by the stream Havgas which gets its water supply from the basin of the polje of Katharo which is situated at the southeastern side of the basin. Of secondary importance are the streams Kloros and Poros as well as some unnamed streams which direct the rain water to a lower area. Parts of the Lassithi plateau are periodically flooded from rain water until the water finally flows through the sinkholes formed at the boundaries of the polje and especially in its northwestern end (sinkhole Honos) as well as in the part between Honos and the dwelling area Pinakianos. The drainage of the polje is achieved through a network constructed by the Countryside Development Service of the Ministry of Agriculture and the volume of the water that falls into the sink and feeds the karstic tunnels of the carbon rocks is estimated to be 17.5 x 10⁶ m³ annually.

As far as the underground water supply is concerned, the most important hydrogeological entity in the area is the formation of the limestones of the Tripolis zone which in combination with the underneath "phyllites-quartzites" has created the spring of Psychro downhill from the "Diktaeon Andron" cave. This spring is estimated to supply around 40 m³/hour. The Psychro spring as well as most of the springs (Perganti, etc) which are found in the boundaries of the plateau, constitute the karstic contact springs which collect and give out part of the water of the hydrogeological basins which are found uphill (Kourmoulis 1979, Knithakis and Kalo-giannakis 1987, Kallergis 1999). In the low alluvium the water supply is satisfactory and is used by approximately 8,000 shallow wells which yield around of 5 m³/hour. There are two main water tables which are found the first in a depth 8-10 m and the second in a depth of 14-22 m, while deeper water supplies can also be found in the sandstone layers of the alluvium formation.

2.5 Method of research

In order to record the existing environmental situation in the near and the greater area of the "Diktaeon Andron" cave, topographic, geological and vegetation maps were used, while the area was visited in order to make in situ observations and verify the recorded data. In order to estimate and evaluate the burden to the environment an important role was played by the in situ observations as well as the data from the "Environmental Study" and the "Study for the showing off of "Diktaeon Andron" cave which were conducted for the Archaeological Receipts Fund of the Greek Ministry of Culture.

3. Results - Discussion

3.1 Human activities and their impacts to the environment of the cave

The most important burden on the environment of the "Diktaeon Andron" cave which resulted in changes of the non-biotic characteristics of the cave and therefore also caused changes in the biotic characteristics are:

(a) Its use over a time period of more than one thousand years as a place of worship, initially during the late Minoan era and later during the Hellenistic era, a fact that can be proven amongst other things from the findings that are kept in the museum of Heraklion. It is worth noting that the "Diktaeon Andron", during the Prepalatial Period (2000 - 1700 B.C.), was more important than the Trapeza cave which can also be found in the plateau of Lassithi. It remained famous during the Hellenistic era (around 700 B.C.) when it lost importance due to the showing-off of the Idaion Andron in Rethimno (Platakis 1973, Watrous 1996).

(b) The excavation works and other activities necessary to reveal the immense archaeological material that it contained. These interventions happened in the beginning of the previous century and helped bringing about the destruction of the chamber which formed a distinct level in the interior of the cave. In this chamber which is known as the Upper Cave were located most of the findings and the most important ones of the late Minoan era (altar, cyclopean wall, temple, libation places, copper statuettes, weapons, etc).

- These interventions and especially the fall of the Upper Cave which was assisted with the use of explosives, resulted, apart from the alteration of the morphology of the cave, in the fall of rocks and rock fragments which covered a large area in the Lower Cave, where we have the presence of stalactites. From the Upper Cave remains only one part which sits on solid ground and its greater part consists of rock fragments.

- The fragments from the fall of the floor of the Upper Cave have altered the morphology of the central part of the Lower Cave. The change of the morphology resulted in the destruction of certain natural biotopes of the fauna.

- The fall of the roof resulted in an increase of the area where there

is prominent presence of bryophytes. The fall of the roof abolished the different micro-environments that existed in the interior of the cave and disrupted the conditions on its floor.

(c) Its use as a tourist attraction without any prior measures taken for the protection of the cave which happened in contemporary times and especially during the sixties and further until the end of the previous century. The burden to the environment of the cave from its use as a tourist attraction in combination with the pollution caused as a result of this, disrupted the environmental conditions and the flora habitats and caused serious but reversible effects in the ecosystem of the cave. The uncontrolled number of visitors inside the cave, have in the past caused serious damage to the flora and fauna, due to movement, noise, lighting and the emission of CO₂ from the breathing of the visitors, from the transportation of organic matter as well as micro-organisms that the visitors bring in the cave with their shoes. This burden to the environment of the cave leads in complete degradation of the ecosystem of the cave and the evacuation of all the higher organisms (chiroptera), especially from the parts of the cave that are directly affected from the burden of the movement of visitors and which are found near the nesting areas of the chiroptera. An important consideration for the ecological equilibrium of the environment of the cave, is the creation of suitable conditions in the interior of the cave, which will allow the protection of the fauna and the flora, the preservation of biodiversity in the area but most importantly safe nesting and feeding places for the chiroptera. The fact alone that there are chiroptera present even today in the interior of the cave, is by itself an indication that the biotope of this kind as well as their numbers is possible to be reinstated provided that it is possible to cancel out the burden.

- The environmental damages to the interior of the cave were significant, caused by the use of the candles used for lighting purposes until 1999 when the cave was electrically lighted. The use of candles caused the covering of the stalagmites with wax and the covering of stalactites with fume, whereas the lake inside the cave was also seriously polluted as its bottom was covered with wax.

- The layer of wax that rots and decays in combination with the slow rates of biological decomposition, due to the low temperature of water around 5-7°C, contributed to the formation of a deposit layer of wax in the bottom of the lake.

- Due to the pollution of the lake the fauna specimens of the area have migrated. Also in order to construct a passage part of the lake was filled with rubble and this resulted in shrinkage of its area and its volume as well as its rate of water replenishment. It is noted here that the lake constitutes an implicitly ecological niche, since the pollution has caused the migration of all the living organisms that used to inhabit the lake earlier. (Paragamian 1991). If the conditions in the lake return to normal, it is possible that the original habitats will return.

- The existing great amounts of organic matter in the form of wax creates a stress in the environment due to the products from its anaerobic decomposition.

- The large number of visitors in the near past and the lighting of the interior of the cave with candles, disrupted the evolution conditions of the organisms and created deposits of fumes and wax in the geological formations. The deposition of fumes and wax on the geological formations complicates the movement of the natural inhabitants of the cave inside the cave.

- The expansion of the entrance area of the cave resulted in more light entering the area and thus making this part of the cave more lighted. These lighting conditions brought about the further evolution of the low growing vegetation (bryophytes, ivy, etc) of the geological formations and the typical terrestrial micro-fauna (gasteropodes of the species of *Bulimus* and *Helix*, micro arthropods, etc) in the interior of the cave.

- The great opening of the entrance to the cave allows the pollution of the species of flora and fauna that are usually found inside the cave with

dust and mainly with micro-flora and micro-fauna from outside the cave.

- The great opening of the entrance of the cave affects the temperature of the interior of the cave which changes depending on the season from around 6 to 13 °C. This fluctuation of the temperature interferes with the living conditions of the natural inhabitants of the cave.

Another impact to the caves which is a result of their intense tourist exploitation, of which typical examples are the caves of Perama (Ioannina-Epirus) and the cave of Diros (Mani-Peloponnesus), is the creation of micro-flora of natural origin (fungi and algae) which is formed as a result of the long time micro-climatic changes in the interior of the cave (electrical lighting, temperature increases, wind drafts from the man-made entrances and exits as well as the transport of microorganisms and fungi from the visitors) and on the surface of the lit stalactite formations and generally from the internal geomorphological decoration of the cave.

4. Conclusion

The uncontrolled tourist exploitation of the caves is an important but short term asset of the local economic development in an area, which nevertheless in all cases leads to serious self destruction of this "tourist asset". The case of the "Diktaeon Andron" cave is a characteristic example in Greece, of the use for over thousand of years of a cave by man, initially as a worship place and more recently as tourist attraction.

The destructions in the environment of the cave as a result of the human activities are in direct correlation with the way they operated: (a) the excavation works and interference in the beginning of the previous century in order to reveal the rich archaeological material present, which led to the fall of the Upper Cave and resulted in the alteration of the morphology of the cave, the fall of rocks and rock fragments, the covering of a large part of the Lower Cave as well as the destruction of certain of the natural biotopes and the fauna and (b) its tourist exploitation without prior protection measures taken which happened in contemporary times and especially from the decade of the sixties until the end of the previous century. From the unplanned and uncontrolled tourist exploitation of the cave, there was pollution and derangement of the environmental conditions and of the fauna of the cave as well as serious but reversible effects to its ecosystem. To deal effectively with these effects there is a need for eliminating the burden to the environment as well as taking suitable protection and restoration measures.

5. Acknowledgements

This work was based on data from an "Environmental Study" drafted by "G. Vavizos - K. Zannaki - D. Zafeiropoulos and Associates - Eco-Consultants S.A.", Environmental Consultants. The above mentioned study forms an integral part of the study titled: "A study for the overall demonstration of the cave "Diktaeon Andron" which was assigned by the Archaeological Receipts Funds of the Ministry of Culture of Greece to the following Contributing Consultants: M. Arvanitakis, civil engineer, P. Varvitsiotis architect, D. Dalavangas, electrical engineer and P. Hourdakis, rural and surveying engineer.

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P-49

Columns of Cretan earth: "The speleothem and the symbol"

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Speleological Club of Crete, SPOK

Abstract

Photographic exhibition is attempted showing off the speleodeposition, that is the way in which a calcareous deposition shapes into a pile / column, the figures / shapes it takes during its inflation / bulges and the alteration it undergoes in the course of time until it's decay / corruption is attempted in the photographic exhibition (fair).

Moreover cases of columns in caves with anthropologic interest are

shown off / set off.

These columns are probably connected to devotional processes and usually characteristics holds of the earth or the fixation? Are attributed to them.

The poster's dimensions are 2,30 X 0,40 m. and it includes at most 10 photographs with dimensions 0,30X0,21 m. As well as a brief text of 100 words.

W-1

Exploration and Preservation of the Kipuka Kanohina Cave System, Ka`u Hawai`i

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Abstract

In 1998, members of the Cave Research Foundation and the Hawai`i Speleological Survey began a systematic exploration of Kula Kai Caverns. The Caverns lie in an ancient volcanic island of land called Kipuka Kanohina, located beneath the Mauna Loa volcano. The Kipuka also contained other caves - Poha Cave, Eli's Pit Cave, and The Maelstrom. Each cave is highly braided and mazy, with multiple levels of passage. Eventually all four caves were connected together, along with a fifth section of cave called The Cordwinder. The cave system yielded several surprises. There are several lava balls in the cave, with one lava ball over five meters tall. The cavers also found beautiful gypsum formations throughout the dry sections of the cave. Many of these secondary formations have impurities of copper or iron, coloring them brilliant red or blue. The surveyors

also found that the ancient Hawaiians used and explored the cave extensively. Gourd cradles are evident in many areas of the cave, along with torch sticks, opi`i shells and charred kukui nuts. The exploration team also found sleeping platforms, fire rings, and tool making sites. The team has currently explored the cave to a length of over 32 kilometers of contiguous passage and over 38 kilometers within the flow unit. This makes Kipuka Kanohina the second longest lava tube system in the world. In 2002, several members of the exploration team formed a non-profit corporation to protect the cave. The Cave Conservancy of Hawai`i has now purchased several pieces of property over the Kanohina cave system, and is working with other landowners to protect the cave. The Conservancy is also working to protect other significant cave systems in Hawai`i.

W-2

Revealing the Caves of Soqotra Island (Yemen), the Soqotra Karst Project (2000-2005)

P. De Geest and the members of the Soqotra Karst Project

*Vrije Universiteit Brussel, Department of Geology, Brussels, Belgium***Abstract**

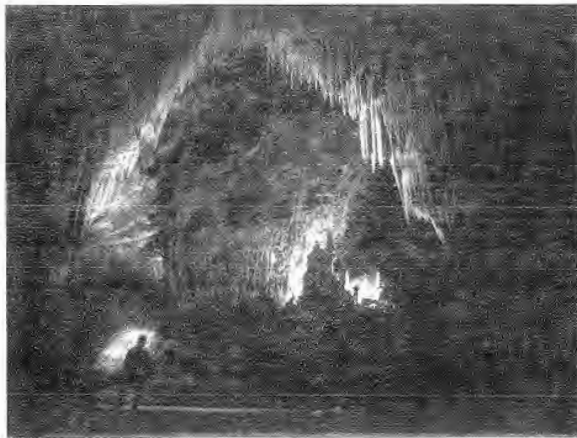
The existence of cave systems on the arid, tropical island Soqotra (Republic of Yemen), situated between the Horn of Africa and the Arabian Peninsula in the Indian Ocean, was unknown until recently. The combination of a bi-annual rainy season generated by the Indian Ocean Monsoon and extensive fractured limestone areas causes rapid underground water drainage, resulting in poor drinking supplies for local communities. During the last 5 years the Soqotra Karst Project, a multi disciplinary team of Belgian cave explorers and scientists, supported by international counterparts, explored and mapped approximately 25 km of underground galleries in 35 different caves during 7 expeditions (De Geest et al., 2005). This study provide essential information about vast underground freshwater resources, enabling a pilot project, which provides running water for about 600 people from the Nissam and Irisseyll villages (De Geest P. & Van Damme K., 2004). Some caves reveal archaeological artefacts such as ancient pottery and different sorts of mural paintings. A perfectly preserved wooden tablet with Syriac inscriptions was found in Hoq cave, dating back to 258 AD (Robin C. & Gorea M., 2002), demonstrating that this cave must have been a well known place visited by merchants sailing the trade route between East Africa, the Arabian mainland and West India

(Dridi H., 2002). New endemic cave fauna give clues about the palaeogeographical evolution of the archipelago and complements the rich biodiversity of the islands. Speleothems are dated, while the study of their geochemical content enables a regional palaeoclimate reconstruction, which can provide insights in the monsoon variability over time. Together with the Yemeni and local governmental agencies a deontological code is under construction to assure cave protection and new possible eco-tourist assets. Some references De Geest et al., 2005. Soqotra Karst Project 2000-2004: cave exploration and karst reseach on Soqotra Island (Yemen). Private publication, pp.140. De Geest P., 2004. Soqotra Karst Project. Spelerpes 2004-2: 13-17. De Geest P., 2003. Soqotra Karst Project: Karst exploration and Cave research on Soqotra Island. Dioscorida, issued by Friends of Soqotra, vol.2 : 4. De Geest P. & Van Damme K., 2004. The study of underground karstic water resources of Soqotra: an application. Tayf, the Soqotra Newsletter, issued by the Soqotra Conservation Fund and the Friends of Soqotra, vol.1 : 3. Dridi H., 2002. Indiens et Proche-Orientaux dans une grotte de Suqutra (Yémen). Journal Asiatique 290.2: 565-610. Robin C. et Gorea M., 2002. Les vestiges Antiques de la grotte de Hoq (Suqutra, Yémen). Academie des Inscriptions & Belles-Lettres. Compte Rendus, avril-juin 2002: 409-445.

W-3

Le Karst du Massif du Falakro et la Résurgence de Maaras Résultats des travaux hydrogéologiques et Topographiques

Par PASCAL REILE

Province de DRAMA - MACEDOINE, GRECE du NORD**Preamble**

L'objectif de cette résumé est d'établir un récapitulatif de nos investigations initiées par Me Anna PETROCHILOU en 1978. Les expéditions fut réalisé en collaboration de Mr AVALIANOS puis de Mr IANOPOULOS

Nous publierons en 2006, une étude scientifique sur le secteur du FALAKRO (Province de DRAMA Macédoine GRECE du Nord) en groupement avec nos collègues grecs

La collecte de ces données doit déboucher sur la modélisation de la dynamique hydrogéologique locale.

Nous pourrons ainsi donner une ébauche de sa restitution et une évaluation des potentialités hydrologiques.

1) History of exploratory expeditions:*Summer 1978:*

Missis PETROCHILOU, who is the president of Greek caving society welcomed us in Athens and indicated us an area to study and a list of interesting caves to visit.

Missis PETROCHILOU advised us to dive in the resurging sources of Macedonia and introduced us to mister G. AVALAINOS who would later be our guide.

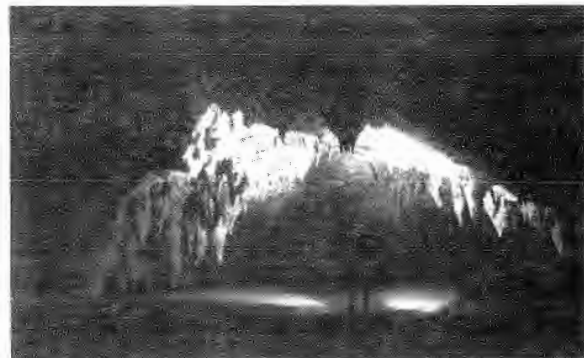


Photo: The first photo of the cave after siphon from CORDIER Vincent in 1978. - The story has began.

With our guide, we visited some old Greek mines near Athens. After that we were heading in the direction to northern Greece to the Macedonia. There, we visited the cave of ALISTRAS which is full of beautiful mineral concretions. From this cave, we realize a topographic map and a set of photo slides.

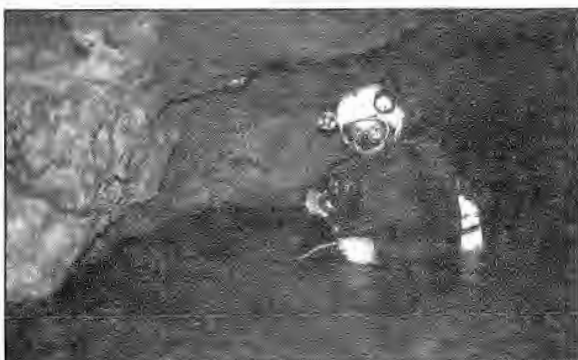
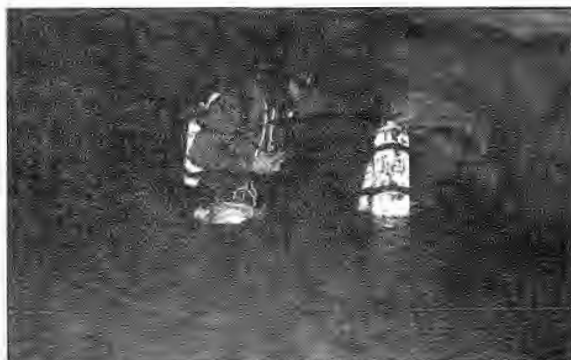


Photo: 1 - CORDIER Régis et Vincent at the siphon 3



2 - REILE Pascal and CORDIER Vincent. Diving siphon 1980.

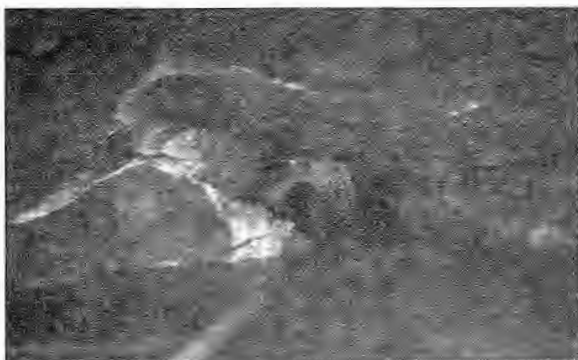
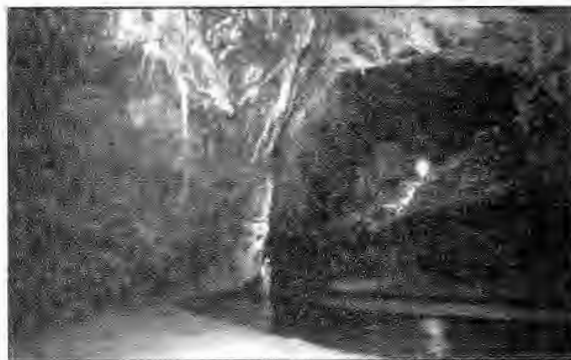


Photo: Dynamite opening of the siphon number 2 called siphon NIKOS.



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After this, we dove in the resurgence source of MAARAS. We went through the first eight meter long siphon. Behind this obstacle, we found a three hundred meters long free air gallery, of which we took topographic measures.

Mister AVALIANOS was accompanying us during this exploratory expedition.

1978-1980:

The district chief of drama, and the engineer KAPAS initiate the important program concerning rock perforating and tunnel masonry at the entrance of the cave of MAARAS.

This artificial access, which is built bypasses the first eight meters long siphon.

August 1981:

Thanks to the help of architect miss Anna BAZDEK, who was also our interpreters, our exploratory expeditions could progress further. We dove two siphons, one of three and the second of thirty meters. Behind these two siphons we discovered two kilometres of new gallery. We helped mister Nikos IOANINIS to go through the first siphon. In kind recognition of the courage of our friend, who was just discovering diving, this access was given his name.

It was the first important discovery after the siphons.

Easter 1982:

The weather circumstances don't allowed us to dive in MAARAS. We investigate in the region looking for shafts or caves which could be connected with the underneath Karst system. A 138 meters deep shaft was

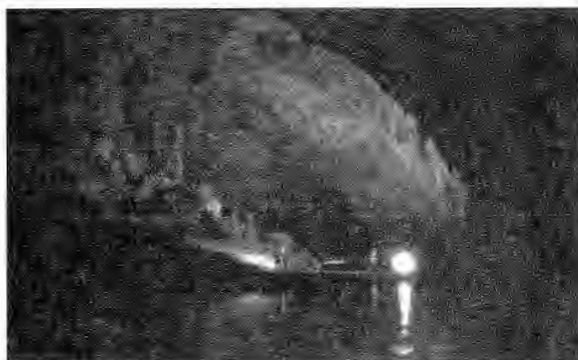
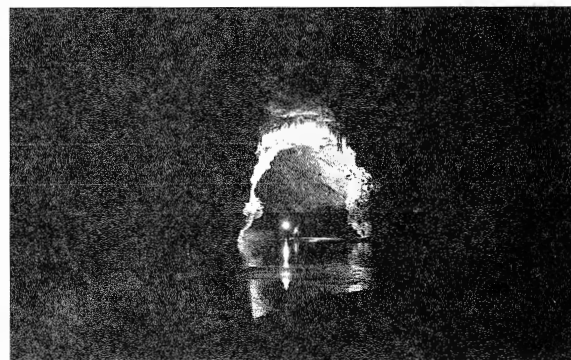


Photo: The chamber called AKROPOLIS.



discovered thanks to the help of an inhabitant hunter of OHIRON: mister CHRITOPHOS. During a farming accident he passed away So his short name CHRISTOS will be given to the shaft.

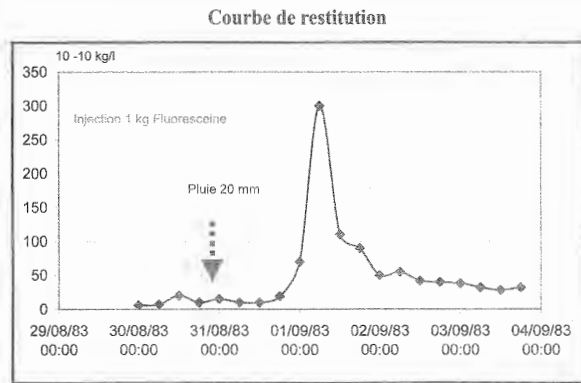
Summer 1983:

For a road a tunnel which bypasses the entrance area was built. During the works, palaeontologic layer was discovered in the gallery. This was a fossil over flood gallery of the cavity. Bones of rhinoceros were discovered there. We went on exploring and we could pass through the S4 siphon which much difficulties. At this point, 4280 meters gallery were discovered at all.. An injection of fluoresce in co

lour was realized in the area of OHIRON at the point where the water is going under the earth.

- COLOUR TRACING RÉSULTAT DU TRAÇAGE DE LA KATAVOTHRE DE OHIRON

Le traçage a été réalisé à l'aide de 1 kg de fluorescéine en Aout-Septembre 83.



Result: Time: 26 H 40 Km: 9000 metres
Déniv: 376 m Speed 341 m/heure

1992:

Works GREEK of tunnel building. Discovering of archeologic and paleontologic layers.

Building of the tunnel. Beginning of public visits.

Summer 1995:

During a short visit, we could see that our discovery was revalorised by local community and that arrangements were made to enable every public



Photo: Pascal REILE in the siphon 7

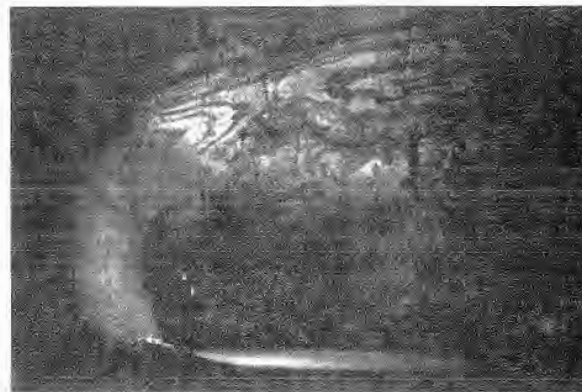
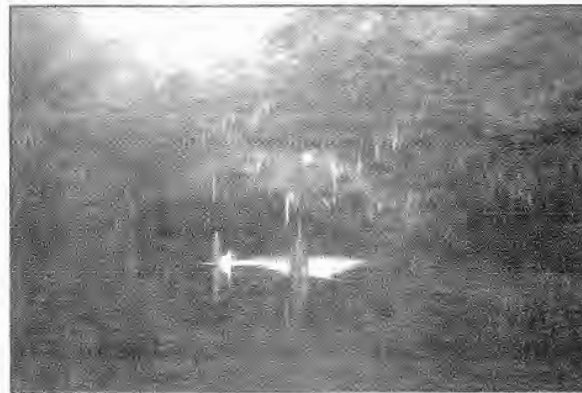
to access a part of the cavity. An exploration until S4 siphon gave us opportunity to find a violent current of air at this point. This passing awake our curiosity and would be a goal of a new exploratory expedition.

Summer 1997:

We requested to be authorized to explore one more time the cavity. But the matter is connected with archeology and so the university and the ministry dont give us easily the

permission. At the end a contact with professor XEIDAKIS and the culture ministry representative Mrs IANOPOULOS, allowed us to receive a restricted permit under Mrs XEIDAKIS responsibility.

We began new explorations. The water stream was very low, of one cubic meter each second. The clearing of a bypass of the fourth siphon gave a good result. This bypass is a only five meter long little lake. It enable to short cut the sixty meters long siphon. After that, we could find one more time the already discovered gallery that continue to the point 4280 meter from the entrance.



Photo

In the futur the siphon would be more easy to cross after digging out the sand which obstruct near the roof of it. After that we explore until the point 5871 meters, where the main gallery divide in two. Both ends with siphons. The first one is situated 6076 meters from the entrance. And the second 7791 meters. During this year, the topographic measures, at all 8544 meters long was totally achieved. Mister Nikos IOANINIS did explore the all gallery during the works of topography.

We received help from the representative of the district mister LEFTERI, who is the mayor of KOKINOIA.

Chemistry and temperature water studies would complete the colour tracing which we had previously done.

CHEMISTRY WATER ANALYST

Résultats des mesures du 06/08/97 à 5871 m de l'entrée.

Full Flow in the spring : 1.029 m3/seconde

Temp.: 12.9°C, Cond.: 356 p siemens, pH: 7.6

Paramètres	ZESTO POTAMOS Affluent chaud	KRIO POTAMOS Affluent froid
Q	150 litres /seconde	60 litres /seconde
Temp	16,5 °C	12°C
Cond	389 µ siemens	320 µ siemens
PH	7,53	7,50
Po4	0,140 mg/l	0,469 mg/l
Carbonates	320,86	241,26
Sulfates	10,40	8,99
Chlorures	2,12	1,44
Nitrates	7,8	2,5
Fluor	0,69	0,56
Sodium	4,2	3.8
Potassium	2,7	1,9

Le zesto potamos est influencé par des drainages de bordure du polje ou l'agriculture se développe de manière notoire.

Summer 2000:

We brought the diving equipment in the cave of MAARAS to the old S5 siphon and where after the gallery is divided in two. We reached the siphon

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Fish in the Krio potamos : in 5871 m of the Entrance

number six. The water is muddy because of the storm of the previous days. In all the cave the level of the water is very low, that is to say about ten centimetre less than three years ago. And this level continue to lower in spite of rains.

The siphon number six is thirty meters long. It is muddy. And after that we discovered and topographic measures of 1500 meters galleries. The river gallery follow its course until a siphon again at point 7500 meter distance from the entrance. This gallery become parallel with a large fossil gallery during about 500 meters This fossil gallery is collapsed at a point of it. We dove into the siphon number seven at 7800 meters far from the entrance, but without success. Water is muddy and we could explore until point 15 meter deep. The siphon goes probably deeper, and is almost filled with sand. We explored also both of the starts of galleries at the point where outside the water disappear under the earth. The first one gives access to a little siphon 25 meters long and 10 meters deep. The second one, after a short digging out and descending a 10 meters shaft is occupied by water at this point.



Line of Manganese in the Cave

We tried colour tracing in this area where water goes under the earth. We wanted to know which part of the Maaras cave this water feeds. But it was difficult to realize because it was not raining since a week and water was pumped to irrigate the agricultural fields of the polje (= a kind of dry valley). Nevertheless we demanded to have a necessary volume of water to the mayor administration.

So finally we could experiment the colour tracing with five cubic meters of water delivered by a firemen truck and a kilogram of fluoresceine colour. In the previous exploration such a tracing was a success, but now it was not the case. The transit was slow and it is difficult to make use of the restitution of the colour, because organic material contaminate it.

Diving in the last two siphons in Maaras cave has added 1500 meters of topographied galleries. Then now totality of developed galleries are 10 040 meters. In the Maaras cave, today nobody has dove the 'Krio potamos'. And may be it is possible with a better equipment to obtain success at the siphon number 7 that's to say with more air bottle and a Fenzy buoy.

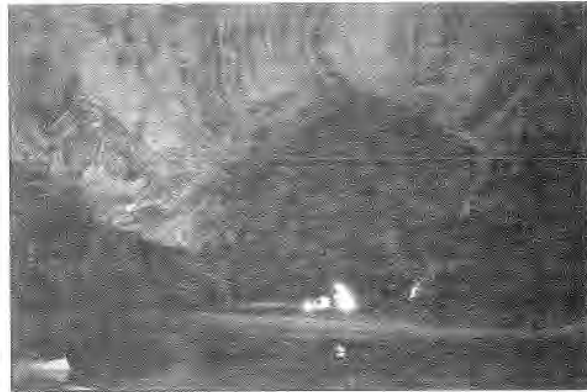


Photo Marbles and Manganese lithology

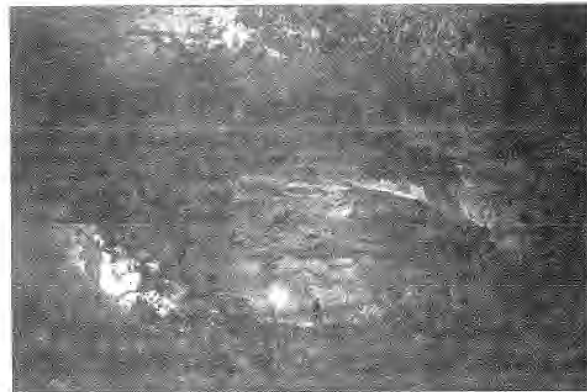


Photo : Greek team at terminal cave



Summer 2003:

We did a set of exploration in the area, but water conditions don't allow us to full fill all our planified program. The team of Greek and French cavers keep on exploring the area. A lot of rains and inundations over flooded the disappearance points of the river in the mountain.

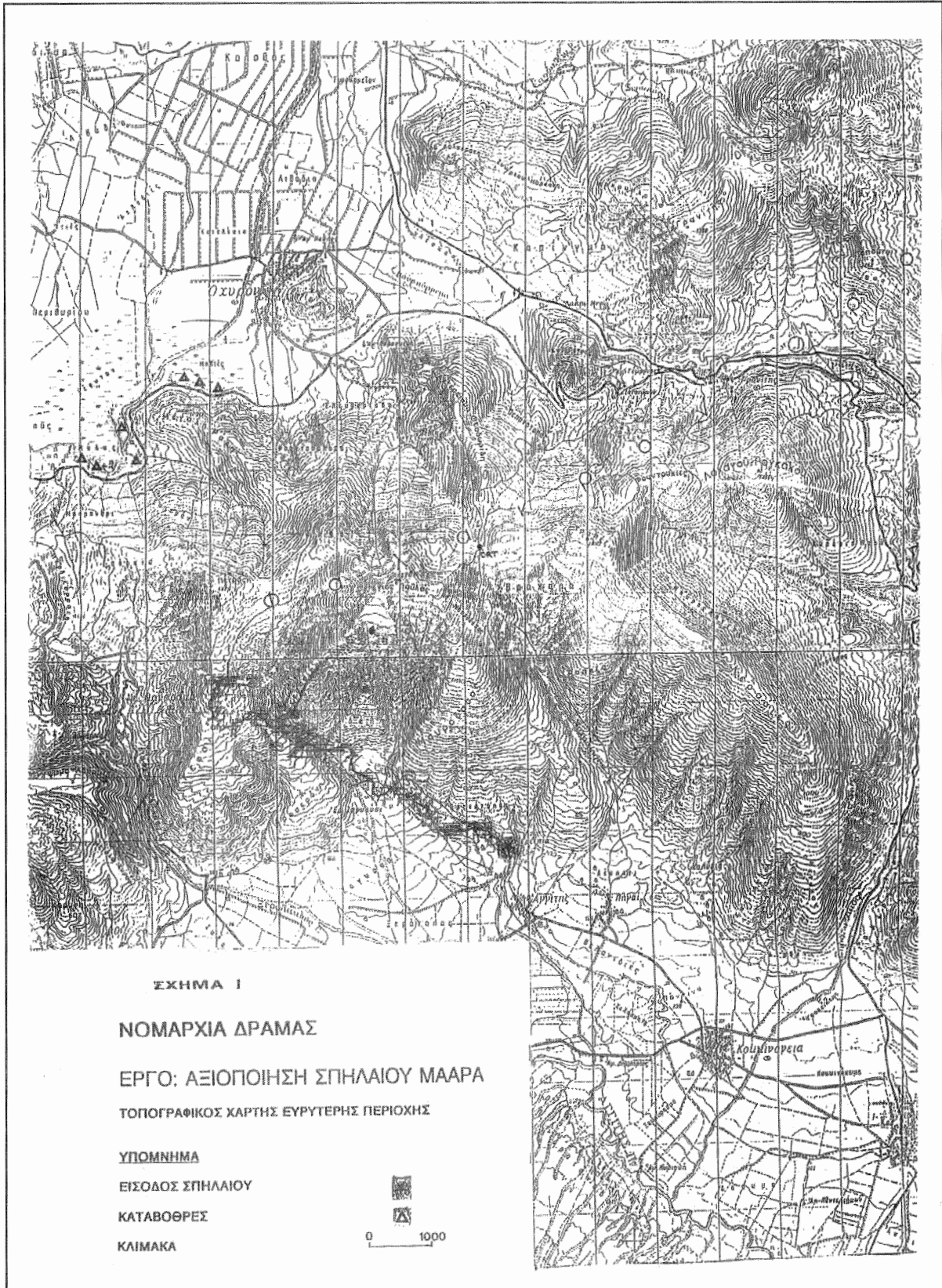
The Greek team a week in advance in the program has dove one more time the ending siphon . The diver went a few meters more and reach the depth of 30 meters. A cave situated Drama north east is promising a lot.

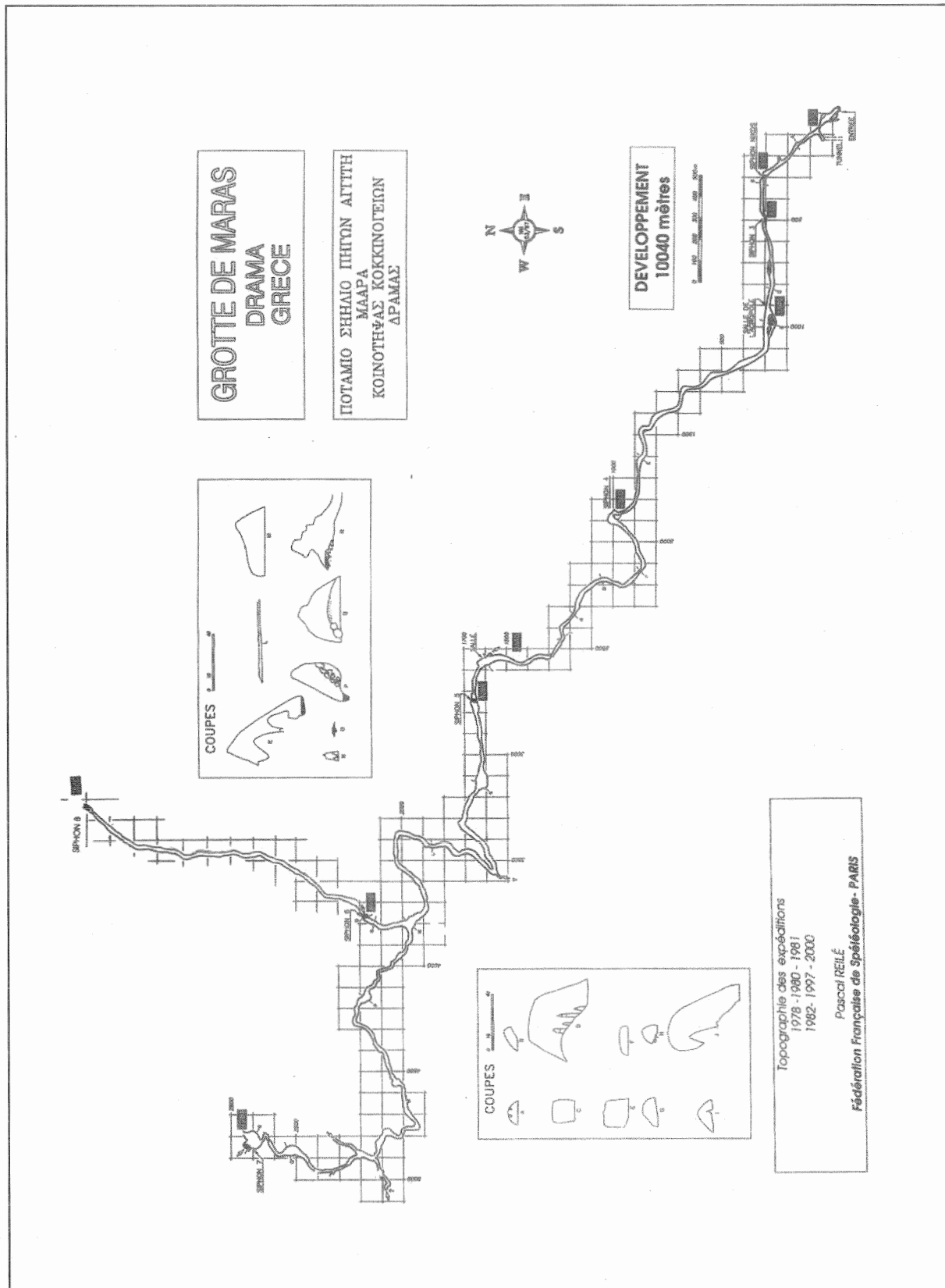
Prospectives

In the future , the work of the team Greek et French will be focused on the study and revalorisation of the 3 great sources of the Falakro mountain:

- Maras,
- Milopotamos,
- Drama sources.

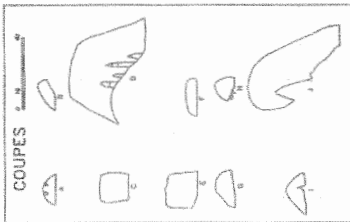
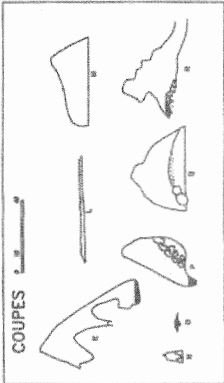
And the polje of Katonevrocopi/Ohiron





GROTTE DE MARAS
 DRAMA
 GRECE

ΠΟΤΑΜΙΟ ΣΗΗΛΙΟ ΠΗΓΥΝ ΑΓΓΥΗ
 ΜΑΡΑΡΑ
 ΚΟΙΝΟΤΗΤΑΣ ΚΟΚΚΙΝΟΓΕΙΩΝ
 ΔΡΑΜΑΣ



DEVELOPPEMENT
 10040 mètres

Topographie des expéditions
 1978 - 1980 - 1981
 1982 - 1997 - 2000
 Pascal REILÉ
 Fédération Française de Spéléologie - PARIS

1978	1980	1981	1982	1983
Avalianos Giorgos Cordier Régis Cordier Vincent Filippi Elisabeth Ioannidis Nikos Laethier pascal Reile Pascal	Cordier Régis Cordier Vincent Filippi Elisabeth Ioannidis Nikos Laethier pascal Reile Pascal	Cordier Régis Cordier Vincent Filippi Elisabeth Ioannidis Nikos Laethier pascal Reile Pascal	Cordier Vincent Filippi Elisabeth Ioannidis Nikos Trouillot Gérard Trouillot Chritine Reile Pascal	Cordier Régis Cordier Vincent Filippi Elisabeth Ioannidis Nikos Laethier pascal Reile Pascal
1995	1997	2000	2003	
Filippi Elisabeth Ioannidis Nikos Reile Pascal Xeidakis G.S	Durlet Pierre Filippi Elisabeth Ioannidis Nikos Giannopoulos V Langlois Dominique Langlois Marie Trouillot Gérard Trouillot Quentin Reilé Adeline Reilé Benoit Reile Pascal Trouillot Gérard Xeidakis G.S	Cailhol Didier Cailhol sylvie Filippi Elisabeth Durlet Pierre Giannopoulos V Langlois Dominique Langlois Marie Laureau Pierre Nicod Lionel Reilé Benoit Reile Pascal Trouillot Gérard	Filippi Elisabeth Reilé Benoit Reile Pascal Giannopoulos Vassili * Divers * Speleologist	

W-4

The Lava Tube Caves of Rwanda

M. Laumanns

*German Speleological Federation, Speläoclub Berlin***Abstract**

The principal caving area of Rwanda is located in the NW of the country (Ruhengeri and Gisenyi provinces). This region belongs to the East African Rift Valley and the Virunga Mountains form a big chain of volcanoes along the border with Uganda to the North and the Democratic Republic of the Congo to the West. The largest volcano is the Karisimbi that summits at 4,507 m. The mountains are covered by a dense jungle and are host to the last Mountain Gorillas on Earth. Most of the volcanoes belong to the Rwandan "Parc National des Volcans" (PNV) which significantly contributes to the tourist income of the country. At the foot of the mountains extensive lava flows cover the region at an elevation of between 1,900 and 2,700 metres. The known caves are entirely of volcanic origin formed in Cenozoic basaltic lava. Lava tube caves are very abundant. The main first phase of cave exploration in NW Rwanda took place between 1975 and 1977. Belgian speleologists from the Centre Routier Spéléo Belgique visited the area in 1975. They surveyed 4 caves including Ubuvumo bwa Musanze (to a length of 1,600 metres) and 4 other caves (Grottes de Bigowe, Grotte de Salomon and Grotte des Commandos) in the Mutura region (Gisenyi province). In 1977 a Spanish team from Barcelona visited the volcanic regions of NW Rwanda. Their studies included Ubuvumo bwa Musanze at 4,560 metres and Ubuvumo bwa Nyirabadogo at approximately 1,500 metres (the latter cave remained unsurveyed).

A recent phase of exploration was initiated in 2003 when a Rwandan-Swiss-German speleological project surveyed nearly 10 km of cave passages in 42 caves of the Ruhengeri province. The most significant findings were lava tube caves like Ubuvumo Nyabikuri-Ruri (Bukamba district) at 3,384 metres (unsegmented), which is currently the longest cave of Rwanda as well as Gacinyiro 2 (Kinigi district, unsegmented, 1,470 metres). Ubuvumo bwa Musanze, formerly reported to be the longest cave of Rwanda at 4,560 metres was found to be segmented with the longest segment being just 1,600 metres long. Some of the caves still contain human remains from the 1994 ethnic genocide and later conflicts. In 2004, a second international speleological expedition of cavers from the Netherlands, USA, Kuwait and Germany resulted in the exploration of 20 more caves with a total passage length of about 9.1 km both in the Ruhengeri and Gisenyi province. The most significant findings in 2004 were lava tube caves such as Ubuvumo Manjari deux (Mutobo district, Ruhengeri province) at 1,660 metres, which is currently the second longest cave of Rwanda, and Ubuvumo Cyamazera (Mutura district, Gisenyi province, 1,484 metres). Ubuvumo Nyiragihima (Mutobo district, Ruhengeri province) was explored to 1,116 metres and is currently the eighth longest cave of the country. Many caves in NW Rwanda still await exploration and the potential for further discoveries is as excellent as the co-operation with the local authorities proved to be.

W-5

An overview of caving regions in Northern LaosJoerg Dreybrodt¹ & Michael Laumanns²¹Bekassinenstr. 86, D-28357 Bremen, Germany (joerg_dreybrodt@yahoo.de)²Unter den Eichen 4 C, 15834 Rangsdorf, Germany**Abstract**

Four expeditions were undertaken from 2000-2005 to achieve an overview of the caving regions in Northern Laos. The first project was conducted by a Dutch team in 2000 and followed by German (2002, 2003) and joint German-Dutch (2005) expeditions. Five main regions of the North were visited yielding caves with a total length of 25 km: the Nam Ou valley near Muang Ngoy; the Luang Prabang district; the area of Phoukhoun near Kasi; the Vieng Phouka district and near Muang Nan. The largest potential was discovered in Vieng Phouka (Luang Nam Tha province) with the river cave system of Tham Nam Eng. It consists of a 3,120 m long upper fossil system and a 3,460 m long lower active river system. Further planned expeditions will focus on this area which has also the highest potential for show caves.

1. Introduction

This chapter gives an overview of speleological expeditions to Laos and introduces the caving areas in the north. A geological abstract follows. Chapter 2 introduces the cave regions in more detail and the most important discoveries. A look on the Laotian and his relationship to caves is done in chapter 3. The last chapter summarizes and gives an outlook.

1.1 Overview

Since 1992 Laos has rapidly opened to foreign tourists and many successful speleological projects have been carried out, mainly by French teams. On an occasional basis Italian and British caving expeditions have contributed to the knowledge on karst and caves of Laos (Brouquise et al. 1999). Most of the caving expeditions were dedicated to Khammouane province (Mouret (2001) in central Laos and the area around Vang Vieng (Vientiane province) (Hédouin & Renouard 2000).

Although caves were known from the north of Laos (e.g. the historical Pak Ou show cave near to Luang Prabang) no systematic cave exploration had been done there before a Dutch team started work in the Luang Prabang province in 2000. They surveyed 7.3 km of passages in 16 caves in the Nam Ou Valley and around Muang Nan and released a report on their findings (Eskes & Damen 2004).

The Dutch trip was followed by a lightweight German reconnaissance project to the Nam Ou area around Muang Ngoy in 2002/03 and a larger German project in 2003/04 to Luang Prabang district. This yielded 34 caves with a total of 5.6 km, amongst which was, so far, the longest known cave of northern Laos (Tham Loum at 1.6 km).

Finally, a common German-Dutch expedition to northern Laos was conducted in February 2005. The first part of the project focused on caves at Phou Khoun close to Kasi. The expedition succeeded to connect three separate known caves to one 2.6 km long system (Tham Seua-Nam Lot). However, the main part of the expedition was dedicated to an until then untouched area at Vieng Phouka (Luang Nam Tha province) close to the Burma and Thai border. Here a European Community based micro-project that promotes eco-tourism as an additional local income actively supported the exploration of the caves with local transport and guides. The area surprised with the longest active river caves in the north. It took only a week to survey caves with a total length of 8.9 km. The longest the Tham Nam Eng system consists of an upper 3,120 m long fossil cave and a 3,460 m long lower active river cave. A link could not be found yet.

1.2 Geology

The natural history, as well as the morpho- and orogenesis of northern Laos is complex and poorly known. The following observations were taken from Mouret (2004). Most limestone occurrences in the region are of Upper Paleozoic age (Permian to Carboniferous, 360 - 250 my old). Towards the south some Jurassic limestone successions have been identified in the area around Luang Phrabang. Deposition of limestone obviously has not been continuous in all cases as sometimes 20-50 m thick limestone sequences can be observed that are sandwiched between clay or sandstone layers. The thickness of the limestone succession varies and is suspected to reach at maximum 5,000 meters. The carbonates are in most cases underlain by schists.

Tectonic movements from the Triassic onwards have strongly affected the limestone sequences. The main tectonic fractures run from N-S and from NE to SW. The carbonates are heavily deformed, often shows a steep or even near-to-vertical dip, are partly re-crystallized and metamorph in a way that the porosity of the limestone went lost and even the distinction of the formerly separated layers disappeared. Weathering, known as "case hardening" further contributed to the diagenetic modification of the carbonates leading to a less favorable solubility and lower subsidence rates.

Karstification of the limestone took place in a moderate tropical climate and the karst landscape is covered by a dense forest. The morphology of the limestone regions can be subdivided into different types:

a.) Extensive karst massifs with spectacular peaks that summits at about 1,600m-1,900 m in the northern part of the Nam Ou river while the Nam Ou river flows at about 360 m only. The slopes of the massifs are steep and vertical cliffs are abundant. These large massifs cover up to 15 sq. km and are intersected by rivers and dry valleys. The karstifiable limestone has its base at or beyond the current level of the main river.

b.) Isolated karst mountains that also can form high peaks. These small limestone cones rest on top of non-karstifiable rocks with a diameter of about 250 by 500 meters and a height of 120 m. These isolated mountains are dominant in the region along the Mekong between Luang Phrabang and Pak Ou.

It is suggested that the larger karst massifs and isolated karst cones belonged to much more extensive limestone regions in the past, which are today eroded to a great part. The limestone massifs and cones are fairly easy to locate on the topographical maps due to their steep walls.

Caves are developed on different levels above the current water drainage and give evidence of a multiphase speleogenesis. The Mekong is the main stream in the whole region with the Nam Ou being its largest tributary river. Both rivers are still important transport and traveling routes. The Nam Ou traverses several large karst massifs in a deeply incised scenic gorge, which appears to be mainly the result of erosive down-cut of the river.

The limestone massifs of the Vieng Phouka area are in general of lower elevation and of limited extend but they are strongly karstified and host significant caves, probably due to a different stratigraphy or diagenetic modification of the rocks than those in the Luang Phrabang province.

2. Caving Areas

An overview of caving areas is found in map 1. The most intensely investigated area is around the villages of Nong Khiaw and Ngoy Nua in the north-east relatively close to the Vietnam border. Two of the four

expeditions focused on this area and a large number of caves have been found along the banks of the Nam Ou river. The Vieng Phouka district in the north-west has only recently been visited in February 2005. It revealed as an unexpected surprise the longest caves in northern Laos.



The Luang Prabang district was targeted in the 2003/04 expedition and searched for caves in a radius of about 50 km. Most of the 26 surveyed caves are 100-200 m long with the exception of the 1.6 km long Tham Loum. They show a great variety including caves with only one straight passage to mazes and big chambers. Just a short trip was done to the Phou Khoun area about 100 km south of Luang Prabang with one cave completely surveyed. The area is still sensitive due to activities of Hmong rebels. The last section covers the Muang Nan area that was explored by the Dutch expedition in 2000.

Caving areas in northern Laos.

- A: Muang Ngoy/Nam Ou
- B: Vieng Phouka
- C: Luang Prabang
- D: Phou Khoun
- E: Nan

2.1 Nam Ou Valley at Muang Ngoy

The investigated area is crossed by the wide Nam Ou river from the NE to the SW. Where the national road no. 1 crosses the river, the village of Nong Khiaw (named Muang Ngoy on the topographical map) is



View from Muang Ngoy Nua towards the North into the gorge of the Nam Ou river (photo: J. Dreybrodt)

situated. The small district town is a transfer point where people arrive by car or bus and continue to travel up- or downstream on the Nam Ou by boat. These limestone areas were first investigated by the 2000 Dutch expedition. Four caves were surveyed and a site with ancient rock paintings was visited. Restrictions made by the administrative representatives of Muang Ngoy forced the team to stop the exploration and to return to Luang Phrabang. They were allowed to continue as a joint project with the provincial forest department in the area around Muang Nan. The same area was investigated by the German reconnaissance in 2002.

About 14 km upstream (north) of the town of Nong Khiaw the Nam Ou river crosses an approximately 20 km long and 15 km wide area of large limestone massifs that summit at 700 - 1,500 m and that are covered with a dense monsoon rain forest. The Nam Ou partly has created an extremely scenic gorge with breathtaking cliffs up to 600 m high. The village of Ngoy Nua is situated right in the middle of the Nam Ou gorge where the tributary creek of Nam Ngoy coming from the East joins the Nam Ou. Ngoy Nua is accessible by a 1 hour long boat trip from Nong Khiaw/Muang Ngoy only.

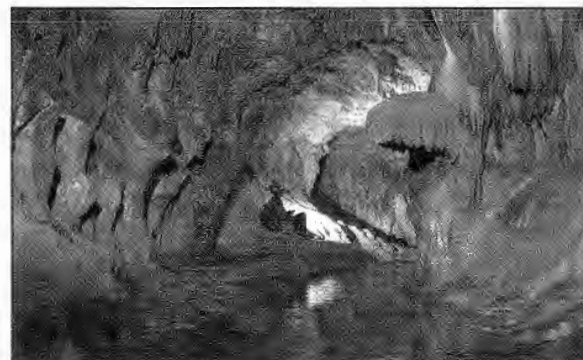
The longest cave along the gorge is the Tham Kham / Pageo (Holy image cave / Middle cave). The cave is reached in 30 minutes by foot from Ngoy Nua village along the Nam Ngoy creek. The Tham Khan cave (520 m) has a wet lower entrance and an upper dry entrance. A sump is reached after about 200 m that certainly connects to Tham Pageo. This sump was free-dived for about 10 meters and two air-filled chambers were reached. However, no connection to Tham Pageo was made. UXO Laos (the regional explosives clearance project) has removed explosives from the cave. Traces can still be seen in Tham Khan.

The entrance to Tham Pageo (1,550 m) opens immediately east of the Tham Khan resurgence. The entrance and the subsequent 100 meters of phreatic passage are pretty low with less than one meter and filled with mud. Later the cave becomes walkable and two crawls and a duck have to be passed until the cave divides into an East/Northeast and West section. The later one ends in a sump that connects to Tham Khan. The East/Northeast section of Tham Pageo continues for another 500 m until it ends abruptly.

The 21 caves so far known along the Nam Ou can be subdivided in two groups:

- a.) Active river caves like the Tham Khan/Pageo and the Tham Doun's. These caves are flooded during the Monsoon.
- b.) Fossil caves that are situated about 50-150 m above the river of Nam Ou. These caves often have a rich calcite decoration and sometimes high contents of CO₂. The average length is about 100-200 m.

It has to be noted that during the expeditions caves with easy access mainly near the river were investigated exclusively. The upper cliffs and tops of the enormous karst plateaus still remain virtually untouched and



Side passage of Tham Nam Eng (resurgence cave) (photo W. Zillig).

a full-scale expedition will require exhaustive "jungle-bashing" in steep terrain.

2.2 Vieng Phouka

The district village of Vieng Phouka is situated in the Luang Nam Tha province half-way along the road from Luang Nam Tha towards Huay Xai at the Thai border. In a few years the region will experience an economic boost due to a highway that is currently in construction between Thailand and China. Caves play an important role in the Vieng Phouka based eco-tourism project from the European Community and are visited in combination with trekking activities. The 2005 speleological investigations of the Dutch-German team were logistically supported in a generous way by providing transport and well-trained guides. Due to the excellent conditions the 2005 cave investigations led to important discoveries within a period of one week only.

The Tham Nam Eng is the best known cave in the area and used for eco-tourism. It is mentioned in several international guide books and also indicated on tourist maps from Laos. The guides pay great attention on the protection of the cave which is therefore looked. Waste has to be carried out and nothing should be left in the cave. Despite the intense use of the cave no systematic survey has been done and the guides visited only the known areas. Their fear to get lost kept them out of any new passages and exploration.

The cave is reached by a 1 hour drive on the dusty main road from Vieng Phouka to Luang Nam Tha just a few km further north from name giving village Ban Eng. It takes only 10-15 minutes to walk from the road eastwards to the base of the mountain ridge that hosts the Nam Eng system. It consists of the upper fossil cave of 3,120 m length and the lower active resurgence cave of 3,460 m length. Some of these passages are situated less than 100 metres from each other on a comparable level. However, no link between both caves was found. There are also several vertical shafts that ascend from the main passage of Tham Nam Eng (resurgence) that may connect both caves. Tham Nam Eng resurgence cave drains massive water during the wet season. The walls nearly of the complete cave show scallops with a diameter less than 1 cm. Dripstone formations are rare in Tham Nam Eng resurgence cave and can be found in the upper parts of higher passages only.

Other caves surveyed in the area are the Tham Pasat ("Tunnel cave", 1,490 m) and Tham Phou Pasat (645 m). They are located in an isolated ridge about 25 km north of Vieng Phouka. The active river cave Tham Nam Lot crosses the ridge and has at least 5 entrances.

The Vieng Phouka area offers probably the biggest potential in northern Laos. Several other caves were reported in the district. Unfortunately they are less close to the roads. The 3 hour intense jungle hike to Tham Phoulan on the last day surprised with a 250 m long, 80 wide and 100 m high huge chamber. The cave remained unsurveyed due to lack of time.

2.3 Luang Prabang District

Most of the caves in the vicinity of Luang Phrabang have easy access due to the well developed infrastructure near to the provincial capitol. Furthermore the city of Luang Phrabang is a focal point of the local tourism. Consequently, caves play an important economic role. The Pak Ou caves are the most known tourist caves of Laos. They are situated on the western Mekong shore opposite the confluence with the Nam Ou, approximately 25 km upstream the Mekong from Luang Phrabang. The caves were visited by foreigners since 1867, when Douart de Langré first explored the Mekong. Both caves contain thousands of Buddha statues of different size. The statues are mainly made from wood. They are covered by leaf-gold in many cases.

Luang Prabang has two large 30 km long and 1,000 m high limestone plateaus located to the east and south that are directed from NE to SW. The search for caves was intensified around the plateaus and the Mekong.

In total 26 caves with a total length of 4.1 km were surveyed and mapped. Most of them have about 100 m of length.

The longest cave Tham Loum (Wind cave, 1.6 km) is found in the remote village of Longkhoay in the southern Phou Phaxang Noy plateau. The cave follows the axis of the limestone ridge from NE to SW. It consists of a single rift-controlled meandering gallery with no significant branches. Except of a small entrance with a strong current of air and few other crawls the entire passage is of walking size.

The second longest cave is the multi level river cave Tham Pha Man (405 m) north of Luang Prabang at the Mekong near Ban Man Phone Sai. A steeply descending but climbable passage gives access to a complicated maze of inter-connected phreatic passages on several levels. While the upper level of passages are decorated with calcite formations the lowest level reaches the static karst water level.

The eastern plateau of Phou Longhouay has only few short caves of 50-80m at its northern end at the Nam Pa river and on the plateau near Ban Long Kout. The Chompet district on the west side of the Mekong hosts the after the nearby monastery named Tham Khou Ha Sakhalin (120 m). Furthermore an overnight trip was done 25 km upstream the Nam Kham river to Tham Kengkong (Crystal cave, 373 m) named after the nearby village.

The caves in the Luang Phrabang area surprise by its great variety from straight passages to large chambers and mazes mostly located high in the ridges of the mountains. Often CO₂ is present. The highest potential seems to be at Ban Longkhoay with 6 other caves mentioned by the villagers.

2.4 Phou Khoun

The T-junction of the north-south road 13 with the road 7 to the Plain of the Jars marks the location of the village of Phou Khoun. It takes 3 hours on the winding road 13 from Luang Phrabang until Phou Khoun is reached. The area was a showplace of Hmong rebels and a long time considered to be unsafe. Only recently the situation relaxed and the first time a permission was obtained in 2005 to visit the caves nearby. Nevertheless the local authorities insisted on certain safety measures and 3 soldiers and 2 policemen equipped with automatic guns escorted us to the cave on the first day.

The Tham Seu (Tiger cave) - Nam Lot (Tunnel cave) system was originally known as two separate caves which could be successfully linked during the survey to one 2.7 km long system. It takes a 10 minute walk from the T-junction along the road 7 to about 200 m beyond the hospital until a footpath to the left is reached which descends to the valley with the caves. The entrances are found after another 45 minutes at the very end of the valley at the base of a north-east to south-west stretching mountain ridge. The system consists of the maze like Tham Seu that connects to the main river passage of Tham Nam Lot. A 60 m higher upper level with three separate entrances has several interlinked and richly decorated chambers. One passage descends steeply to the river passage. The river crosses the mountains and exits as a spring between boulders and blocks. An intense search for a crawl that connects to the river passage failed. Other caves further away were reported, but located in still unsafe areas and out of limits for the time being.

2.5 Muang Nan

The Muang Nan area is reached by a 1.5 h drive from Luang Phrabang. It has been intensely searched by the Dutch expedition in 2000. The longest cave is Tham Gia with 1.4 km length while Tham Thia has a remarkable depth of -105 m and was once the deepest cave in Laos. In total 7 caves with 2.5 km passages are known.

3. Laotian tribes and Caves

There is a remarkable difference of the attitude of Laotian tribes to-

wards caves. It varies greatly from area and tribe and is influenced by beliefs in spirits, hunting tradition and war history. In general the first day in a new caving region is always the most difficult with any tribe. People do not understand the reason behind caving and are therefore reluctant to give information. But the cave survey techniques once shown are easy understandable and to draw a map in order to get not lost creates usually high confidence after the first day. Suddenly on the 2nd day the "known" caves in the area at least double.

The Hmong who live high in the mountains have the most practical attitude. Asked about cave entrances they know the exact locations, walking distances and even the approximately size of the cave. The most fascinating encounter we had in the 1.6 km long Tham Loum at the Hmong village Longkhoay south of Luang Prabang. Children use the cave as playground and we got greeted by a cheerful group of about 10 boys and girls equipped with some candles and "one way" Chinese torches in the remote parts of the cave.

The Khmu tribe settles along valleys and rivers and mix with the Hmong in villages. Answers like "the cave is huge - 1 day to walk in" can result in findings of few Buddha statues at the entrance of a 19 m long cave. This happened at Ban Nun Savat near Luang Prabang. Usually Khmu know the entrances, but not what is behind. Exceptions exist as always.

The influence of the Vietnam war is easily realized in the once heavily bombed region of Muang Ngoy Nua at the Nam Ou river. Villagers are very hesitant to reveal any information since the caves were used as shelters and hiding places during the war. Whole villages spent several years in nearby caves and left them only at night to farm the fields. They believe in ghosts and bad spirits that still have influence on their life. Any visit of such a cave without the permission of the nearby village can have serious consequences. Besides that unexploded ordnance (UXO) might be present and the villagers know about it.

Almost every village asks immediately for an official permission that must be issued from the provincial tourism office. The reason may be in

shifting responsibilities to higher authorities, because caves are in general considered dangerous. Guides always accompanied us for our safety.

4. Conclusion

The former unknown north of Laos slowly discloses its face on the speleological world map. An overall of 25 km passages has been surveyed in the last 5 years with increasing success. A major cave region with a high potential has been found around Vieng Phouka in the Luang Nam Tha province. Future expeditions will focus on this area. White spots are still the former cave shelters of the communist resistance fighters at Viang Xai (Sam Neua).

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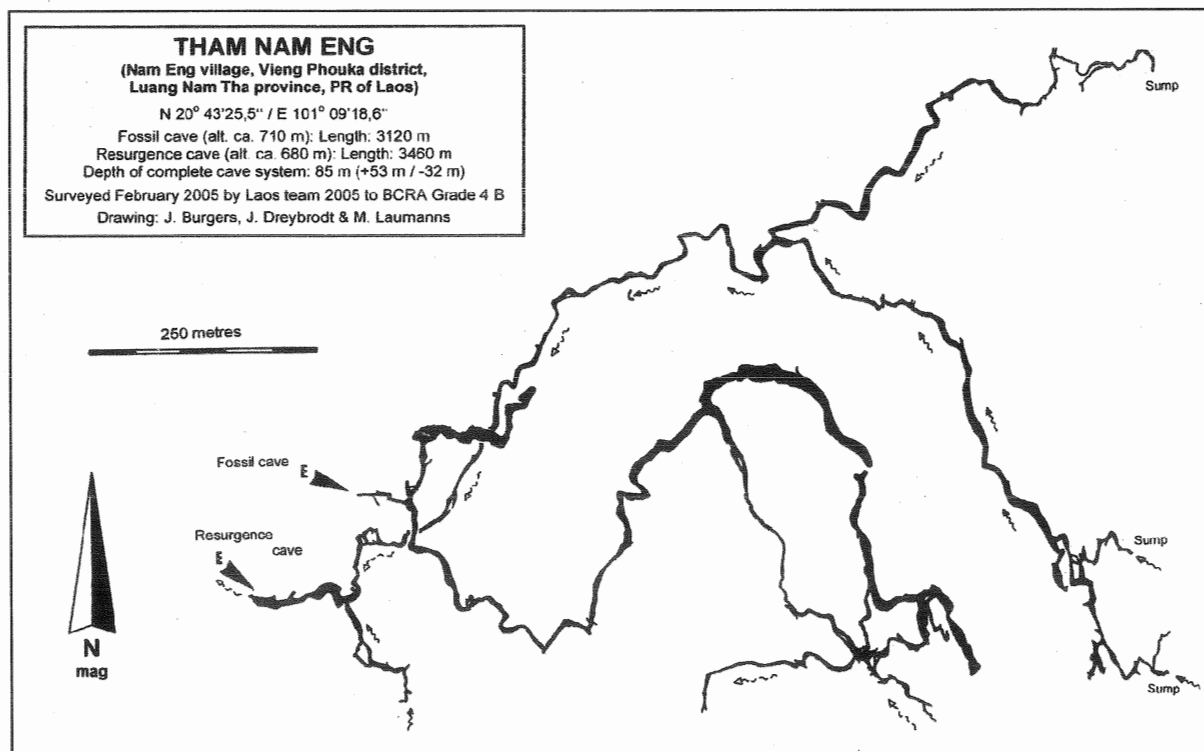
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W-6

Karst, Caves and Speleology in the Islamic Republic of Iran

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*Geological Survey of Iran, Tehran, Iran***Abstract**

Iran is a vast country that has a wide variety of soluble rocks, especially carbonates. Karst areas, covering approximately 11 % of Iran's land surface, have a significant importance for the water supply of many regions. Most of the occurrences are karstified. Caves were used as shelter for living and defence purposes in the past. Therefore, inscriptions, statues, manmade wells and caverns, and ancient monuments can be found inside caves. Most of the Iranian Universities that have karst areas in their neighbourhood, as well as several governmental institutions, deal with respective geological and hydrological investigations. Since 1945 amateur groups from the Iranian mountaineering clubs started with cave investigations. Beginning in the early seventies foreign speleologists started to visit Iran, mainly British, French, Polish and Italian teams. The investigations led to the discovery of the deepest caves of Iran, namely -751 metres deep and 1,364 metres long Ghar Parau (Kermanshah). This cave remained to be the longest cave of Iran until the late nineties. Czech cavers started to

conduct speleological projects in Iran since 1997. They organised surveying projects every year until 2001. Their work was dedicated to the Hormoz region in southern Iran where they discovered remarkably long caves formed in salt. One of them, Tri Nahacu, is currently the second longest cave of the world formed in salt at 5,010 metres. It was the longest surveyed cave of Iran in 1999. Joint Iranian-German-British surveying projects to Iran were carried out in 2000 and 2001. The successful projects resulted in 11,440 metres of mapped passage length for Ghar Alisadr (Hamadan) and firmly established the cave as being by far the longest cave of Iran at that time. This was superseded by Ghar Katalahkhor (Zanjan) in 2003 when during a two-weeks Iranian-German-Swiss surveying project this impressive newly opened show cave was measured to 12,860 metres of length. Approximately 1,000 caves are currently known from Iran but only data on about 500 of them are published in an "Iran Cave Directory". This indicates the enormous amount of work that remains to be done with respect to Iranian caves.

W-7

Recent explorations in Krubera-Voronja cave (West Caucasus).

D. Provalov, I. Zharkov

Abstract

Since 1999 there have been many breakthrough discoveries in the Kru-

bera-Voronja cave (-2080 meters) made by teams of Ukrainian Speleo association and by Cavex team. We will discuss achievements of the most recent expeditions.

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W-8

Le ricerche geospeleologiche condotte in Etiopia dal CIRS negli anni 2003/2005

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*Centro Ibleo di Ricerche Speleo-Idrogeologiche, cirsggr@inwind.it***Summary****CIRS geospeleological research in Ethiopia in the 2003/2005 years**

A research agreement carried out through 2003 and 2005, between the Geology Department of the Addis Abeba University and the CIRS of Ragusa, has finalized the study of karstic phenomenas, both superficial and deep, present in some areas of Ethiopia. During the 2003 expedition some reconnaissances were undertaken in some areas of Tigray and Hararghe which underlined regions with limestone outcropping showing different karstic potential. In the 2005 expedition efforts were concentrated just in the Mechara area, in the Hararghe south-eastern sector, which resulted, based on the first results, interest to both karst and speleological. In the above mentioned area the Rukiesa cave was explored, an interesting active karst system which captures the meteoric floods of a wide area, creating an underground river with an outlet created by the Burka spring located some kilometers away on the right bank of the Mechara river.

The exploration of the Rukiesa-Burka system, undertaken in the inlet sector for about 1 km and in the outlet for about 80 m in an extremely narrow conduit flowing in a gallery with water, presented critical difficulties during both the two expeditions: the first in the 2003 year because of a flood; the second in the 2005 year because of an unexpected high value presence of CO₂ along the river gallery, luckily there were zero incidents. Still in the Mechara district, in the Ejersa river basin, a second interesting active system, make up of two caves, Garayati and Eyefeyete, has

developed into two different levels which are probably connected. This karst system was only partly explored due to the presence of a sump in the Eyefeyete cave and an overflowing conduit in the Garayati cave which was left for the following year's exploration. As the research in the area of Mechara is not yet completed, and will be the objective of future expeditions, the main efforts during the research will be to lead the explorations in a safe condition concerning both the flood events and the danger of high values of CO₂.

All that said, it is currently possible to summarise the presence of a karstic phenomenology of particular interest for the speleogenetic, geomorphologic and hydrokarst displayed aspects. Similary interesting, in some caves, the observed fauna was characterized by the presence of arachnid and isopod showing trogloby characters to be evident.

Antefatto

A conclusione delle ricerche speleologiche condotte in Zambia nel settembre del 2002, si coglie l'opportunità, prima del rientro in Italia, per effettuare una breve tappa in Etiopia per un concordato incontro con la direzione del Dipartimento di Geologia dell'Università di Addis Abeba. Con il Capo Dipartimento si discute sulla fattibilità di porre in essere un congiunto programma di ricerca sugli aspetti carsici di alcune aree

dell'Etiopia da realizzare l'anno successivo. Individuate alcune aree e definiti in linea di massima i punti cardini dell'accordo che doveva sancire l'avvio della ricerca si approfitta dei pochi giorni precedenti il rientro in Italia per effettuare alcune ricognizioni preliminari nel settore nord-ovest del paese fra le Gole del Nilo Azzurro e il lago Tana. In queste aree vengono osservati alcuni degli aspetti morfologici più peculiari e interessanti del territorio Etiopico costituiti dagli elevati rilievi dei verdeggianti altipiani settentrionali (amba) ricoperti da spesse colate basaltiche e dissecati da profonde gole. Nel settore delle Gole del Nilo Azzurro, lungo la strada che da Addis Abeba conduce al Lago Tana, discendendo per più di mille metri la profonda incisione creata dalle acque del fiume, si ha, altresì, modo di osservare tutta la serie dei terreni della formazione Antalo nei cui calcari giurassici, affioranti nelle aree inserite nel progetto, sarebbero state, da lì a poco, realizzate le ricerche concordate.

Le ricerche precedenti

Le prime ricerche speleologiche condotte in Etiopia in forma sistematica risalgono al 1972 organizzate dal British Speleological Expedition to Ethiopia a cui va attribuito il rilievo delle grotte Sof Omar (15,1 km), la cavità attualmente più lunga del paese, e Nur Mohammed nella regione di Bale oltre all'esplorazione di altre cavità prevalentemente verticali nel settore orientale della regione di Hararghe. Alcuni anni dopo, nel 1976 una spedizione organizzata nell'ambito dell'Università di Addis Abeba esplora altre grotte nella regione fra cui la Enkoftu Mohu (-192 m) attualmente la cavità più profonda dell'Etiopia. Sebbene qualche anno dopo, nel 1980, altre ricerche vengono effettuate da un team russo, delle quali però non si hanno notizie di nuove scoperte, l'avvio di nuove esplorazioni in forma documentata si realizza quasi 20 anni dopo nel 1995 prima, con una spedizione organizzata da un team di speleologi dell'Università di Huddersfield, e nel 1996 dopo, con una seconda effettuata dal Limestone Research Group della stessa Università. Nel corso di queste ultime spedizioni ricognizioni vengono effettuate nella regione di Sidamo, senza risultati degni di nota, nella regione di Bale e in quella occidentale di Hararghe. In quest'ultima nel distretto di Mechara viene esplorata la grotta Aynage (3,3 km) e la grotta Achere (3,8 km), allo stato attuale il secondo sistema carsico più lungo dell'Etiopia.

Nota geografica e climatica

Compresa nella fascia di latitudine 2° - 14° Nord e longitudine 33° - 48° gradi E, l'Etiopia con un territorio di poco più di un milione di Km², presenta aspetti morfologici estremamente vari che possono essere ricondotti a due principali aree geografiche: il vasto e fresco altipiano centrale con una altezza media compresa fra 1800 e 2400 m e i torridi bassopiani ad est e a sud. Nel tavolato centrale si erge la quarta cima più alta dell'Africa il Ras Dashen (4620 m) e nascono quattro grandi fiumi fra cui il Nilo Azzurro dal lago Tana.

A sud il paese è attraversato diagonalmente dalla grande depressione della Rift Valley, ampia fino a 50 km, e costellata da laghi, che nel settore settentrionale si apre nella ancora più profonda depressione della Dancalia uno dei luoghi più caldi del pianeta.

Sotto il profilo climatico gli altipiani godono di un clima temperato con temperature medie diurne sui 16° C e precipitazioni distribuite fra giugno e settembre di circa 1000 mm d'acqua.

La parte meridionale della Rift Valley, situata ad una altitudine media di 1500 m, presenta un clima da temperato a caldo con precipitazioni simili a quelle degli altipiani, mentre nella depressione della Dancalia le piogge sono inesistenti con temperature che possono raggiungere i 50° C.

Nel settore sud i bassipiani presentano un clima da caldo secco (quelli orientali) a caldo umido (quelli occidentali), mentre nei bassipiani del nord-est, soggetti a siccità, le piogge sono circa la metà di quelle degli

altipiani.

Lineamenti geologici

Rocce del Precambriano, costituite prevalentemente da metamorfici con locali intrusioni di rocce granitiche, affiorano nel settore nord del paese, mentre altrove sono ricoperte da sedimenti paleozoici e mesozoici. Questi ultimi, originatisi a seguito di una trasgressione marina da sud-est, presentano spessori di circa 3000 m nell'area prossima al confine con la Somalia, che vanno poi a ridursi verso nord e ovest fino a scomparire in Eritrea e lungo il confine con il Sudan. Arenarie e calcari con intercalazioni di argille e gessi costituiscono la Formazione Antalo di età da Giurassico a Cretaceo inferiore, mentre calcari cocenici sono presenti nell'estremo settore orientale del paese.

Nel Cretaceo superiore si completa il sollevamento dell'area al di sopra del mare cui si accompagna una diffusa laterizzazione dei sedimenti affioranti, mentre con il Terziario inferiore-medio una importante attività vulcanica produce un diffuso ricoprimento del territorio con lave basaltiche. Nel Miocene una intensa attività tettonica con faglie, accompagnata da attività vulcanica, inizia la separazione dell'Africa dall'Arabia e lo sviluppo della Rift Valley orientale africana. Mentre l'apertura della Rift Valley si accompagna al progressivo sollevamento delle regioni circostanti a formare altipiani con altezze superiori ai 4000 m, l'erosione delle lave terziarie porta in affioramento le sottostanti rocce mesozoiche e precambriane.

Sotto il profilo carsico, la Formazione Antalo, costituita da calcari con intercalazioni di argille, siltiti e gessi, risulta la più importante per ciò che concerne lo sviluppo di cavità carsiche. Nell'area di Mekele, nel nord-est, la formazione presenta gli spessori maggiori di calcare, intorno agli 800 m, sebbene in gran parte marnoso, mentre nelle Regioni di Bale e Harar, a sud-est della Rift Valley, gli spessori di calcare puro sono intorno ai 400 m, ma con minori intercalazioni di marna. A nord-ovest della depressione gli spessori di calcare si riducono a 50 m, e fino a circa 25 m lungo i versanti delle Gole del Nilo Azzurro, prevalendo di gran lunga gli strati marnosi e argillosi.

Le aree di ricerca

Obiettivi della prima fase delle ricerche, condotte dal CIRS con la spedizione del 2003, sono state alcune aree della Regione settentrionale del Tigray e altre nel settore sia centro-orientale che occidentale della Regione dell'Hararghe.

Con la seconda fase, realizzata nel 2005, le ricerche vengono invece concentrate nel distretto di Mechara, est Hararghe, per la prosecuzione delle esplorazioni iniziate nel 2003.

Tigray

La struttura geologica di Mekele, capoluogo del Tigray, si presenta come un Outlier circondato da rocce del basamento precambriano su tre lati, mentre nella parte meridionale da sedimenti più recenti.

Le ricognizioni in questo settore interessano le Gole del fiume Enda Gabre, a circa 20 km a SE da Mekele, una profonda incisione che ha evidenziato, al di sopra della copertura doleritica che ricopre l'altipiano, circa 20 m di calcari della Formazione Antalo sostenuti da rocce marnose impermeabili. In questa valle, in prossimità di una cascata viene osservata una piccola cavità, chiamata Kidane Mimret, a quota 2229 m, originatisi nei travertini e poco distante sul versante sinistro una cavità di natura tettonica chiamata Manchelfo - Mai Auli a quota 2275 m viene rilevata.

Una seconda ricognizione interessa, in un'area al confine fra la Regione di Gondar e di Welo, la Golden Cave, a quota 2676 m, una cavità

originatasi nelle rocce ignimbritiche con particolari morfologie paracar-siche ubicata a circa 3 km a sud-est di Debre Zebit.

Hararghe

Le ricerche nella regione di Harar si realizzano in tre aree: nell'area di Hirna, nell'area di Kombolcha e nel Distretto di Mechara.

Nell'area di Hirna in località Agè, circa 120 km ad ovest di Harar, viene esplorata e rilevata la grotta Goda Ferda il cui ingresso, un ampio androne, si apre a metà versante sulla falesia carbonatica sovrastante un'ampia vallata. Lungo quest'ultima sempre sulla falesia carbonatica si osservano diversi ingressi di cavità naturali, alcune di chiara origine nei travertini.

Grotta Goda Ferda

Dall'ingresso, si risale sulla sinistra un polveroso pendio infestato da escrementi di capre, fino a raggiungere, oltre un basso passaggio, un ampio e alto vano con depositi di calcite e un secondo ingresso, sul settore sinistro, a strapiombo sulla vallata. In questo ambiente si osservano, altresì, riempimenti detritico-argillosi lungo alcuni solchi che denotano fasi di riempimento della cavità.

La grotta prosegue, quindi, risalendo sulla sinistra un più irto e polveroso pendio fino ad arrivare su un meandriforme condotto impostato su una frattura. Sulla sinistra il condotto risale per alcuni metri con andamenti a spirale fino ad un ultimo ambiente in cui si osservano alcuni pipistrelli; sulla destra il condotto, più ampio, prosegue ancora per alcuni metri per poi chiudere in corrispondenza di un piccolo vano. In questo livello rialzato della cavità sono presenti lungo le pareti del meandro morfologie sia di erosione meccanica che di corrosione chimica quali solchi e alcune nicchie. Ritornando nel settore d'ingresso si risale sulla destra un ultimo condotto il cui soffitto nella parte superiore presenta una tipica morfologia a canale di volta. Quest'ultimo condotto dopo alcuni metri risulta ostruito per la presenza di depositi detritico-chimici.

Grotta Goda Wonji

A 15 Km a NNO da Harar e a circa mezz'ora di cammino dal villaggio di Kombolcha, sulla sommità di una bassa collina calcarea è ubicata la grotta Goda Wonji a quota 2221 m. La cavità, esplorata e rilevata, dopo un ingresso di forma subellettica in parte modificato dai locali, si presenta nel complesso come un angusto condotto freatico fossile parzialmente riempito da detriti clastici e colonizzato nella parte terminale da pipistrelli.

Distretto di Mechara

E' nel Distretto di Mechara tuttavia che le ricognizioni producono i migliori risultati esplorativi in virtù di un rilievo particolarmente carsificato, sia in superficie che in profondità, stante la presenza di un notevole spessore di calcari massivi puri giurassici della Formazione Antalo con ridotti spessori di intercalazioni marnose.

Nell'area vengono individuate 14 cavità, 6 delle quali, di seguito descritte, vengono esplorate e rilevate.

Pozzo Kilibesera (area di Haro Gurati)

Si raggiunge il fondo del pozzo, a quota 1615 m, discendendo prima il blando pendio di una dolina, fra una fitta vegetazione, fino all'ingresso di una forra, mediamente larga sui 2 m, impostata su una frattura N 226, e un successivo pozzetto profondo 5 m. La parte terminale del crepaccio, dopo

un ulteriore dislivello di circa 2 m, si restringe infine con un condotto largo circa 40 cm chiuso da un sifone.

Nel corso dell'esplorazione condotta nel febbraio del 2005 il tentativo di provare ad immergersi nel condotto abortisce sul nascere per la presenza di un piccolo nero serpente sulla parete in prossimità dell'acqua, molto probabilmente velenoso stando a quanto ci viene riferito dalle nostre guide locali.

Grotta Shimbiwochi (area di Haro Gurati)

La cavità, chiamata Shimbiwochi, a quota 1602 m, a circa 500 m in direzione SSO dal pozzo carsico Kilibesera, si sviluppa allo stesso modo su frattura NE ma chiude dopo circa 30 m con un basso sifone allagato. Sulle pareti, si osservano diversi fossili quali echinidi e coralli e alcuni piccoli geodi riempiti da cristalli di calcite.

Sistema carsico Garayati - Eyefeyte (Ejersa river)

Il sistema carsico Garayati - Eyefeyte, in località Neno nel bacino del fiume Ejersa, risulta costituito da due cavità: la Garayati con ingresso a quota 1461 m e la Eyefeyte a quota 1490 m e ubicata a circa 100 m a SE dalla precedente. La Garayati è una cavità-sorgente emittente anche nei periodi secchi, mentre la Eyefeyte, risulta eruttare un cospicuo volume d'acqua solo nel corso della stagione piovosa dei monsoni, stante a quanto riferito dai locali peraltro suffragato dalle accentuate forme di erosione concentrata osservabili lungo i fianchi dell'incisione che dall'ingresso della cavità va a sfociare nel limitrofo alveo del fiume Ejersa.

Sebbene al momento non è stato possibile collegare le due cavità a causa della presenza di un sifone, è molto probabile che il sistema idrocarso sia unico e costituito da un livello di base rappresentato dalla Garayati e da un livello superiore di massima escursione freatica costituito dalla Eyefeyte.

Morfostrutture della Grotta Eyefeyte

Il grande ingresso della cavità è ubicato sul versante sinistro del fiume Ejersa a quota 1490 slm all'inizio di un breve canalone. Risaliti il primo terrazzo del grande ingresso, sulla parete destra si nota una precaria impalcatura, costruita con alcuni tronchi di alberi legati assieme con liame, che raggiunge una cengia impostata su una frattura. Tale struttura precaria viene utilizzata dai locali per raccogliere il miele depositato dalle api nelle parti dell'antro.

Superato il grande ingresso, ci si immette sulla destra in un basso condotto che dopo pochi metri conduce in una dolina di crollo aperta all'esterno per il crollo della volta. Superata la dolina, la cavità riprende nuovamente con una nera pozza d'acqua alimentata dallo stillicidio di guano proveniente dalla volta ricoperta quasi interamente da una colonia di grandi pipistrelli. In questo settore l'atmosfera è fortemente permeata da un intenso odore di ammoniaca prodotta dal guano. Si baipassa la pozza risalendo sulla sinistra un ripido pendio, cosparsa e reso scivoloso dal guano, e proseguendo dopo attraverso un basso e stretto budello. Superata la strettoia la cavità si allarga e si apre nel settore destro con una cengia che si affaccia a monte sulla nera pozza di guano, mentre sulla sinistra si addentra con una grande galleria. Nel terrazzo soprastante la pozza una seconda impalcatura con tronchi di alberi è presente eretta per gli stessi scopi della precedente.

Percorrendo la grande galleria si osservano morfologie generatesi sia lungo giunti di strato sia su fratture orientate N 170. La presenza di strati calcareo-marnosi, nell'ambito della formazione giurassica calcareo-dolomitica, si evidenzia nelle parti alte della volta con piatte morfologie a domo allungate nella direzione della frattura. A circa metà percorso è

presente un primo complesso di depositi calcitici, stalagmiti e colonne, a tratti corrosi probabilmente dai gas acidi generati dal guano, cui fa seguito un secondo complesso più imponente in cui spicca una caratteristica formazione stalagmitica a forma di cammello.

La cavità dopo circa 300 metri si arresta apparentemente in corrispondenza di un piccolo laghetto che con molta probabilità nasconde un sifone.

Morfostrutture della Grotta Garayati

La cavità attraverso un basso ingresso, a quota 1461 m, emette un ruscello perenne con una portata di pochi litri al secondo nella stagione secca. Nel complesso risulta svilupparsi per circa 500 m su un'unica galleria ad andamento meandriforme, impostata prevalentemente su due sistemi di frattura principali NS e N 250 e secondariamente con tratti su interstrato. La presenza dell'acqua è costante lungo tutta la cavità con profondità media su 1,5 m con morfologie delle sezioni mediamente strette a forra che si allargano nei punti di intersezione fra due sistemi di frattura a formare dei piccoli laghetti. In alcuni tratti, la parte superiore delle gallerie appare a sezione rettangolare piatta allargata lateralmente in corrispondenza di livelli carbonatico-marnosi poco carsificati e erosi meccanicamente dalle acque.

La galleria nella parte terminale, superato un basso laminatoio quasi del tutto allagato, si allarga a formare una sala con un tratto che risale sulla destra ostruito dopo una decina di metri da depositi e una galleria sullo stesso asse della precedente da cui sopraggiunge il ruscello. Proseguendo da quest'ultima, dopo circa 50 m, la galleria chiude frontalmente con un camino posto a circa 2 m di altezza dal pavimento, da cui si precipita una piccola cascata. Risalito il camino alto circa 3 m, parzialmente ostruito da alcuni grossi tronchi nella parte superiore, la cavità sembra proseguire con un piccolo condotto quasi completamente occupato dall'acqua.

La parziale rimozione di alcuni dei grossi rami incastrati nella parte superiore del tratto ascendente del camino, fa aumentare la portata della cascata prima parzialmente arginata.

Sistema carsico Rukiesa - Burka (Mechara river)

Il suddetto sistema carsico è costituito dalla grotta Rukiesa con ingresso, a quota 1618 m, nel settore destro del bacino del fiume Mechara, dalla cavità - sorgente Burka, a quota 1515 m con scaturigine su una falesia carbonatica, a pochi metri dal greto del fiume, e da una cavità verticale, denominata Grotta Bunakerabbasi, distante dalla sorgente circa 500 m, a quota 1618 m, in direzione ESE da quest'ultima. Per quanto concerne queste due ultime cavità, sebbene non si hanno ancora evidenze esplorative della loro appartenenza al sistema Rukiesa, considerazioni di natura idrogeologica fanno ritenere molto probabile che il sistema sia lo stesso e che la grotta sorgente Burka costituisca il punto di emergenza del corso d'acqua sotterraneo della grotta Rukiesa.

Morfostrutture della Grotta Rukiesa

La cavità, ubicata a 7 km dal villaggio di Mechara in direzione ENE, si raggiunge dopo circa un'ora e mezzo di cammino percorrendo un sentiero, non sempre ben definito, che costeggia la sommità del versante destro della valle del fiume Mechara. Dal paese dopo aver raggiunto il fiume, il sentiero costeggia delle suggestive gole, incise al passaggio delle arenarie carbonatiche con i calcari della Formazione Antalo, quindi risale e discende più volte il versante prima di raggiungere la cavità. Si accede alla grotta Rukiesa, a quota 1618 m, attraverso un'angusta apertura ubicata sul fondo di una depressione di forma subellittica allungata in corrispondenza di una struttura tettonica. Dall'ingresso, disceso un salto di circa 2 m, si entra in

un grande salone con morfologie sia di crollo sia di riempimenti calcitici sulle pareti. Da quest'ultimo, nella parte terminale sinistra attraverso un condotto si scende in un primo livello inferiore dove la presenza di un persistente stillicidio e di vasche piene d'acqua evidenziano come la prima parte della cavità in occasione di piogge funga da grosso punto assorbente verso i livelli inferiori. Su questo secondo livello risalendo il settore destro si percorre una galleria-laminatoio che viene parzialmente esplorata per la presenza di acqua, mentre discendendo sulla sinistra e dopo aver attraversato uno stretto e basso condotto si raggiunge l'orlo di un pozzo di circa 30 m che conduce al terzo livello inferiore del sistema. Quest'ultimo risulta costituito da un grande ambiente iniziale interessato sia da fenomeni di crollo sia da depositi calcitici sulle pareti e sul pavimento di vario tipo. In questo settore un consistente e diffuso stillicidio interessa ampie aree creando diverse vasche piene di acqua. Dal salone, discendendo il settore sinistro, fra grandi massi di crollo cementati l'un l'altro, si diparte una galleria interessata dalla presenza di un corso d'acqua che prosegue in direzione NE. L'andamento della galleria, impostata su frattura, presenta brevi tratti impostati su discontinuità secondarie orientate NO e altri ad andamento meandriforme con evidenti morfologie freatiche sviluppatesi lungo la discontinuità generatrice. Il corso d'acqua, contornato lateralmente da depositi sabbioso-argillosi, a tratti scompare al di sotto di blocchi di frana. Proseguendo lungo la galleria si supera una prima frana risalendo sulla sinistra un ripido versante fangoso-sabbioso e riscendendo nuovamente, poco dopo, attraverso aperture fra i blocchi rocciosi fino a riprendere il corso d'acqua. Si procede, quindi, lungo quest'ultimo fino ad una seconda frana che ostruisce fino al soffitto la galleria. Da uno stretto passaggio fra clasti, in parte cementati, si attraversa la frana fino a ritrovare nuovamente il corso d'acqua costretto questa volta in uno stretto condotto parzialmente allagato. Da quest'ultimo si diparte una galleria-laminatoio in direzione NE fino ad arrivare in prossimità di un pozzo di circa 5 m, da cui si precipita il corso d'acqua a formare una piccola cascata. Al di sotto del pozzetto la galleria prosegue ancora, con una sezione a forra occupata sul fondo dall'acqua. Quest'ultima promettente galleria, lungo la quale prosegue il corso d'acqua, sarà l'oggetto delle future esplorazioni del CIRS indirizzate a raggiungere il punto di emergenza idrico del sistema carsico che si ipotizza corrispondere con la sorgente Burka, di seguito descritta, distante in linea d'aria circa 1,5 km dalla anzidetta galleria.

Ritornando nel salone sottostante il pozzo da 30 m e risalendo in arrampicata nel settore sinistro una parete di circa 3 m si raggiunge un ripiano che discende rapidamente con un fangoso pendio lambito da un piccolo laghetto. Da quest'ultimo si diparte in direzione NE uno stretto meandro con acqua che viene parzialmente percorso e rilevato per circa 50 m prima di interromperne l'esplorazione per problemi di sicurezza legati al possibile verificarsi di piene improvvise.

Altri ambienti del sistema sono presenti nel settore antecedente il secondo livello ubicati al di sotto del salone iniziale con evidenti morfogenesi da frana.

Morfostrutture Grotta - sorgente Burka / Grotta Bunakerabbasi

La sorgente Burka scaturisce a quota 1515 m tra massi sul versante a circa 5 m dal livello del greto fluviale creando una piccola cascata e un sottostante laghetto perenne anche nei periodi di secca. Sebbene la scaturigine delle acque non sia visibile, risalendo il versante di alcuni metri si può accedere ad un livello superiore del sistema di alimentazione attraverso uno stretto budello su frattura. Il condotto si sviluppa per circa 80 m in modo particolarmente stretto e tortuoso prima di sfociare in corrispondenza di una galleria completamente allagata.

A circa 500 m in direzione ESE dalla sorgente ad una quota di 1618 m è presente una seconda cavità verticale denominata Bunakerabbasi che si ipotizza collegarsi con il livello delle gallerie che alimentano la sorgente Burka.

La cavità, raggiunta dopo circa mezzora di cammino da Haro Gurati, si presenta con una iniziale depressione di 2 m di dislivello, allungata su una frattura N 50, sul cui fondo si diparte un condotto carsico che dopo pochi metri si affaccia su un pozzo di circa 20 m, quest'ultimo ugualmente impostato sulla anzidetta direttrice strutturale.

L'esplorazione della galleria allagata della Grotta-sorgente Burka e del pozzo della Grotta Bunakerabbasi saranno oggetto, così come anzidetto per la Grotta Rukiesa, delle future ricerche programmate dal CIRS nel 2006.

Conclusioni

I risultati delle prime fasi di ricerca realizzate nel 2003 e 2005 dal CIRS in Etiopia hanno evidenziato la presenza in alcune aree carbonatiche di fenomenologie carsiche di notevole interesse per ciò che concerne sia gli aspetti esplorativi sia gli aspetti geomorfologici, idrogeologici e biospeleologici.

L'area di particolare interesse su cui si sono indirizzate le ricerche è stata il Distretto di Mechara dove la presenza di calcari particolarmente puri della Formazione Antalo di età giurassica ha consentito la formazione di sistemi carsici attivi con discrete potenzialità di sviluppo e caratterizzate da particolari morfogenesi.

Nel corso delle ricognizioni numerose sono state le cavità individuate che saranno oggetto di future esplorazioni in aggiunta al completamento delle ricerche avviate nei sistemi Ganayati - Eyefeyte nel bacino del fiume Ejersa e Rukiesa - Burka nel bacino del fiume Mechara.

Nel primo sistema carsico, costituito da una grande galleria di circa 300 m (Eyefeyte) con un sifone terminale e da una cavità percorsa da un ruscello per circa 500 m (Ganayati) fino ad un condotto parzialmente allagato, gli sforzi esplorativi saranno indirizzati sulla possibilità di attraversare quest'ultimo condotto in condizioni di sicurezza per ciò che concerne il pericolo di piene improvvise.

Più problematica appare la prosecuzione delle ricerche nel sistema carsico Rukiesa-Burka, esplorato e rilevato al momento per 1,1 km, in considerazione del pericolo costituito sia dalle piene verificatesi nel corso delle prime esplorazioni del 2003, sia dalla inaspettata presenza di alti tenori di CO₂ nella galleria del fiume nel corso delle esplorazioni condotte nel 2005. Al riguardo, si è sfiorata per poco la tragedia stante lo stato avanzato di malessere che aveva colpito tutto il team in un settore della cavità distante dall'uscita e con pozzi e strettoie ancora da superare.

Le esplorazioni future di questo sistema dovranno, pertanto essere condotte, nel settore a monte con l'adozione di sistemi di rilevazione di CO₂ che consentano di stabilire la possibilità o meno di una progressione in condizioni di sicurezza, mentre nel settore a valle nel corso della stagione secca onde evitare il pericolo di piene nella galleria allagata della sorgente Burka, individuata dopo circa 80 m di strettissimo condotto. Al riguardo, un probabile punto di bypass del sistema allagato potrebbe scaturire dalla futura esplorazione del soprastante pozzo Bunakerabbasi, distante solo 500 m dalla sorgente Burka, la cui esplorazione è stata impedita nel 2005 dalla aggressiva opposizione manifestata dai locali del vicino villaggio.

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W-9

New speleological developments in Africa and the Middle East

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Abstract

Since the previous International Congress of Speleology (13th ICS, Brasilia, 2001), several major speleological developments - on the national as well as the international level - took place in Africa and the Middle East. This contribution summarizes some of these events and discusses their impact on the national and international realms. One of the major events occurred in Lebanon, a few months before the 13th ICS, where the first international symposium on the speleology of the Middle East took place grouping more than 200 local participants and about 35 eminent speleologists from the Middle East and almost all continents. 38 oral presentations discussed various speleological issues related to Lebanon, Syria, Egypt, Tunisia, Saudi Arabia, Turkey and Iran. This event forged rewarding ties between the Spéléo-Club du Liban and the Saudi Geological Survey, which have led to a joint training campaign in Lebanon (summer 2002). The Saudi Geological Survey has been caving and exploring new caves in Saudi Arabia and breath-taking discoveries were published. Meanwhile, Tunisia adhered back to the UIS through efforts from Belgian cavers and local Tunisian cavers - who were enjoying perfect international collaboration. This was officially settled during the UIS Bureau meeting in Samcheok (Korea) in July 2002. In 2001, Michael Laumanns (Berliner

Hohlenkundliche Berichte) published a compilation of the international speleological expeditions to Tanzania (between 1994 and 2000). This was followed by the "Atlas of the Great Caves and the Karst of Africa" in 2002 - also by Michael Laumanns. The same group made momentous discoveries in Iran and coined a perfect international collaboration. Contacts with Pakistan were launched and a request by the national Pakistani climbing and speleological organization was transferred to the UIS Bureau during the latter's annual meeting in Hanoi (September, 2004) to get Pakistan as a country member of the UIS. Africa, and namely Kenya were also the subject of international expeditions, recently (cf. Michael Laumanns). On a UIS initiative and through the efforts of cavers from about 11 countries (Belgium, France, Germany, Hungary, Japan, Lebanon, Poland, Spain, Tanzania, Tunisia, U.K.) an international expedition devoted to support a newly established national organization for speleology in Tanzania (Tanzania National Speleological Trust) was succeeded (December 2004 - January 2005). Results of this expedition may set the example for future international collaborative expeditions. Finally, future caving projects will be discussed namely the upcoming 2nd International Symposium on the Middle East Speleology (April, 2006) in Lebanon.

W-10**Speleological Notes on Afqa Cave, Syria**

M. Metni, I. Bou Jawdeh

*Speleo Club du Liban, Antelias, Lebanon***Abstract**

This paper presents the results of the speleological investigation conducted by the Spéléo Club du Liban (SCL) in the Afqa Cave in Palmyra, Syria on April 24-25, 2004. The Speleo Club du Liban was requested by the Directorate General of Irrigation for Steppe Basin in Syria to study the cave. SCL was also requested to find means to restore the hot mineralized water baths that used to exist inside the cave prior to drying out

of the spring. The cave used to be an important touristic attraction in the city where tourists enjoyed bathing in its water renowned for its medicinal benefits. In addition to mapping the cave and identifying previously unreported gypsum speleothems growing rapidly in the altered cave environment, SCL assessed and presented a solution for restoring the baths. Means to promote tourism and education on the cave environment were also provided

W-11**Speleological exploration of Hoher Göll massif (Northern Calcareous Alps, Austria)**

Z. Rysiecki, K. Najdek

*Wielkopolski Klub Taternictwa Jaskiniowego (Poznań Caving Club), Poznań, Poland***Abstract**

Hoher Göll massif is situated 20 km to the south from Salzburg. This massif is an east-west elongated crest, 11 km long and 3 km wide. The highest peak - Hoher Göll reaches 2522 m a.s.l. The surrounding valleys lie at altitude of c. 500 m. The deepest and the longest caves are: Hochschartehöhlsystem (1033 m of depth, 7 km of length), Grubernhornhöhle (854 m of depth, 9 km of length) and Jubiläumschacht (1173 m of depth, 2 km of length). The Hoher Göll as a part of the Northern Calcareous Alps consists of a sedimentary succession ranging from Late Carboniferous to Eocene times. Hoher Göll massif is built of Dachstein limestones of the upper Triassic, which are 2-3 km thick. There until 1960 only twenty caves were explored. At the beginning of the 60's a group of cavers from Salzburg, led by Walter Klappacher, began to explore the Grubernhorn area. Hoher Göll massif has been explored by Polish cavers since 1969, which played a major role in the exploration of the eastern part of the massif. During this time Polish and Austrian cavers discovered 30 caves. At

that time the Grubernhornhöhle was fourth on the list of the world's deepest caves (856 m of denivelation). In the 70's Polish cavers discovered 15 caves, including Jubiläumschacht and Monhöhle. Our group organized by Katowicki Klub Speleologiczny (Katowice Speleological Club) is including cavers from Poznań, Katowice, Ruda Śląska and Kraków, has been exploring this massif from 1990 to 1999. Since 2000 expeditions to Hoher Göll massif are organized by Wielkopolski Klub Taternictwa Jaskiniowego (Poznań Caving Club). We have discovered 121 caves of total length of 32 km. In 2001 the most important success of this exploration is a discovery of connection between two big caves: Kammerschartenhöhle and Höhle Der Sprechenden Steine, which formed a great Hochschartehöhlsystem (-1033 m of depth). Last year the Schartenschacht Cave was explored to -924 m. This year it is possible to explore this cave to a depth over -1000 m (it could be third cave in Hoher Göll massif which is deeper than 1000 m). Otherwise every year during summer the exploration is provided in all parts of this massif and we have discovered a lot of caves.

W-12**Report on Multiyear Project to Map and Photograph Caves for the Belize Institute of Archaeology**

D. Larson, E. Burns Larson, B. Pease, W. Hunt

Abstract

In February and March of 2005, NSS cavers from the US and Canada, an informal group named XMET (Xibalba Mapping and Exploration Team) made their sixth annual trip to survey caves in Belize under the auspices of the Belize Institute of Archaeology. The Maya made extensive use of the caves during the height of their civilization and many of the caves contain cultural material. Over the course of the project, the cavers of XMET have mapped eight km of passageway in Barton Creek

Cave, have done dye tracing to find the source of the water in Barton Creek Cave, have mapped and are in the process of mapping eight other, smaller, caves. Cave divers have penetrated sumps at the back of several of the caves and have extended the surveyed length more than a thousand meters. The caves of Belize have beautiful large rooms, which XMET has photographed while surveying them. In 2005, XMET received permission to visit the Chiquibul System to photograph the second largest room in Central America, the Chiquibul Chamber in Actun Kabal. XMET will return to Belize to continue the project in February, 2006.

W-13

New information on the plutonic and tectonic prerequisites on the genesis of "Arjer" Cave

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Abstract

In 1977-2004 in the "Arjer" cave worked the expeditions of the Academy of Sciences of Armenia, the Geographical Association, Speleologists of Ukraine and the Armenian Speleological Center. Balyan, Vanyan, Klimchouk, Doublyanski, Shahinyan and Haroutyunyan came up with scientific reports.

After rather serious examinations and on the basis of certain materials Dublyanski found that it's a hydrothermal karst.

The new data collected by the ASC in 2001-2004 not only confirms Dublyanski's and Klimchouk's viewpoints, but also finds that it originated and developed not only under the influence of till 100°C hydrotherms, but under the influence of even higher, up to 800-900°C hydrotherms and fumaroles.

The large number of calcites, aragonites, Icelandic ...shpar... consequences of low and high temperature, the thick stream sediments on the ceilings, walls and the floor confirm the hypothesis of hydrothermal origin. But the recently discovered $S:O_2$ till 30cm crystal druzes, which was in a relevantly chlorised camera of 2m diameter, evidences that during speleogenesis here has been high tension and high temperature. Similar druzes were found in the same karst area, near Mozrov village, 4 km from "Arjer".

In this area of monolith $CaCO_3$, numerous signs of Fe, Mg, Mn have been discovered. For the ceiling of the cave to bear all the high tension, it had to be very thick. But we know that the ceiling of "Arjer" doesn't have a powerful ceiling. This allows us to form a hypothesis that the karst area of Vayk, where the biggest caves of Armenia are situated - Arjer, Magil, Mozrov, Karmir, Cyclope, Anahit, etc, should have been covered with a thicker geological layer, which was missing. From this we conclude that Arjer and the other caves originated during the last ice-covering or the last two ice-coverings - during Vyurm and Ris. As that hypothetical geological layer, which prevented the cave ceilings from bursting under the high tensions was nothing less than a powerful ice-layer of several tens of meters long.

This hypothesis allows to explain why in this zone, with no water reservoir and with an arid climate, there has been so much water as to dig denudate and suffusive tunnels up to 2.5-2.8 m diameter in the mentioned caves and in different places.

All those who are acquainted with the geology of Armenian Highland will agree with that here everything is difficult and complicated to such an extent that the implementation of a scientific examination, basing only on some facts and details is impossible, just like a general picture can't be formed and one will easily blunder.

That's why any new scientific version or theory is usually subjected to the severest criticism, or creates favorable grounds for endless debates.

The version I would like to bring to your attention now is a result of scientific quest of long years and is based on the data obtained by our scientists during laboratory works.

"Arjeri" cave is in Yeghegnadzor region of Vayots Dzor Marz. It is situated in the depth of karst limestone massifs between rivers Gravi and Jerovani. The region is characterized by dry continental climate, the annual precipitation making no more than 600mm. All the caves we revealed and examined in Yeghegnadzor karst massif are dry, without lakes. The karst-forming processes are stopped or are missing.

The development of geological constructions and structures of the area were greatly influenced by tectonic and plutonic processes, that in N-Q periods functioned more actively, modifying and reconstructing the whole geological complex.

This is evidenced by the tracheandesiological lava cover pumice-ash sediments and tuff andesit composition in neogen species. The thickness of these species at places reaches 300 meters. The Quarternary lava in Yeghegnadzor region and in Vayots Dzor Marz according to A.G. Aslanyan (1958) fall into three types: low - middle - upperquaternary. To the low quarternary lavas belong streams of light-gray andesites of upper stream lavas of Yeghegis and Arpa rivers. To the middle quarternary group belongs the Gyuludus stream of olivin-pyroxilic andesit-basalt, that stretches till Jermuk. The upper quaternary lava streams cover the territory with a thick (till 60m) layer, starting from Yeghegnadzor till Vayk. The main lava mass has flown to the side of river Arpa, the volcanic and tectonic processes still very active rather recently (of course according to geological conceptions). As a result of a strong earthquake in 735 the city of Moz was destroyed, leaving under its ruins 10 000 inhabitants. Historians confirm that from the mount Vayotsar volcanic cone crater erupted smoke and ash. The presence of numerous hydrothermal and mineral sources in the region once again evidence that the plutonic activity won't be extinguished in the entrails. In Jermuk the mineral waters in springs have the temperature of 80°C.

In the Gravi gorge the expedition of Armenian Geographic Society and the Speleological Center in 1989 have discovered mineral formations that could only originate in case of high temperature and tension. We have discovered monocrystals and druzes SO_2 , high-temperature aragonites, Icelandic spars (width 35cm, extension 20, 40, 50, 60m) in the caves Arjeri, Karmir, Anahit, Cyclope, as well as in the old and ruined paleokarst caves.

Myself, I have no doubts on the Gravi gorge being a series of ruined paleocaves (for example Tskhaltub tunnels). Here too, among clear carbonate, karst species we have discovered crystals SO_2 30cm-55cm long. For such formations an environment of high temperature and tension is necessary. But the caves situated in the width of carbonate karst species do not have thick covers, thus the cover of Arjeri is maximum 20-30m, Morz no more than 10m, Anahit - 18m. Then a question arises: how come the cover did not ruin in the presence of such tension? why $CaCO_3$ did not undergo metamorphosis? how come no ore pockets were formed common to the plains on the way to mineralized hydrotherms?

The given version for explaining the karstogenesis and the processes, which according to geological measures took place at the end of neogen and at the beginning of quaternary, could be the freezing Ris-Vyurm.

The ice-cover 100-200m thick put pressure on the earth's crust with the weight 200 tones per meter. In the places where tectonic trenches are developed, the breakings and the depth distortions, that is the lithosphere was in a static state but easily distortable because of stratigraphic tension and fragments the misbalanced and provoked processes started to influence with whole of its might. Warm gases and hydrotherms started going up by tectonic trenches to the upper layers and came out, on the ice.

Under the cover there formed lakes and not large water basins. Water in these waterfalls is rich of active chemical compositions, for which it has acquired big carotene quality. In case of activation of the warm stream from the plutonic inculcation the melting of glaciers became faster, because of which great amounts of water formed, which by the already opened ways speedily moved by the massifs, forming "water-pipes" of 1,0-1,8m diameter with very well polished walls.

Thus summing up the above-said, the conclusion is the following:

1. The previous karst massifs are situated on a same absolute height, as the traces of freezing in Gegharkunik and Sisian, as well as in the northern slope of Aragats.

2. In the karst regions traces of huge karsts were discovered. The existence of huge water-reservoirs was supposed, but it appeared that they do not exist.

3. Up to our days have preserved caves with hydrodynamic "pipes" (diameter 1,5-3m) and tunnels with ruined roofs (e.g. Arjeri, Magil, Karmir, etc.).

4. The formation of Magili cave (1,9km) in the conglomerates without active and formational processes of dynamic water would be impossible.

With such arguments and taking into account the fact that there are minerals in the caves that could originate only in active chemical warm water solutions (originated from intrusion) or from penetration of hydrotherms, we may bring up the following hydrotherms about the formation of karst caves in Vayk.

The limestone massifs were covered with ice. The hydrotherms went up to the surface from tectonic breaking because of depth intrusions. As a consequence of thermobalance destortion melting began under the ice. Melting dissolved with chemical compounding (originated in hydrotherms) and became very active. Carthogen processes started, spilling into tectonic breakings.

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W-14

Activities of Czech and Slovak cavers in Riviera Maya, Mexico

Zdenek Motycka

Czech Speleological Society

Several expeditions of Czech and Slovak Speleological Society to the Mexican semiisland Yucatan were proceeded in last two years in cooperation with UNAM - The Mexican National University and QRSS - Quintana Roo Speleological Survey. The area of the activities of expeditions is known as a Riviera Maya. Besides as a result of geological and climatic conditions it is a unique area with large underwater cave systems.

The expeditions worked in the surroundings of the towns Tulum and Chemuil. First exploration brought discovery of new passages in cenote Cangrejo, where total 1328m has been discovered and documented up to now. The most important discovery was in cenote Joolis. The entrance was found in 2002 and 167m of corridors have been known. During first exploration another 180m long continuation was discovered and surveid. The following dives brought the discovery of huge, several hundred meter long tunnel "Esperanza." Within the first week more than 1000m of new corridors were discovered, while the second week brought the discovery of a new cenote, called Tatch. Totally 2405m of new passages was discovered, documented and joined them with other 3 neighbour cenotes - Polo, Hoyt a Chu-much-cho. So the system long 3587m arose.

Later, two new cenotes were found, 600m far from the end of the known parts of Joolis and 200m far from the end of the another cave called Ich - Kin. In the first of them, called Nai-Bosch due to the black walls, huge tunnel 200m long was found. It leads directly to Ich-Kin. The second cenote brought a big surprise. Near the wall of the spread corridor old Mayan ceramic pot was found. Then the cavers discovered dry

cavern with the small island in the middle of lake with the ruins of the stone wall nearby and connected to the cave. All these discoveries were documented.

Also other cenote called Zebra was found. Huge tunnel 30m wide and 200 m long was found during first exploration. This tunnel leads to another big cenote. Tottaly 1819m was explored and documented.

Near Tulum new cenote Dos Locos was found, explored and surveid 493m of new passages there.

Totally 6860m of new corridors was discovered and surveid by Czech and Slovak cavers in Riviera Maya up to now.

The important part of the expeditions was also the soil taking and and catching up of the troglodytes animals for the research of UNAM.

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Fig.1 The cenote Nai Bosh, Riviera Maya, Mexico. Photo by: Radek Husak



Fig. 2 Old, Mayan ceramic pot found in the cave Chac Ha, Riviera Maya, Mexico. Photo by: Radek Husak

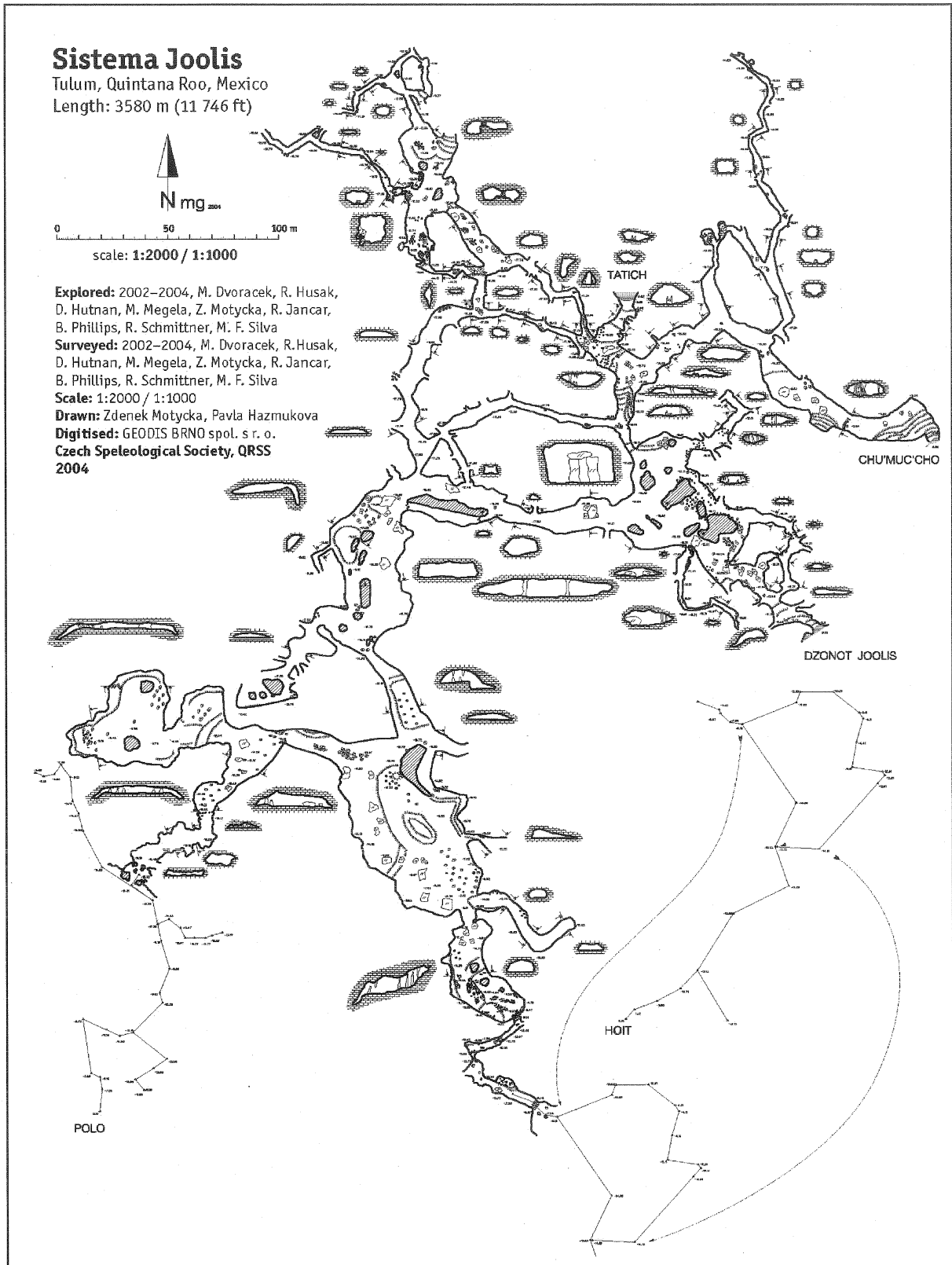


Fig. 3 Map of Sistema Joolis, Riviera Maya, Mexico

W-15

Chinese/American Cooperation in Cave Exploration and Survey in Water Resource Development, Da Long Dong, Hunan China

C. Groves, P. Kambesis, H. Shiyi, J. Zhongcheng, D. Groves

*Hoffman Environmental Research Institute, Western Kentucky University, Bowling Green, Kentucky USA, Institute of Karst Geology of China, Guilin, Guangxi, CHINA***Abstract**

During two trips in late 2003 and early 2004 collaborative teams from the Hoffman Environmental Research Institute and the Guilin Institute of Karst Geology of China did reconnaissance and karst water resource assessment work in the Xiangxi area, a remote section of the Guizhou Plateau in northwest Hunan Province. The Da Long Dong (Big Dragon Cave) system, which drains this section of the plateau, resurges into the Xiangxi river via a 260 meter waterfall. Sumped passages at the upstream end of the cave system were explored and mapped using cave diving techniques. The recharge area for this cave system encompasses 200 km² of plateau top tower karst. A number of fault controlled shafts and caves located on top of the plateau were explored and mapped. High water, geology and local culture/language added extra challenges to the exploration and survey work conducted in the area. The main objectives of work included 1) exploring the unknown sections of the underground river beyond the upstream sump (water-filled passages) in Da Long Dong, specifically the area beyond the first sump in Da Long Dong and the underwater sections between Da Long Dong and Leigong Dong (Thundering Cave) and 2) exploring and documenting the series of shafts and caves on the plateau above Da Long Dong to determine if they are associated with the cave

system and the Da Long Dong underground river. Both of these objectives were in support of determining the feasibility of, and aid planning for, the construction of an underground/surface reservoir that if successful may provide much more accessible drinking water to thousands of poor Miao Minority Nationality residents on the plateau. Overall the team was successful in meeting the objectives of the study given the constraints of time and planning upon the caving teams. During the original planning in December 2003 it was made clear that, due to the difficulty of logistics, a full-scale, successful, cave surveying and diving expedition would require enough time for planning to occur during the next dry season after the end of the 2004 Asian Summer Monsoon (ASM). However, due to the requirement on the Chinese side to complete all surveying before the onset of the 2004 ASM (expected in April), we completed arrangements and with considerable difficulty went forward with the expedition as soon as was possible. The resulting difficulty was primarily that the monsoon rains began while the expedition was in the field, making the cave diving, in particular, more difficult and dangerous, and potentially precluding the opportunity to connect plateau shafts to the river because of higher water levels

W-16

Cave complex Samsar

Gagik H. Pogosyan

692

Location

The described place is in territory of today's Republic of Georgia in area Samckhe-Javakheti, in area Akhalkalak on northeast suburb of the Armenian village Big Samsar¹. It is situated on the right bank of rather shallow canyon with 2 km depth, west from Samsar² Mountain on Samsar mountain ridge³ of Javakhk Hills of Akhalkalak table-land. A river originating in springs lying in 1 km, on South-East of Big Samsar village flows on the gorge.

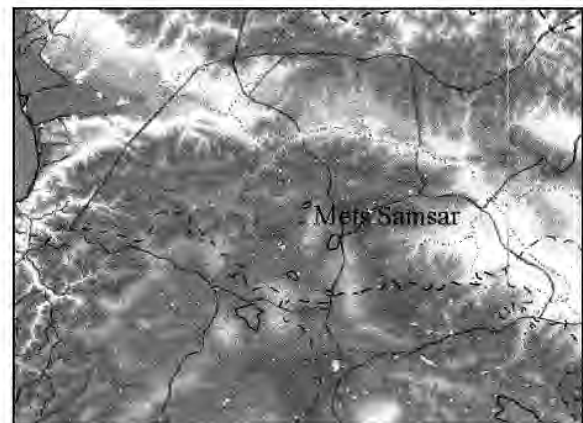
Investigations

The cave complex concerned is not a new found one.

As far back as in 1896 E.Lalayan in «Materials for further investigation» collection become to given Samsar complex [1, Материалы для дальнейших исследований, стр. 167-192, See Appendix 1]. Owing to its actuality the work has been republished [4, page. 80-83]. In this complex the attention of E.Lalayan was mainly attracted to the caves, which he has described in details. In separate paragraph named «An animal found in the caves of Samsar» was given the documentary description of events occurred in 1837 [1, page 171-172; 4, page. 82-83, See Appendix 2.

The next person investigated given complex was S.Karapetyan, who has prepared «The list of historical-architectural monuments of Akhal-

kalak region» in 1987 [6, page. 18, 19]. The investigator has dated the complex by 9-4 centuries. Later on the certain part of materials has found a place on web-page [11, Three photos of cave complex of Big Samsar village]. Research on Armenian Architecture Organization, when the complex is dated by 11-12 centuries.



¹ Big Samsar village is located at a height of 2034 m above sea level, position data: [41° 31' 60N; 43° 36' 0E].

² Samsar mountain is located in 2.5 km to North-North-East from Great Abul Mountain. Height - 3284 m.

³ The mountain ridge consists of igneous rock with prevalence of trachyte lava. Greatness is about 70 km North-East. The highest point is Great Abul volcanic mountain (3301 m). Consists of trachyte-andesite rocks. The slopes are covered with Alpine plants. [3, v.10, page 160].



Photo 1. The panorama of canyon.

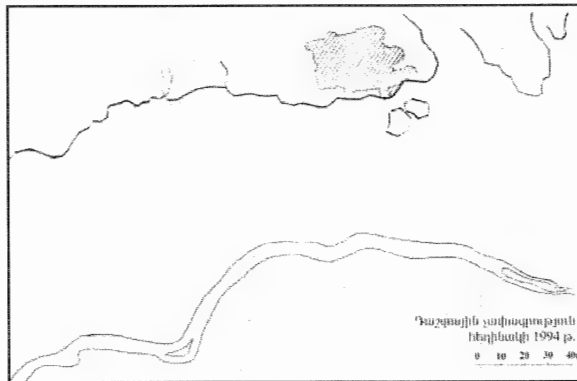


Chart 1. Situation plan of cave church.

Thanks to the next expedition organized by cultural organization "Khoran" in August, 1994 the complex has been investigation by the author. The objectives of the expeditions contained the investigation of cultural-historical heritage of Armenian people at the territory of Northern Javakhk, in this case - at the territory of Akhalkalak and part of Borzhomi regions of Georgia.

In 1996/97 the complex was investigated by N.Vakhishvili. As a result of which in 2002 the materials have been published in «Javakheti» volume of the guidebook publ. by Georgian Cultural Heritage Information Centre is a Non-Governmental Organisation (GCHIC), where the monument is dated by 10th century [10, page 28, #113].

Monument description

There are many monuments in the outskirts of Big Samsar village and inside the village. There are many caves burrowed in the rocks on the right of the ravine (see photo 1)⁴ go on the northeast outlying districts of the village. The largest one among them is the cave church.

Cave church

The cave church is located in 55 meters from the river (see chart 1) is three-nave rectangular in plan domical basilica with non-central construction (see chart 2). The bearings for supporting arches are two pares of square columns situated by the centre. By the dint of supporting arches the cupola leans on in-apsidal attached columns and eastern pare of columns.

⁴ All photos used are made by the author in 1994.



Photo 2. The interior of cave church.

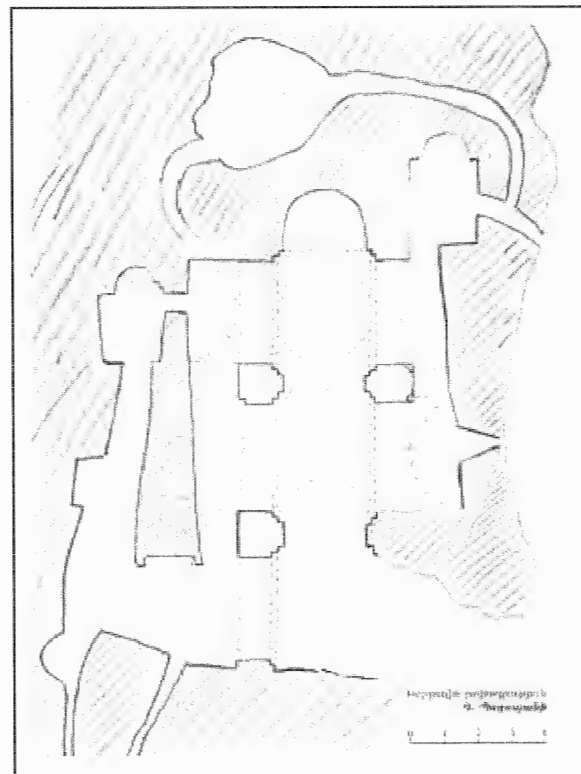


Chart 2. Field plan of cave church.

The altar is utterly ruinous, although on the perimeter of conch the traces of its remains are visible (see photo 2). The floor is fundamentally cov-



Photo 3. Entrance embrasure of cave church from south-west.

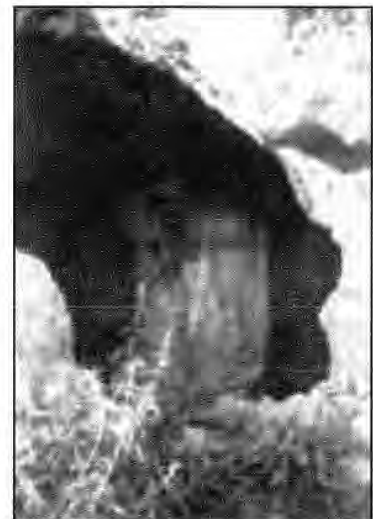


Photo 4. View on the damaged window of cave church from the south

ered with earth. The church has two skew side-altars. The right-side side-chapel is a logical extension of right hall, closer to side-altar entrance the height of the nave notably sinks. There is a passage communicating with surface in the southern wall of the side-chapel. The left-side side-altar has two entrances. The first entrance is in the northeast angle of the church. The second admission aperture is realized from long and convergent hall situated behind the northern wall of the main hall.

The embrasure of the entrance is located in southern-west angle of the church (see photo 3). The only window is hacked through in the southern wall between columns. The southern wall has many damages, including in the areas of window and entrance (see photo 4).

Artificial or anthropogenic caves and passages.

Many artificial caves, passages, and manholes surround the cave church.

As it has been already said above there is a passage communicating with surface in the southern side-altar. There is a manhole in it, which is nothing else but a secret passage that going a way roundabout the southern side-chapel amplifying leads to a large cave located immediately to the northeast from altar apse. From the northern-eastern part of the round cave on the height of 1,8 m the manhole continues. Making a turn to the church, but already having slope of 35-40°, the manhole goes up and sets against the dome, in which the crack existing opens magnificent vista to the church hall. The crack is rather narrow and so it is not visible from



the hall.

Second and third entrances are located in northern-western angle of the church. Both passages are equal by height and width - 50 x 50 cm approximately. One begins in one and a half meters from the west engaged column literally from the surface of the floor and extends upwards at angle of 30-35° during 12 m, going out in almost right-angled in its plan cave having window opening in the southern wall, from which the view to the canyon opens from 4 m height. The entrance to another manhole is situated in 2 meters to the north of the previous one and extends to the joint with the next cave.

There are many communicable passages, hollows and caves out of the cave church as well. Thus originating in the cave church three manholes joining with other caves create advanced anthropogenic cave complex.

Cells and chapel in rock debris

There are wreckage detached from the rock between the river and the cave complex. Cells and even one chapel have been gouged in them (see photos 5 and 6). It is obvious that this debris of the rocks had been detached before the creation of cave complex, because the entrance embrasure corresponds with the relief. Perhaps one of the rock's wreckage (see photos 7 and 8) lies on the side, which allows to state that it have been detached later than origin of complex. It contains cut out cavity with trace of candles, the location of which was failed to be determined.



Photo 5 and 6. Cells and chapel in rock debris.

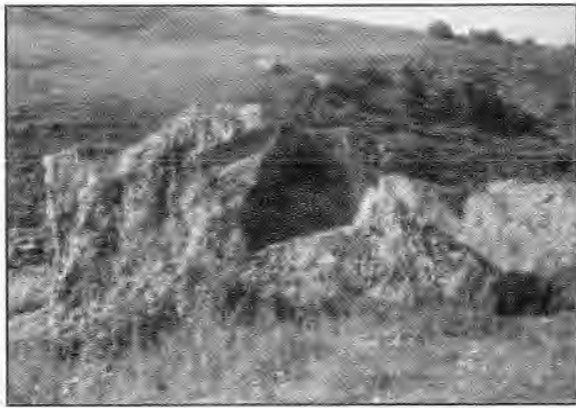


Photo 7 and 8. Other rock wreckage.

From the modern history of the village

The forefathers of present population of Big Samsar village settled down here during «Great Karin resettlement» in 1830⁵. Perhaps it is necessary note that there was a village in Western Armenia of the same name Samsar, which was located in Malatia, Yusni-Mansur (Adiaman) gavar⁶. The interpretation of «samsar» word is not quite clear⁷.

Before the middle of 1850s the village was called Tok (Ááú), later on - Tok Samsar (Ááú é³Úé³ñ). Since 1921 the village was named Big Samsar (Ø»Í é³Úé³ñ). The fact of similar name of the village even earlier in 1877 is notable. After the collaps of Soviet Union and till today the village begins to be called Didi Samsari (didi-samsari - Georg. lit. Big Samsar, which is metaphrase from Armenian language).

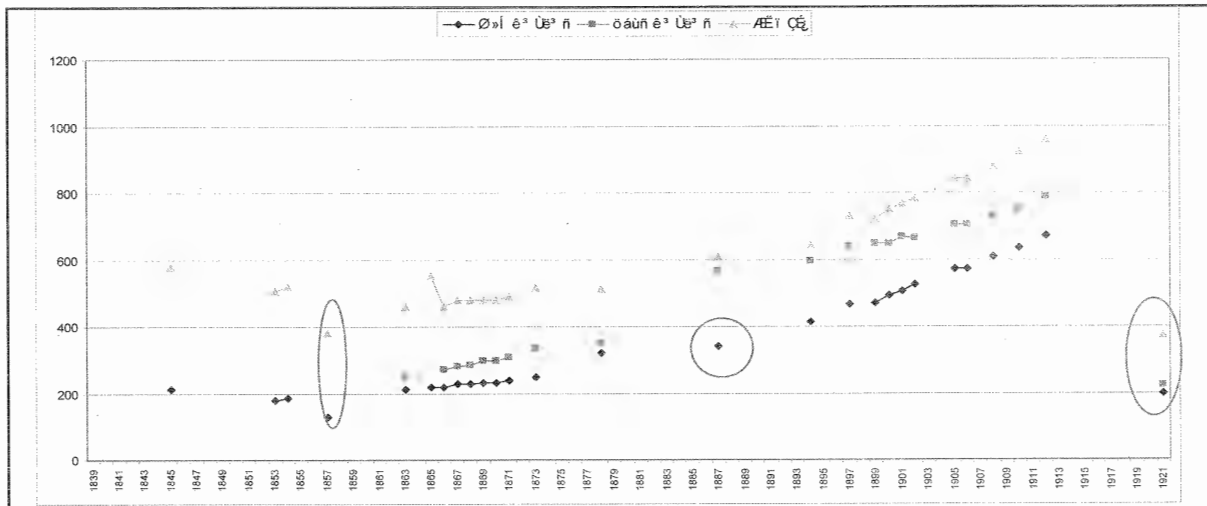


Table 1. The curve of population dynamics in Big Samsar, Small Samsar and Ikhtile villages⁸.

Three recessions are observed in the dynamics of the growth of village's population. (see table 1). The first slump was observed in 1853-57 and was conditioned by the rise of a new village in the neighbourhood. The matter concerns Ikhtile Samsar (ÆËÏÇÉŁ é³Úé³ñ), and later on Small Samsar⁹ (óáúñ é³Úé³ñ), 1/3 of the population of which (about 70 people)

has been resettled from Big Samsar village, and 2/3 (about 150 people) - from Ikhtile village¹⁰ (hence the name). The second slump was observed in 1887, caused by the second wave of immigration in near by village. The third slump concerned with the next intrusion of Turkish barbarians in 1918¹¹.

⁵ Village are occupied in agriculture and cattle breeding. There is secondary school acting in the village. [3, v. 7, p. 438].

⁶ Before the beginning of the First World War the village had 150 Armenian people (about 20 houses). The village were occupied in fields as proceeding of different sorts of cereal crops, cotton wool, and tobacco, gardening, cattle breeding and different arts. During the Great Genocide in 1915 the population of the village has been outcast. Most of them perished during transmigration. Few escaped have found shelter in different countries [3, v.10, p. 160].

⁷ SAR (šéʔò) - Arm. lit. MOUNTAIN). According to G.Acharyan - SAMSAR or SENSAL: «At the times of Rubenids - junior official raising taxes from the shops», from this - SAM-SRCHEK Karst, Jud. II 79, 234. [2, p.168]

⁸ The foundations are archive materials [5, 5.1-5.6; published in the second collection 7, appendix 8, ¶ ááÓáéÚ³Ý, é³Úé³ñÇ ì³ñÝÓ³²ÚÇÝ Ñ³Ú³ÉÇñ, p. 136].

⁹ Patara Samsari village (patara samsari - Georg. lit. Big Samsar, which is a metaphrase from Armenian language) is situated at a height of 2065 m above sea level, position data: [41° 32' 60N; 43° 36' 0E].

¹⁰ Ikhtile or Ekhtila village is situated at a height of 1736 m above sea level, position data: [41° 32' 60N; 43° 32' 60E].

¹¹ [9, 250. The Government of Armenian Akhalkalikian friendly association to the central council of associations Tiflis, 2 December 1918].

It is noteworthy that there was the lack of coincidence between numerical strength of the villages and their names.

Appendix 1

Samsars

...
There are weather-beaten rocks of black and white, big and small stones, lime and clay earth and sand at the two sides of the hollow.

In these weather-beaten rocks is dig majestic church, several chapels and great number of caves. The church situated on the right bank of the river in the hollow of Small Samsar is entirely dig out in the rock.

...
There is a quantity of caves in the whole hollow particularly in Big Samsar, they are mainly big and small underground caverns connected with each other by narrow and long passages that sometimes descend, sometimes go up little by little, and sometimes extend straight opening new passage in different sides. In general these passages have such size that a man can easily move bowing down, and here and there they are so high that one can go upright.

The caves, which most likely served as dwelling for people, are always higher than one sazhen¹², from 1 to 10 sazhens in length and 1-5 sazhens in width.

There are also caves, where stone cribs are built, shelves, stone stairs are dig in the rock, there are windows with stone lids in the rooms closer to the hollow. There are small holes in the window-sills.

Upon the whole all these passages and caves are very clean, the air is clean also, and there is water in one of the caves and it is clear and very cold.

Nowadays this spring crashes down in the canyon, thanks to richest village man and very hospitable Karapet Gdlyan it provides with water whole Big Samsar village.

Among these caves I have climbed into all significant ones. Worthy Ter-Makar, lively and interesting young man Ter-Harutyunyan, as well as several village men accompanied me from the village.

I think that it is enough to describe the direction of only one cave: called by people «Khach maghara»¹³ and located at the right bank of Big Samsar's ravine, just a little higher up from the spring.

We get in through small passage dig in the rock stone and climbing up by stone stairway 10 steps athwart, we entered spacious and lightly room. Village people have taken and used the lid of the passage.

The room is square, size 7 arshines¹⁴ and 1 sazhen in height, there is a window in the northern wall with 1,5 length and 1 arshine width that looks to the canyon. It is noticeably that the window has stone leaf. There is one hole in the windowsill. At the left of the window at a distance of 1 arshine there is a small hole and a sitting-place for one person. It has three doors.

In the eastern wall opens a door with $4 \frac{3}{4}$ arshines height, 1 arshine width, and $1 \frac{1}{4}$ arshine thickness, near which from the height of $\frac{3}{4}$ arshines a Christ is cut out. At the both sides ' and 1 letters are visible, and two small hollows below. Armenians from the village come here for worship

and light candles. Through this door we entered a room with the same size but with only 1 sazhen length and 2 arshines width, where in the northern wall oval window with 0,5 arshines length and a quarter of arshines width opens, and there is a hole for gun below. There is a stone storage here in the eastern wall, will 1,5 arshine length and 1 arshine width. In the southern wall a door with the same sizes opens, which leads us to a cavity with 1 sazhen length and half-sazhen width, the same height, where were no more passages. We returned to the room of Christ and entered in the passage in the western wall, which would be with 1 arshine height and $\frac{3}{4}$ arshine width. Squating we went 10 steps forward, the passage became a litter wider and higher, 10 steps more, and we went down in a square room with 1 sazhen depth and 8 arshines size, in which we have found human's and animals' bones. Perhaps they were not noted by same size. From here through one narrow passage they literally hanged over and dropped in the big room, more than 1 sazhen in height, 3 sazhens in length and 8 arshines in width. From this room for a long time we went by one narrow passage, one more passage went down, perhaps it was already collapsed, and we continued to go being bent, and finally have seen that the passage falling off was closed.

Through the same passage we returned to the cave with Christ again and entered a narrow passage leading from the southern wall, which was 1 arshine in height and 1 arshine in width. After 20 steps another passage opened in this passage, which led to northwest. We continued to go by the same passage, perhaps after about one hundred steps we had to turn back, because the passage was closed over the collapse. Accompanying village people said that several years ago they climbed into this passage and went very far. They stated that this passage extends to Merenia¹⁵ and jointed with the cave visible on the hill till now. At the return we climbed from this passage into the passage leading to northwest, which after long way opened in a room where was a reservoir. We returned, went out from this cave and climbed into other caverns. In Big Samsar there are 8 such remarkable caves.

Besides the church and numerous caves, two small mills gouged in one stone are noteworthy in Samsar, which are situated in the depression of Small Samsar, at the right bank of Kekhut river.

One of them is gouged in a stone with 4 sazhens width, 6 arshines length and 5 arshines height. On its side looking to the north a small door with 1,5 arshines height and 14 vershoks¹⁶ height is opened. It is visibly that there was a stone leaf inside. Whole gouged space in the stone has 3 arshines width, 4,5 arshines length and 3,5 arshines height. Near the door, 4 vershoks below the ceiling and 12 vershoks higher than floor a place with 0,5-1 arshines width and 2 arshines length spreads, which probably was the place where the miller was sleeping.

Close to him down to the floor a hollow for water drain is gouged with 1,5 arshines width, from another side a place for goods with one-and-half arshines width and 2 arshine length and the same height. The rest 2 arshines of length and width is the place for mill, from which no stone or other things remained, since village people took them away. There is a oviform window with 12 vershoks length and 0,5 arshines width at the southern side.

¹² Sazhen is an archaic long measure (was in use before adoption of metric system), first mentioned in Russian sources at the beginning of XI century. In 1835 by the decree Peter I the value of sazhen was equated to 7 English feet or 84 English inches, or 3 Russian arsheens. 1 sazhen is equal to 213,36 cm. [8]

¹³ Khach maghara (Քէ՛՛ա Մ՛՛ճիկ) - Arm. lit. «The cave of christ».

¹⁴ Arshin is an archaic long measure (was in use before adoption of metric system). In Russia was in use since XVI century (before was cubit). Initially was equal to 27 inches. In 1835 by the decree Peter I the value of arshine was equated to 28 English inches. 1 arshine is equal to 711,19 mm. [8]

¹⁵ Merenia village (Մերեն) is situated at a height of 1756 m above sea level, position data: [41° 32' 25N; 43° 33' 14E].

¹⁶ Vershok is an archaic long measure (was in use before adoption of metric system). A vershok was equal to the width of two fingers (middle finger and forefinger). In 1835 by the decree of Peter I the value of veshok was equated to 1/16 arshine or 1,75 inch. 1 vershok is equal to 4,44 cm. [8]

Appendix 2

Wild being found in the caves of Samsar

Present witnesses have settled in Big Samsar at the times of transmigration¹⁷. In 1837, when Samsar was covered with dense forest, today already an old man Nahapet found a wild man.

«Once in the night, - he told me, - with an axe on my shoulder I went to the mill, the mill which is higher than Khach maghar in Big Samsar canyon. Suddenly I heard some unknown sound and see a man of middle height, without beard and moustache, with small eyes, naked from head to foot, only belted by grass, with uncovered head, and something leathern is tied on the neck, is standing and whistling, knitting his brows. Slowly stepping up to him I wanted to stab him on the head with the axe, perhaps he attacked me and bitted in the shoulder so heavily that blood became to flow as from a spring. Gathering all my forces I delivered him such kind of blow that he tumbled down to the ground. Right away catching him by his leg I make myself heard to a friend miller Petros, with his help I dragged the savage up to the mill and hammered in the door behind him. The savage began to dash to different ways trying to break loose, but seeing that he cannot, uttered unintelligible: hm, hm, hm... began to show first to the ground, then to the sky. In the morning together with Petros properly hanging his hands and feet we guided him to the village. Two days he remained in the master's cattle-shed. They gave him bread and foot - he didn't eat, made a bed -he didn't lie down, he fingered grass thrown in front of caw and ate it. I walked up to him, unleashed and took away the leathern bandage from his neck; and he began to show to the sky and to beg until I didn't tie in on his neck again. On the third day firmly binding his hands with solid lashing gave him to four people to take him to Khrtviz¹⁸ (ĒĀñĀĀ½) - as a gift for the steward, I also went to change my

clothes and to get ready with them. Perhaps before I arrived the wild being vastly clamouring, in the way that the escorts were terrified, pulling break off the cordage and run away. Coming in time I dashed after the wild, he already runaway climbed into Khach maghara (cave). With my friends I came to the door and fired a gun. That moment he suddenly jumped out, vastly cried out and disappeared in the forest».

Litracý

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W-17

"Dueça speleological Cave System"

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Abstract

This presentation describes the work carried out by speleology groups (CIES, GPS, NEC e SAGA) who have been associated with **Dueça Cave System** for the past 6 years (1998-2003), in particular in relation to the clearing, the exploration, the diving, the topography, the photography and interpretation of the various caves of the system.

1 - Introduction

1.1 - General geomorphologic background

The Limestone ridge of Condeixa-Sicó-Alvaiázere mountains comprise a group of limestone chalcocomarly and chalcodolomitic relieves, which, are situated at the mesocenozoic western Portuguese border between the parallels of Condeixa and Alvaiázere. Even though, as a whole, they are not considered a limestone massif as such, their distinct tectonics

and the erosion places this orographic group, with no more than 400 km², above the surrounding areas, to the East and West, and even though in a more subtle way, to the North and the South. There are also different geomorphologic units linked to these levelling lithologies, the main one being (for its extent, altimetry development and importance in the karstic functioning) the group nominated "Serras e Planaltos Calcários" ("Limestone Ridges of Mountains and Plateaus") (CUNHA, 1990) which is associated with the levelling of the "purest" limestone favourable to the karst of the Medium Jurassic.

In relation to this unit, the outline of the landslide system, especially, the structural combination during Jurassic and post Jurassic periods, allows us to see in the current regional landscape two sub-units which, in a way, correspond to two small massifs functioning independently. Thus, there is the Massif of Condeixa-Sicó (to the NW) and the narrow Massif of Castelo do Sobral - Alvaiázere (to the SE), separated by a complex area

¹⁷ It is intended «Great Karin resettlement» in 1830.

¹⁸ Khertvisi (ĒñĀĬÇ½) village is situated at the junction of rivers Kura and its right-bank confluent Parvan. Over the settlement medieval stronghold of the same name is dominated, where at the mentioned time the steward was seating. The village is located at a height of 1197 m above sea level, position data: [41° 28' 0N; 43° 16' 60E].

of landslide and fold related with the great tardi-hercynian accident of Lousã-Pombal-Nazaré.

It is precisely in this last, most northern massif that the **Dueça** Cave System arises. It is, generically, not a very high sector in comparison to the basic level which commands the drainage in the area, which is the bottom of the Dueça valley at approximately 200 m. As it is, the highest point of the area is at 347 metres in the VG of Castelo do Sobral.

1.2 - Location and surroundings

Dueça Cave System is situated at the extreme East of the limestone massif of Sicó-Alvaiázere, in the county of Penela, district of Coimbra, in a sector of great morphological and structural complexity, with diversely oriented landslides which impede the levelling of dolomitic limestone (Inferior Lias), marls and marly limestone (Médium and Superior Lias) and limestone (Dogger).

The karstic levelling where the system occurs, which is the top of a residual anticlinal structure consisting in marly limestone from the Superior Lias and Dogger, is now nearly totally isolated from the rest of the massif in relation to the karstic underground flow, except in the SW, where an isthmus of limestone makes a link with the East. To the East, the limestone is in contact with the schist of the Massif Hespérico along a area of intense landslide directed to the N-S. To the North, NNW, S and SSE, the normal and karstic erosion provoked the total dismantlement of the top part of the anticlinal structure, showing therefore marls from the Lias, not too favourable to karst and permeable. The evolution of the basic level on the edge of the levelling presents a complex history, which we will only be able to study after a future synthesis of speleological work currently in progress. However, we can say that it has a significant role in the determination of the genesis and the evolution of the system's galleries, which is constituted by an intricate crossing of springs, at various stages of the hydraulic activity.

In this underground cavity system, we highlight Sumidouro da Várzea, the Caves of Algarinho, Soprador do Carvalho, and Olho do Dueça - the main spring.

2 - Soprador do Carvalho / Algar do Carvalhal

2.1 - Summary of the history of the exploration

The cave of Soprador do Carvalho, also known as "Gruta Talismã", was discovered in 1992 by the Archeology and Speleology Group of Pombal (GAEP) following the indications given by Mr. António Dias - an inhabitant of the village Taliscas. A strong current of air flew through a small crack in the limestone, which indicated a link to a big cavity. A few days of clearing generated a pit 4 metre deep, which led into the cavity and to an underground river with unique characteristics. It is probably the largest underground water course in Portugal that may be followed without diving techniques. The cave's exploration was carried out by GAEP, who thought it to be of about 4000 m. However, the cavity's topography was never presented. To proceed with the exploration and the study of the cave, GAEP asked for the collaboration of CIES and SAGA, but did not allow these groups to do a topographic survey, which was essential for the continuation of the work. This impediment enabled the possibility of collaboration, and the group's incapability to proceed with the work on their own, ended up compromising the exploration of the cave in the following years. The feelings was that the group was not up to what was expected and therefore, in 1999, the speleologists of CIES, GPS, NEC and SAGA groups decided to put all their efforts together and engage in the exploration and topography of Soprador do Carvalho. They very quickly cleared new galleries and did more than 2000 metres of topography.

In the meantime, the local council of Penela was attracted by the idea of potentially increasing their tourism with the exploration of this cave, and, in 1999, acquired the land where the entrance of the cave is situ-

ated and started organising touristy visits of the cave. Even worse, they impeded the speleological community to have access to it, compromising therefore the continuation of the study. This situation still continues today. We still do not know the real extent of the Cave of Soprador do Carvalho, for which mainly the group that ironically discovered it and the Local Council of Penela may be held responsible.

2.2 - Hydrogeology and Morphology

Situated at the Eastern border of the system, Soprador do Carvalho arises from South to North, along landslides with the same direction, parallel to the edge of the limestone levelling, following the valley where Sabugueira Stream flows. This is the stream along which we may find, on the way down, the main spring of the system. At this point it changes its name to Dueça River, which collects mainly the waters coming from the Massif Hespérico composed of schist and quartzite.

The fact that the stream got in contact with the sedimentary land of the limestone massif resulted in the emergence of springs, as the underground flow followed the already existing landslide, which essentially originated the galleries of Soprador do Carvalho. The changes of the water level and the deviations of the streambed along the years, due to the erosion, and successive periods of obstruction and clearing of the springs provoked the areas of spring to change location either up or down river, and therefore forming new galleries and sometimes even changing the course of the flow within these galleries. Thus, on the left side of the valley we can see various infiltration areas, both fossilised and active, which are successively springs and emergences. Nowadays, the main spring area of Sabugueira Stream only exists partially. It is situated near the main road IC3 which crosses it. This spring is responsible for the great flow of the underground stream of Soprador do Carvalho in winter. However, these are not the only waters it collects. In the summer, even after a very dry period and when Sabugueira Stream is dry, even though there is less flow, it remains in the siphon and right up to the point where the cave has been explored. This fact has not yet been explained (Could it be deep phreatic waters?).

The spring area, or the joining of external waters, has not yet been totally explored. Most probably it still carries on for more than a kilometre upwards beyond the point we reached. It comprises both paragenetic galleries - sometimes several metres high - and siphons in smaller channels, intersected by a few chambers due to subsidence and landslide with rejection, allowing the contact with different lithologies. This is the most intricate area of the cave.

Algar do Carvalhal is situated in this area. There is an old entrance - found with the help of the SLOTER system - which may have been functioning has a spring or as an emergence. This entrance is well-hidden and blocked by large blocks cemented in with calcite. It was opened in 2001 by the groups referred to above, who worked very hard for several month to clear it. Chronologically, it was the second entrance of this cave to be opened so that it would allow the access to the last part of the cave at any time during the year. This is also due to the fact that, approximately in the middle of the cavity, there is a 200 metre long mill, which becomes a siphon due to the rising level of the river in autumn/winter impeding therefore the access to the rest of the cave.

On the way down, the cave continues as one gallery of 3 to 4 metres in diameter, allowing for free flow in the dry period, along 1000 metres in a straight line. At this point the underground stream leaves the large gallery and part of it diverts to a smaller gallery. 150 metres of this small gallery has already been explored, which revealed that it is intersected by small siphons in direction to the Dueça spring. The continuation of its exploration is now compromised by the arrival of domestic effluents of the village of Taliscas. The larger gallery continues downwards and is still active in periods of greater water flow. Its exploration is still undergoing. The fact that this gallery is not as important for water flow has resulted in its blockage with sediments, which has made its exploration more difficult. It is

further down from the disjunction of these galleries that we find the first entrance - o Soprador do Carvalho - which was opened in 1993 by GAEP, who gave the cave its designation.

Due to its great hydraulic activity, the cave has relatively low amounts of calcite. It has a few areas exhibiting a great number of fossils, it is of great beauty and speleological interest. Some of these areas may be compromised by the expansion of the "touristy visits" to this cave. Some of these areas have already been vandalised and some concretions have been broken and taken away. It is therefore urgent to find a way to prevent this type of behaviour.

At the present time 2800 metres have been registered topographically and 4500 metres have been estimated. This cave is not only thought to be the largest in the Massif of Sicó but also one of the largest in Portugal.

There is still a lot to study and discover, not only in terms of exploration of the cavity but also in terms of geological interest due to the complexity of the structure of the area where it is set in, in terms of bio-speleology and archaeology. We were not able to go any further due to the impediments imposed by the local council of Penela in the last few years.

3 - Cave of Algarinho

3.1 - Summary of the history of the exploration

The cave of Algarinho is referred to in 1993 by the group GAEP. At that time it was obstructed but water poured out of the blockage during the rainy season.

In April 1998, the speleology groups SAGA, CIES, GPS, and STEA, cleared the entrance of the cavity by using a mechanical digger. After 4 hours removing stone and blocks, we found a small entrance from which we could feel a current of air which suggested that it was a large cave.

The progression in the cave was relatively easy and the speleologists went approximately 1200 metres into the cavity. During this first exploration, two manmade constructions were identified near the entrance. A first analysis revealed that they dated from the pre-roman period.

The next weekend, a new member joined us - the group NEC, who could not proceed further than the Siphon of Areias, 200 metres from the entrance of the cave of Algarinho, due to the rain fall of that week. During the next few months and after the lowering of the water level in that siphon we did numerous exploration and topographic studies of the cavity, going further than the 1200 metres already known right up to a new siphon. The water levels of this siphon were successively checked until, at the end of the second month, a speleology team of NEC managed to go further still, exploring the cave up to another new siphon denominated up to now Terminal Siphon of Algarinho. Two tentative dives in this siphon were done - one by Ricardo Rodrigo (STEA) and another by Jesus Manteca (G.E. GORFOLI - Spain), both were unfruitful as the exploration of this siphon turned out to be difficult and dangerous due to its sandy bottom.

In September 1999, an archaeological team carried out a study of the manmade constructions found in the cave, but it was not possible to determine conclusively the origin of such constructions.

In May 2001, the speleologist Hugo Mendes - member of the group GPS - discovered the spear of Alvado Longo, in Bronze, approximately 2900 years old, in an area of the cave about 50 metres from the entrance. This discovery was of utmost importance as it brought about the possibility of the cave being connected to the old Castle of Castelo do Sobral, situated in the surrounding area. The presence of the spear and the manmade constructions suggest that this cavity may have been used as the tomb of one of the tribe chiefs of the old castle. If this theory is confirmed, we have then a Cave-Tomb, sealed after the chief's burial, which makes it a unique case in Portugal both in speleology and in archaeology.

It is only in 2002 that a new fossil gallery was found near the end of the cavity, which seemed to be an obstructed cavern from which ran a great current of air, probably providing the great flow of air in this cavity.

Although the water level in the siphon has fluctuated in various metres in the terminal siphon of Algarinho, up to now that level has not lowered sufficiently to allow the continuation of the exploration beyond this siphon, which is now dependent on the discovery of a new passage.

We must also highlight the discovery of asphaltic pitch in the water and on the walls of the cavity along 600 metres. An aerial photograph of the implantation of the Cave of Algarinho shows that the cavity is situated near a quarry at the bottom of Monte de Vez, which is probably the source of this pollution.

At the moment, 2296 metres of galleries of the Cave of Algarinho are registered topographically, and they are estimated to be approximately 2500 metres long. It goes from East to West, its entrance is situated at approximately 250 metres from Soprador do Carvalho, and it finishes at approximately 650 metres of the end of Sumidouro da Várzea.

3.2 - Hydrogeology and Morphology

The Cave of Algarinho is a key element to understand the flow within the system. The dimensions of its galleries are not in accordance with its current hydraulic activity as a spring. The flow remains reduced even after heavy rainy periods. This highlights the importance that this cavity had in past years, having probably been the main spring of the cave system. Due to the drop of the basic water level of Dueça Spring, the main gallery formed various springs along 500 metres in an area furthest from the entrance. These springs deviated further and further way towards Olho do Dueça, which became more and more important as the valley gradually deepened due to the erosion. Up from this area, there was, at a certain point, a spring, which collected nearly all the water, and which still collects the greatest part of the flow. The estimated depth and the characteristics of the terminal siphon suggest that there is a passage to forced channels, maybe near a gallery (spring) which has a direct connection to Sumidouro da Várzea or Olho do Dueça (ver Fig.1).

The galleries of Algarinho follow perfectly the landslide scheme of the local area. They have rectilinear branches and winding areas. The galleries' slopes frequently follow the slight inclination of the deposits. There is hardly any solidification even though there are a great number of galleries with free or sub-aerial flow.

4 - Sumidouro da Várzea

4.1 - Summary of the history of the exploration

Situated in the south-eastern border of the depression of Várzea da Povoia, between the districts of Ansião and Penela, Sumidouro da Várzea is considered to be the most important spring of the Massif of Sicó-Alvaiázere, and it is also the most studied speleologically speaking. In recent years, there have been various attempts to pump up the waters of this spring, which even provoked an accident with the group GAEP due to the accumulation of combustible gases from the water pump installed inside the cave. Fortunately, this accident did not develop into what could have been a tragedy. It was quite a dramatic scenario involving a forward emergency system never seen in Portugal. Ironically, it was because of this incident that Soprador do Carvalho was discovered.

In summer 1998, after the exploration of the Cave of Algarinho, the groups CIES, GPS, NEC and SAGA dived into this cavity, to see if there was an accessible gallery beyond the siphon situated at the entrance. This dive was performed by Christian Thomas and João Neves of SAGA group and resulted in the discovery of a 150 meter long gallery with considerable dimensions across three siphons. After this underwater exploration, the groups decided to set up a pumping system to try up various siphons to find out if there was a connection between the Cave of Algarinho and Sumidouro da Várzea, taking into account that the connection to Dueça spring had already been verified by J.A. Crispim by means of delineation in January 1985.

In October 1998, with the support of Sociedade Portuguesa de Espeleologia (SPE) (Portuguese society of Speleology), the pumping of the siphons of Várzea were carried out, which revealed a 520 meter long gallery right across to a new siphon with water flow. This siphon was later on explored by João Neves (SAGA) and Ricardo Rodrigo (STEA), who confirmed the existence of successive active branches of galleries with high levels of CO₂. These were intersected with siphons that were difficult to explore because they were small and the water was very dirty, therefore, they only managed to go in 150 metres. The rising water levels closed the siphon once more, which meant having to dive or pump the water out again to be able to have access to the majority of the cave.

Sumidouro da Várzea is now topographically registered as being 428 metres long, and is mainly moving towards the NE. It ends at less than 650 metres from the end of the Cave of Algarinho.

4.2 - Hydrogeology and Morphology

Sumidouro da Várzea is another example of the importance of the waters of this system in the past, which drained all the Karstic area situated in the W, and which has now been eroded right down to the impermeable centre. Thus, once again, the large sizes of its galleries are not in proportion with the current water flow.

The first part of the cavity is in sequence with a landslide which is mainly directed to the SE. The cave presents a succession of sprinkles - already obvious at the entrance of the gallery - conditioned by transversal landslide, which are replicas of the large fissure along the depression of Várzea, crossed by horizontal branches. At the base of each sprinkle, we frequently found a siphon. After 100 metres, the entrance area joins another gallery directed to the NE where there is a permanent water flow. Upwards, there is a siphon that is so restrictive that it has not of yet been explored. However, we hope that it will lead to the straight of Dogger which makes the link to the rest of the Massif. This water course, together with the permanent waters in the terminal siphons of Soprador do Carvalho, constitute the greater part of the flow of Olho do Dueça occurring during the dry season. Further down the gallery, there is once more a succession of rectilinear branches intersected by sprinkles, which change direction by taking, yet again, advantage of the directions taken by the landslide system. However, the cavity's morphology changes and becomes mill passages - sometimes only a few centimetres high - and some rooms with subsidence, in a context with a thinner stratification than at the entrance gallery, which suggest a change of lithology (top of Aaleniano?). The typical sprinkles are sub-aerial passages, whereas the horizontal branches are, in their great majority, siphons. All the air pockets are high in CO₂ which makes it very difficult to stay there and, therefore, impedes the continuation of the exploration.

5 - Olho do Dueça

5.1 - Summary of the history of the exploration

The first exploration goes back to the sixties, subsequent to the clearing of the entrance carried out by the water services of the Mondego with the intention of studying the possibility of collecting and stabilising the flow. For years, we had no idea of this fact. We could see that some work had been done to the spring, such as making impermeable the adjacent area, constructing a well in concrete, and rising a dam and canals, which we thought to be due to the needs of irrigating water to the fields nearby. In the eighties, João Neves (SAGA) dived in the well and saw that there was a gallery at approximately 3 metres deep, opened and held with cement blocks and already rotting wood, but the subsidence impeded the exploration to proceed. The water level had visibly decreased and the bottom of the well was full of cement blocks and vegetation down to 5, 5 metres deep. The spring was then considered inaccessible and the hope of being able to get to the system given up. Further attempts to find a way in were

also unsuccessful. It is only in 2002 that we got to know, by striking a conversation with a local inhabitant who participated in the clearing work, that approximately 600 metres of this system - although this distance can not be confirmed - had already been explored in the past. We were also told that, at the end of the 1990s, the bottom of the well had been cleaned which exposed the artificial gallery giving access to the cave. We immediately did all that was necessary to start the exploration again in 2003. As soon as the water flow and the visibility allowed it, a series of dives were done by João Neves (SAGA) and Manuel Soares (CIES), who permitted the exploration and the topography of approximately 300 metres of galleries.

5.2 - Hydrogeology and Morphology

Olho do Dueça is the main spring of the system and constitutes the basic level, which controls all its "recent" evolution. The origin and morphology of the galleries depend greatly on large landslides directed generically towards E-W, where the section may reach several metres in diameter and landslides towards N-S, where a section is highly reduced.

The cavity starts at the vertical well (7 metres deep) which allows access to the 20 meter long, artificial gallery. At the end of it, we then go into the natural gallery which takes approximately a SW direction. 50 metres further, starting at the bottom of the well, and upwards, we find the first room whose dimensions are 3 by 4 metres. From then on, the cave is very close to the surface, with areas where the water flow is done alternatively in siphons and in galleries (or rooms) in free run; there is evidence in these galleries of varied quantities of sand deposits, and a chaos of blocks at various states of erosion. It is common to find a layer of light-coloured and very thin silty clay especially in the galleries where there are blocks. Some of the galleries that have been seen are no more than the areas surrounding fissures from which the river has taken the filling materials.

Nevertheless, the continuation of exploration has been compromised by the emergence of domestic and industrial effluents from the nearby village of Taliscas and the industries implanted upstream.

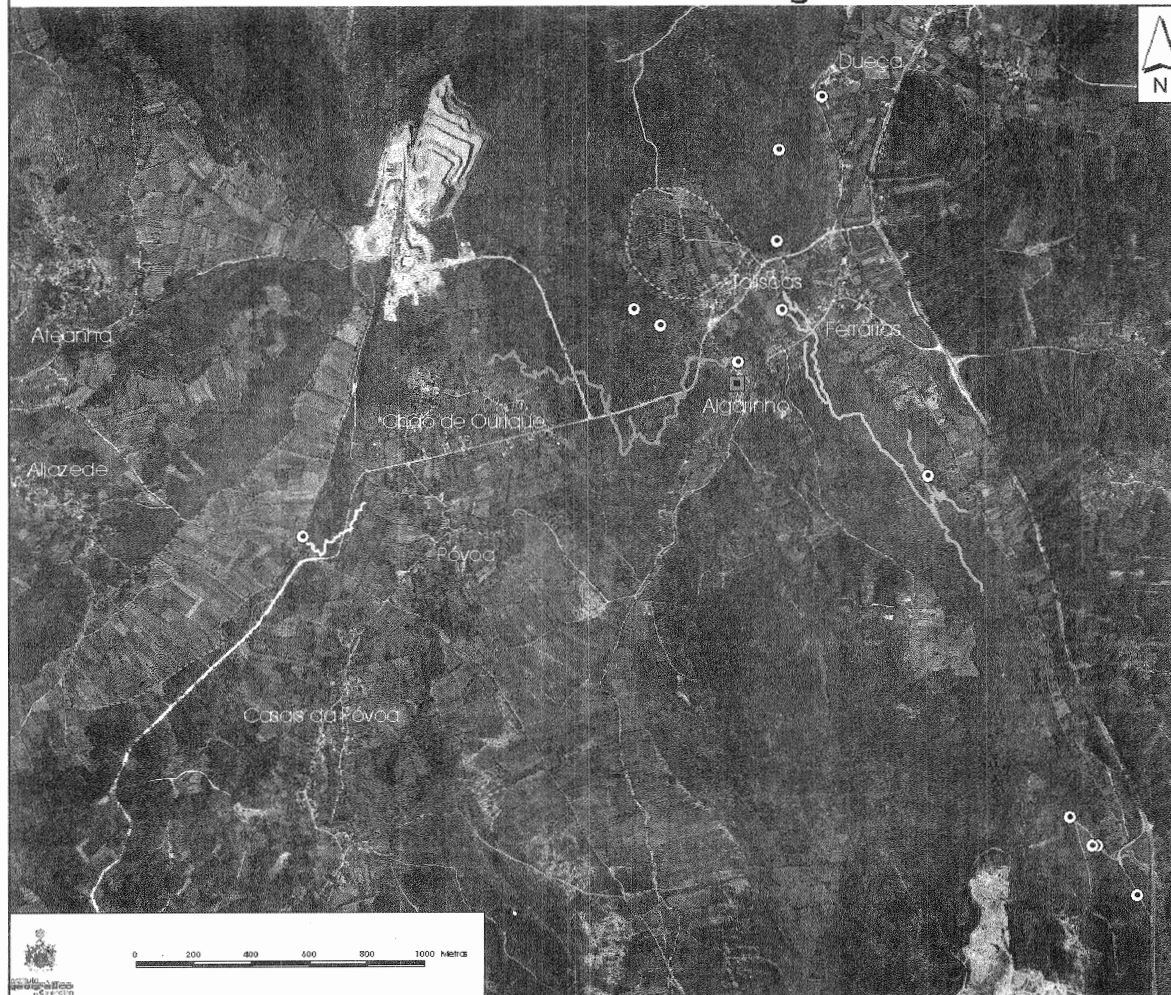
6 - Conclusion

We believe that Dueça Cave System is of utmost importance, both regionally and nationally and we feel it is our obligation to carry on with the exploration work and the research. We know that this is a somewhat modest presentation but it is a start. Therefore, we are prepared to make all the necessary efforts to prevent the work from stopping, so that, with the collaboration of all interested parties, we may show to the speleology community one of the most interesting speleological systems in Portugal.

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Sistema do Dueça (Penela - Portugal)



- Cavidades do sistema
- ∩ Olhos de Água do Dueça
- ∩ Grotta do Soprador do Carvalho
- ∩ Algar do Carvalho
- ∩ Grotta do Algarinho
- ∩ Sumidouro da Várzea
- ∩ Depressão da Várzea
- ∩ Dolina de Taliscas
- ∩ Dolina do Sobral
- Casa abrigo do colectivo espeleo



Centro de Investigação e Exploração Subterrânea (Coimbra)



Grupo Protecção Sicó (Pombal)



Núcleo de Espeleologia de Condeixa (Condeixa-a-Nova)



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Kuzgun Cave: the first super-deep cave in the Aladaglar Massif, Turkey

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Since 2001 extensive speleological investigations have been carried out in the Aladaglar Massif in the Central Taurus Range, Turkey, under the joint Turkish-Ukrainian project. The massif, located between the regional Eceemis Fault on the west and the deeply incised valley of Zamanti River on the east, is comprised mainly by Triassic limestones. The local relief extends between 400m and 3750m elevations. Hydrogeological and geomorphological studies suggest that general potential of the Aladaglar Massif for deep caves is up to 2500m, although the hydrologic system amplitude depth can be up to 2700m. While this project, the part of the "Call of the Abyss" project, was aimed to finding and exploring deep caves in this high mountain massif, the adopted strategy was based on systematic search and exploration of all caves. It accounted for specific features of high mountain glaciated karst and included resources and techniques to negotiate various kinds of blockages and obstacles expected to be encountered in the upper zone of such karst. During four expeditions in 2001-2004 over 150 caves have been explored, mainly vertical, of the total depth of 6640m. Of them 32 caves are deeper than 50m deep, and 12 caves are in excess of 100m. Fifty-seven caves are located above the 3000m altitude, the highest explored cave being at 3410m. The adopted approach has proven its efficiency by the eventual discovery and exploration of the first super-deep cave in this area that was named Kuzgun (=Crown's in Turkish). The cave is located in the middle section of the Kemikli glacial valley, at the altitude of 2840m. Discovered and pushed

to -400m in 2003, Kuzgun had been explored to -1400m during the 2004 expedition; one of the greatest depth advance ever made during a single expedition. Besides the currently deepest branch, another major branch named Veterok had been found that deviates from the first one at -480m. It had been explored to the depth of -600m. In both branches several open leads remained unexplored. The exploration in 2004 has been stopped due to the lack of time and equipment. The total surveyed length of the cave is currently 3187m (as for 2004). Kuzgun is a truly remarkable and important cave that integrates at least three generations of cavities: (1) pre-glacial vadose invasion cave consisting of vertical pits and shafts (cascades of pitches) alternating with inclined meanders, - a typical alpine cave system; (2) ancient (Late Miocene?) cavities represented by large steeply inclined chambers with massive speleothems of various ages; (3) presumably hydrothermal cavities represented by a number of pockets and chambers encountered by the invasion system at various depths. The upper part of the cave (up to -400m) contains an enormous variety of secondary formations. In the 2005 exploration of Kuzgun will be continued in depth in both branches, as well as special efforts will be paid to break into depth into two nearby potential upper entrances, Kosmodrom (currently -125m) and U45 (currently -85m), located at higher elevations (respectively at 3010m and 3040m). Ongoing scientific studies in Kuzgun will be focused on mineral formations and sediments, morpho-structural controls and temperature profiling through the cave.

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Krubera Cave in the Arabika Massif, Western Caucasus: the first 2000m deep cave on Earth

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In 1980 Ukrainian speleologists started their explorations in the Arabika Massif. They adopted a search and exploration strategy that accounted for special characteristics of formerly glaciated karst of the Alpine type. This implied a thorough search in selected areas, guided by the knowledge of glaciokarst specifics, and systematic exploration and siege of obstacles encountered in prominent caves. For Ukrainian efforts the Ortobalagan glacial valley in the southwest part of the massif had been selected. The suggested approach was adopted by other speleological groups of the ex-USSR that joined the explorations in Arabika in 1980s, which resulted in a boost of number and depth of deep caves here during 1980s. In addition, large-scale dye tracing experiments conducted in 1984-1985 revealed enormous potential of Arabika for deep caves by establishing the world's deepest hydrological system with the total amplitude of over 2300m. By the end of 80s, major caves in the Ortobalagan valley were: Arabikskaja System, composed of Kujbyshevskaja (-1100m) and Genrikhova Bezdna (-965m; connected to Kujbyshevskaja in 1989), Krubera (-340m), and Berchilskaja (-500m; by Moldavian cavers). Exploration of these caves required enormous digging/blasting efforts to negotiate numerous boulder chokes and squeezes. Political turmoil in Abkhazia during 1990s suspended cave explorations in Arabika. Resumed in 1999, Ukrainian expeditions focused on Krubera Cave, where major breakthrough has been made. The

successive series of expeditions, in some of which cavers from France, Russia and Spain took part, resulted in establishing Krubera as a new world's deepest cave in January 2001 (-750m in 1999, -1215m in August 2000, -1410m in September 2000 and -1710m in January 2001). Since 2000 the Ukrainian Speleological Association launched the "Call of the Abyss" project to maintain the pace of deep cave explorations in Arabika and another region selected for the project, the Aladaglar Massif in Turkey. Exploration of the first 2000m-deep cave on Earth had been adopted as an ultimate goal for the project. The work in Krubera continued in summer of 2001 (Ukr.S.A., the work and the bottom and in side branches) and then in 2003, when the joint expedition of Kiev and Moscow cavers found a continuation behind a sump at -1410m. During 2004-2005 there were three expeditions conducted under the project, in 2004 sponsored by the National Geographic Society. In August (56 members from Ukraine, Moldova, Spain, France, USA, Britain, Russia and Abkhazia) a new branch was found in the post-siphon section, explored to -1840m. In October (9 members, all from Ukraine) a large series ("Windows") was discovered and explored to -2080m. These two expeditions added 370m to the total depth of Krubera and 3415m to its total surveyed length that is currently about 9100m. The most recent expedition in February-March of 2005 (5 members, all from Ukraine) explored numerous side leads in the Windows series (about 500m of passages explored but not surveyed) and

found a continuation behind the deepest sump in caves dived so far, located at -1990m (10m/-4m). The exploration will be continued in the next two expeditions planned for August and September of 2005. The Krubera Cave has apparent perspectives to advance to a greater depth as no major water flows and "collector" passages were encountered so far in the deepest section. Two potential upper entrances, located 40 and 90m above the present one, are in work to be connected with Krubera. Also, there is an immediate perspective of connecting Krubera to the Kujbyshevskaja Cave through a level of fossil passages at -160 - -200m (the work in progress;

less than 100m remained between the extreme points). When realized, these supposed connections would extend the total length of the Arabikskaja System to about 16km and would make it about 2200m deep. Overall, there were twenty major Ukrainian expeditions to the Ortobalagan valley since 1980, of them eight conducted specifically to Krubera since 1999. This massive 25 years-long effort allowed to pass the magic 2000m mark in caves, almost 50 years after the depth of 1000m was first conquered by French caves in 1956.

W-20

Recent Explorations in Leuka Ori Mnt. on Crete

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SELAS Club, Athens, Greece

Abstract

Between the year 2003 and 2005, a few cavers of SELAS club and a caver from EOS Hanion club participate several speleological expedition in the areas called "Paulia Halara" and "Sternes", situated on the "Leuka Ori" massif (2454m) which is on the island of Crete, in Greece. The base

camp was on a high altitude (1980m). Around this area, the team located more 150 and explored 50 caves and potholes, most of them above 1850m altitude. Explorations will continue in the years to come, by small expedition teams in order to further explore and mark more prospective caves for exploration.

W-21

International Speleological Expedition "Anogia - Ntelina 2002"

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Abstract

Μια από τις μεγαλύτερες σπηλαιολογικές αποστολές που έχουν πραγματοποιηθεί στην Ελλάδα με στόχο την ταυτόχρονη εξερεύνηση τριών από τα μεγαλύτερα σπήλαια της χώρας (Ταγκουρα (-860μ), Πετραδολάκια (-475μ) και Διπλοτάφι (-400μ). Στην αποστολή η οποία διάρκεσε

40 ημέρες συμμετείχαν συνολικά 92 σπηλαιολόγοι από 7 χώρες. Πραγματοποιήθηκε σπηλαιοκατάδυση σε βάθος -800μ, σχολή εκπαιδευτών, βιντεοσκόπηση της αποστολής και συνολικά εξερευνήθηκαν περί τα 3 χιλιόμετρα νέων περασμάτων.

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W-22

Results of the International Speleological Expedition in Tanzania 2005

J.P.Bartholeyns, S. Gotto, A. Kobayashi, H.F. Nader, Pinto, Roemer, E. Van Den Broeck

Abstract

The speleological targets of the ISET 2005, the first one under the auspices of the International Union of Speleology is to continue the work done by the German cavers on Zanzibar, in Matumbi Hill and in the Tanga area; to prospect and explore the Uluguru mountains. But during this work the participants will also implant the speleology in this country and pro-

mote the first speleological association : the Tanzanian National Speleological Trust. Even if the results obtained did not meet the expectations, it is not essential to pile up records, but to produce work that is valid on the scale of the explored karst. And on top of it, the speleological activity has been joined by interests that were pedagogical, social and human, but also relational on the local and international level.

W-23

Remapping of Humpleu Cave (Romania): First results

P. Häuselmann, B. P. Onac

Abstract

Humpleu Cave, the second longest cave in Romania, is currently being remapped by a Romanian-Swiss collaboration. Due to its length (at least 39 km), the remapping is done in the scale 1:1000, both in plan and in longitudinal section. Already after 5 km of remapped passages, some results can be drawn. The cave is organized in five levels which are related to the valley deepening outside the cave. This general pattern, however, seems to be complicated, since the present water course uses three levels. Some indications for hydrothermal influence are found. In order to clarify the cave's genesis, further mapping must be done.

The cave

Humpleu Cave is the second longest cave in Romania. It is situated in the Humpleu hill, in the Bihor Mountains (Fig. 1). Discovered in 1984, it contains about 39 km of mapped passages. The cave is mainly horizontal, but has another entrance on top of the hill, that joins the main passages after a series of shafts. Humpleu is famous for two reasons: the first one is the size of its rooms, which are amongst the biggest in Europe. Moreover, they are often richly concretioned and thus very splendid. The other reason is the beauty of the 5.2 km long underground river, which runs quietly in a huge meander. The river passage has to be negotiated with a diving suit, since there are several ducks and semisumps to pass, before reaching the final sump in a distance of about seven hours from the entrance. The final sump has not been conquered yet, despite several attempts. The distance from the entrance as well as the cold water prevented a success so far.

The first mappings after the discovery of the cave were done rapidly by several caving groups. Sadly, most of the mapping data has been lost subsequently due to various reasons. To date, only data of parts of the active river could be found again. The lack of data and of a beautifully drawn cave plan (and longitudinal section) effectively prevents any scientific work. So, the decision was made to remap the cave in those parts where there are no data, and to use the present data where possible.

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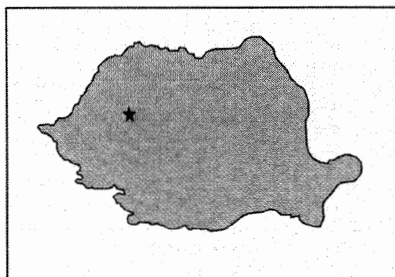


Fig. 1: Location of Humpleu Cave in Romania

The remapping project

The remapping is done in a Romanian-Swiss collaboration. To remap a huge and long cave in the normal 1:500 scale would take several decades of work by very dedicated cavers. So, we decided to remap the cave in the scale 1:1000. This has the advantage that more than one room can be shown on one plan sheet (which will have DIN A2 size), and the time used for drawing inside the cave is reduced to an acceptable amount.

The cave is remapped conventionally with tape, compass and clinometer. A plan view, a longitudinal section and gallery profiles are taken. Caves belonging to the same hydrogeological system are also remapped and integrated into the general overview of the area. The data is introduced into Toporobot. Remapping is done during cave camps of 6 to 10 days duration. If possible, several groups are formed per day, some of them remapping, others equipping shaft passages or climbing chimneys in order to make mapping more effective.

So far, about five kilometers of passage had been mapped in three camps. Of course, a lot is still to be done, especially because there are many sumps in lateral passages near the entrance, which most probably lead to dry passages behind. The results we already achieved are presented below.

Some results

Passage levels and passage size

The 3D representation of the cave (Fig. 2) makes it easy to recognize that the cave is organized in five levels, of which the lowest one is the temporary spring. The next lower level, so far encountered in the "Galeria marmitelor", is active only during floods, and presents shafts going down to the water table. The next level is fossil in its downstream part (Metroul), may get flooded in the middle part (Galeria lacurilor ascunse) and is perennially active in the upstream part (Activ). The entrance level comprises the huge rooms and big, fossil phreatic passages. They are sometimes connected with the uppermost level which also is represented by huge rooms. We think that the lowermost three levels can be expanded after having passed the blocking sumps, in order to get more information.

Even though the river is impressive in flood, and probably has a discharge of 5-10 m³/s (not measured yet), compared to about 20-30 l/s in very dry season, it is clear that the present discharge cannot be held responsible for the creation of the fossil phreatic passages that are way bigger. This implies that the discharge once was higher, which could be attributed to a larger catchment area.

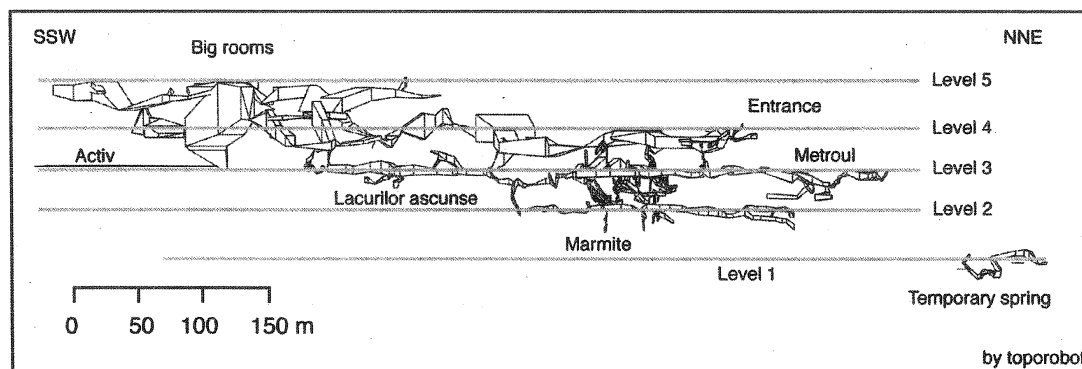


Fig. 2: Projection of the entrance part of Humpleu cave. The five levels are represented by the grey lines.

Hydrothermal influence?

Near the entrance, huge calcite spars can be observed. They were formed by hydrothermal waters, as suggested by fluid inclusion data and oxygen isotope signature that indicate a maximal temperature of 60-65°C. However, it is unclear if these spars were deposited in a room that is genetically linked with the present cave, or if the cave later intersected the crystaliferous void. Another fracture filled with smaller spars is encountered in the Metroul area. Although we do not have any isotope analyses on these crystals, their occurrence suggests a similar genesis.

At any rate, there are some indications that point towards a hydrothermal influence near the entrance:

- The transverse fracture zone where most of the Metroul is situated is responsible for the creation of an intricate phreatic labyrinth that is somehow inexplicable by normal speleogenetic principles, even if we take into account that in that area, there was an ancient karstwater table.
- On a fracture, a passage displays the typical form of a hydrothermal feeder, with steep and very narrow passages below that enlarge upwards and form a nice tube before reaching the main passage. Water flow was clearly upward, ceiling meanders are present in some places.
- In the fractured area, a stratiform breccia predating the phreatic speleogenesis was found. To date, brecciated horizons in the limestone are not known at the surface; it is therefore possible that the formation of the breccia is related to hydrothermal activity.
- Pendants are very typical, especially near the entrance part (Fig. 3). Their morphology is very difficult, if not impossible, to explain by circulation of ordinary meteoric water.

So far, no thermal sources are known in the area. Further investigations and analyses are needed to confirm if a hydrothermal stage originated during the speleogenesis.

Valley deepening and history of the cave system

At first sight, the cave seems to follow the classical pattern of genesis: an episodic valley deepening that reflects itself in the cave in form of various subhorizontal levels. However, the present water table does not fit to that observation: The water table rises considerably from the spring up to the the third level, where it stays subhorizontally for several kilometers. Observation of the watertable in several sumps reveals that there is a more or less horizontal water table in the Metrou-Marmite area, dropping to the level of the spring within a short distance. The water level at the sump located at the downstream end of the active river is, however, higher. This reveals that the whole zone between the terminal sump and the spring level is in fact perched. Is it due to tectonic accidents? Or does it reflect a knickpoint migration responding to a past valley deepening (as suggested by the waterfall in the river passage just before the downstream sump)? If the latter possibility is true: Why is the system behaving differently from other studied cave systems? Was the time too short? Is the valley deepening really episodic? The answer to those questions can only be found after investigating the passages behind the sumps.

Future work

In three expeditions, one eighth of the cave system could be mapped. The results open up more questions than answers. In order to conduct studies, further mapping must be undertaken. This will be the main goal of the years to come. In a first run, the lateral passages in the entrance part will be completely mapped. Then, the many different sumps in that area should be dived, and the continuations behind them, which have to be partially dry, should be explored. Once the entrance part is more or less mapped, we will continue the remapping in the active stream and in the huge rooms above it. The final and first result should be a usable map of this very interesting cave system that can then be used for further scientific studies.

Acknowledgements

To all the cavers of various nationalities which helped in the remapping project, and the motivated students that got infected by the caving bacillus. To Felix Papiu and Gheorghe Fratila for assistance with the old mapping data.

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Fig. 3: Picture of roof pendants. Photo by Bogdan Onac.

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